

**Bti (*Bacillus thuringiensis israelensis*) and Methoprene Application Rates and
Efficacy
Wright Co., MN 1994 - 1998**

Lyle Shannon
Biology Dept.
University of Minnesota – Duluth
Duluth, MN 55812
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Introduction.

Bacillus thuringiensis var. *israelensis* (Bti) and methoprene were regularly applied to a group of experimental wetland sites in Wright Co., MN as part of a long-term study on the ecological effects of mosquito control agents. Results from the initial study (1988 – 1993) have previously been reported (Niemi, et al. 1995). This report summarizes the treatment history of those sites since that time (1994 – 1998).

Methods

Materials. Bti was applied using two commercially available products (Table 1). Abbot Laboratories Vectobac-G was used in all years except 1994, when NOVO's Bactimos material was used. Both are similar materials containing Bti formulated on corncob grits.

Methoprene was applied as Altosid GFM 20-day time release sand (Wellmark, formerly Zoecon) in 1994, 1995 and 1996 (Table 2). In 1997 GFM 20-day sand was registered as a commercial product and the name changed to Altosid XR-G. This product was temporarily unavailable from the manufacturer for the first part of 1997, so the Metropolitan Mosquito Control District (MMCD) produced its own material using an alternative formulation called Altosand. This material was made by mixing Altosid Liquid Larvicide (A.L.L.) with a sand carrier to yield a final methoprene concentration of 0.1%. When applied at 13 lbs./acre this material delivered 0.195 fl. oz. of methoprene per acre, similar to the 0.15 to 0.20 fl. oz. methoprene per acre delivered by A.L.L. at recommended dosages. A.L.L. and Altosand are not extended release formulations. Instead, the active ingredient is released immediately and is expected to break down in 10 days to 2 weeks (Ross et al. 1994). This material was applied for the first 5 treatments of 1997. The final 3 treatments in 1997 and all those in 1998 were done using Altosid XRG 20d sand granules (1.5% methoprene, delivering 1.125 fl. oz. per acre released over 20 days).

Application Rates. All sites were treated by helicopter. Bti was applied at a nominal rate of either 5 or 8 lb./ac. and methoprene sand at 5 lb./ac. (except for the first 5 treatments of 1997 when Altosand was applied at 13 lb./ac.). To monitor more precisely the amounts applied to areas where invertebrate sampling was done, we used a system of particle collectors placed on site. These collectors consisted of a 5-gallon plastic pail (.071 m² area) held in place by a wire frame (tomato cage). Prior to each treatment we aligned 10 collectors at 10m intervals along a 100m transect. In a few cases the morphometry of the site prohibited a 100m transect and two 50m parallel transects were used instead. After each aerial application, the number of particles in each collector was counted, and the application rate calculated using the formula:

$$\text{Material per Acre (lb.)} = (\text{Grits per 10 samplers} \times \text{Mean particle weight(lb.)}) / \text{Total area of samplers (acres)}$$

Both materials were applied approximately 6 times per year. The initial applications were made when mosquito larvae first appeared, typically in early to mid May. Bti was applied after a ½" rainfall event or

after a three-week period with no rain. Methoprene was applied every 3 weeks, except for 1997 when the 10-day sand grains required application at 10-day intervals.

Efficacy of Treatments. - The efficacy of Bti treatments was measured by taking standard dip counts of mosquito larvae in the sites before and after treatment. Ten dips were taken in each site and the number of larvae collected in each dip was recorded. The difference in number of larvae before and after treatment was used as a measure of efficacy.

Methoprene acts much more slowly than Bti and its mode of action is more subtle. Rather than killing larvae outright, it allows them to continue to mature into pupae. The pupae, however, do not metamorphose into adults. To evaluate methoprene efficacy, therefore, we had to measure the emergence of adult mosquitoes from the test sites. This was done by collecting pupae from treated and control sites and rearing them under controlled laboratory conditions.

After treatments were begun each year, control and methoprene-treated sites were regularly monitored for the presence of mosquito pupae. When pupae were found in a site, they were collected and transported on ice back to the laboratory. The goal was to collect 100 pupae from each site. Pupa were rarely abundant enough, however, to collect 100 in any site on a single date. Instead sites were repeatedly visited and pupae collected when available. Collections were continued until 100 pupae were collected or the site dried up.

Pupae were transferred to plastic lined ice-cream buckets containing water from the site where they were collected, and covered with a screened top. Buckets were monitored twice daily to determine the number of mosquitoes which successfully (able to fly) and unsuccessfully (dead on the water) emerged. Observations were continued until all pupae either emerged or died. The efficacy of treatment was then calculated by comparing mosquito emergence success between treated and control sites.

Table 1: Bti formulations used to treat Wright Co. sites, 1994 - 1998.

Year	Material	Lot #	Potency (Toxicity Units)/mg
1994	Bactimos (NOVO Nordisk)	MCO 84 B1200100	unknown
1995	Vectobac (Abbott)	04-588-N8	222
1996	Vectobac (Abbott)	15-713-N8	222
1997	Vectobac (Abbott)	15-717-N8 27-832-N8	215
1998	Vectobac (Abbott)	37917N800	248

Table 2: Methoprene formulations used to treat Wright Co. sites, 1994 - 1998

Year	Material	Lot #	Methoprene Content (% by wt.)
1994	Altosid GFM 20d Sand Granules	03074	1.33
1995	Altosid GFM 20d Sand Granules	95030905	1.33
1996	Altosid GFM 20d Sand Granules	95060705	1.46
1997	10-day sand		.1
	Altosid XRG Sand Granules		1.4
1998		980313898	1.44
	Altosid XRG Sand granules	980320986	1.82
		980323018	1.61

RESULTS AND DISCUSSION

Application Rates - Bti and methoprene were applied on six dates in 1994, 1995, 1996, and 1998 (Table 3). In 1997, Bti was again applied six times, but methoprene (because of the 10d formulation) was applied on 8 dates. The nominal application rates of 5 to 8 lb. per acre (13 lb. for Altosand) were chosen by MMCD personnel to follow a typical mosquito treatment protocol. Rates are normally increased later in the season to overcome the effects of heavier emergent vegetation and growth of duckweed (*Lemna minor*), which prevent some material from reaching the water.

Although methoprene sand samples were collected in 1994 and 1995 they were not available for analysis and inclusion in this report. These samples were collected by NRRI/UMD in a previous study but were not analyzed. Through an unfortunate accident, a lab services coordinator cleaning out a freezer disposed of these samples. We still have available the MMCD application records for these sites and the efficacy data collected from these sites and they are included here along with collector data from 1996, 1997, and 1998 (Table 4).

The amount of material collected in the particle collectors was consistently higher than the nominal amounts being applied, occasionally reaching levels of 25 lb./ac. for Bti and 40 lb./ac. for methoprene. One explanation is that the total area of these sites may be overestimated, so that the treatment material is actually being spread over a smaller surface. Wetland area is clearly not a static value and can increase or decrease over the short-term with excessively wet or dry periods. The areas of these sites may have been estimated during wet times and not readjusted to reflect their actual size during dry spells. Another factor may be that the material is not spread evenly over the entire site but is spread most heavily at the margins where mosquito populations are greatest (and samplers are concentrated). There seems to be an occasional "collector effect" where the pilot isn't sure he has hit the collectors and makes a second pass over them. We have anecdotal evidence that this occurred on at least a few occasions (Kurt Pennuto, pers. com.). On one occasion the pilot reported that he deliberately avoided the buckets because there were people in the area (site 4 - May 29, 1998).

There was considerable variability among sites with respect to the amount of control materials collected in the on-site samplers. For both Bti and methoprene treatments, the difference between highest and lowest application rates on any given date was often 60 - 70%, and sometimes as high as 90%. On an annual basis these differences decreased somewhat. The total amount of Bti applied per acre varied

among sites by 42.1%, 30.4%, 49.8%, 46.7%, and 57.5% for 1994, 1995, 1996, 1997, and 1998 respectively. Summed over the entire 5-year period, the difference between high and low was only 28.6%. Similarly for methoprene, annual variations among sites were 44.7% in 1996, 29.7% in 1997, and 38.4% in 1998. Summed over the 3-year period for which data is available, the variation in methoprene per site was only 26.4%. (Note that methoprene application data for 1994 and 1995 are not available). There was no consistent pattern with respect to which sites received the highest and lowest amounts of control agents. This changed with nearly every application date.

Bti sites received mean annual applications of 110.5, 60.1, 40.6, 53.6, and 53.1 lb./ac. in 1994, 1995, 1996, 1997, and 1998 respectively (Table 3). Methoprene sites received mean annual applications of 63.8, 169.75, and 38.5 lb./ac. in 1996, 1997 and 1998 respectively. These variations may in part be due to the fact that different materials were used in different years. The highest Bti application rate was in 1994, the only year Bactimos was used. Similarly the highest methoprene application rate was in 1997, the only year Altosand was used. These rate differences were also related to changes in climatological conditions over the years. In theory, at least, the same amount of material was dropped on each site on every application date. As sites expanded or contracted with wet or dry conditions, the control materials were spread over a larger or smaller area.

Despite these variations, it is clear that all sites were properly treated (i.e. Bti was not applied to control or methoprene sites nor was methoprene applied to Bti or control sites) with amounts of materials which should have been adequate for mosquito control.

Efficacy. Efficacy of treatments was measured in 1994, 1995, 1997, and 1998. Both the Bti and methoprene used in these treatments killed mosquitoes. The effectiveness of Bti varied widely among sites and dates (Table 5). In some applications it killed 100% of the larvae present, while in others no larvae were killed – in fact, occasionally there were more larvae found after treatment. Table 5 indicates the number of larvae collected at each site prior to treatment (no. lv.). These values are the total number collected in 10 dips. In some cases the numbers are so low that finding a few additional larvae after treatment resulted in a big percentage increase. In those few sites where the annual means indicated no control of larvae, the values are almost always skewed by a single date which showed a large percentage increase (e.g. in site 6 on 06/06/95 only one larva was collected before treatment and 3 were found after treatment – resulting in a 200% increase). Overall, Bti proved moderately successful in killing larvae with a 4-year, all-site mean of 64.2% control (Table 5). Despite the differences in the amount of material applied to sites each year, the rates of control were similar. In 1994 a mean of 55.1% of the larvae were killed by Bti application. This value rose slightly in each subsequent year, from 55.5% in 1995 to 59.4% in 1997 and 64.2% in 1998.

In samples from methoprene treated sites, an average of only 17% of the pupae successfully emerged into adults, while in corresponding control sites 74.7% of the pupae successfully emerged. The value for the treated sites was inflated considerably by the 35.2% emergence success reported in 1997. In the absence of this value, mean emergence success dropped to 11.7% in treated sites. In 1997 one treated site (3) and one control site (13) were not included in the efficacy testing because no mosquito larvae were found despite repeated visits. Tests on two other treated sites (10 and 29) showed essentially no control of adult emergence. The reasons for this are unclear. While there may indeed have been no control at these sites, it is also possible that samples were mislabeled in the laboratory or that pupae were collected at a time when methoprene concentrations in the water were very low. This work was done by a new contractor who may not have been fully familiar with this sites.

For most of these tests the species of mosquito was not recorded. The most abundant mosquitoes in these sites and those used in these tests were *Aedes cinereus*, *Aedes vexans*, and *Culiseta inornata*. No attempt was made to separate these species, i.e. tests were conducted on mixed assemblages.

Summary

We have verified that Bti and methoprene were correctly applied to all sites over the 5-year period from 1994 – 1998. The application rates were typically heavier than predicted, at least in the area of the samplers. For the most part the materials used were effective in controlling mosquitoes although there were several isolated instances where there was no apparent control. Methoprene formulations seemed to provide better mosquito control, but it is difficult to directly compare the efficacy of the materials since the testing methodology was different for the two.

Table 3: Bti application rates in Wright Co. sites, 1994 - 1998. All values are in lb. per acre. Nominal rate is calculated by dividing the amount of Bti dropped on each site by the total area of that site. Measured values were computed from the number of Bti grits collected by particle collectors placed in the area where invertebrate samples were collected.

Date	Nom. Rate (lb/ac)	Measured Application Rates									Mean Annual Rate
		Site 4	Site 6	Site 7	Site 11	Site 20	Site 22	Site 23	Site 24	Site 30	
05/17/94	5	15.0	8.9	14.3	13.4	16.3	16.6	11.1	7.9	9.8	
06/03/94	5	17.4	9.5	16.1	5.7	17.5	10.6	11.6	12.9	19.7	
06/24/94	8	16.6	12.9	27.7	27.4	25.4	22.9	15.0	14.0	22.4	
07/15/94	8	25.6	26.3	32.9	22.2	13.8	26.5	20.6	15.0	37.8	
08/05/94	8	22.4	23.3	32.0	6.1	27.6	14.9	17.7	22.2	29.9	
08/26/94	8	14.3	19.3	23.8	10.9	1.6	14.5	14.1	30.2	28.5	
1994 Total		111.3	100.2	146.8	85.7	102.2	106	90.1	102.2	148.1	110.3
05/18/95	8	13.2	7.5	8.8	18.3	19.0	13.8	14.7	10.4	11.6	
06/06/95	8	15.6	8.2	8.6	12.2	8.1	4.1	10.2	10.2	17.5	
07/07/95	8	11.5	4.7	7.9	1.1	10.4	8.1	5.0	7.9	5.0	
07/21/95	8	7.9	7.2	3.2	7.2	6.6	8.6	7.7	4.8	12.7	
08/14/95	8	4.5	9.8	11.1	7.5	6.4	6.3	10.0	12.5	6.1	
08/25/95	8	21.1	14.9	19.3	13.1	10.2	10.6	11.1	7.5	20.0	
1995 Total		73.8	52.3	58.9	59.2	60.7	51.4	58.7	53.3	73	60.1
06/14/96	5	4.7	3.0	5.4	7.9	4.8	3.9	5.2	8.1	8.2	
06/28/96	5	8.4	4.7	3.9	5.5	3.0	5.7	2.5	6.8	3.6	
07/09/96	5	8.1	3.9	5.9	7.3	7.3	4.8	3.9	3.2	5.7	
07/25/96	5	9.1	2.3	7.3	2.1	2.3	3.2	3.6	6.8	0.9	
08/09/96	5	22.0	10.6	10.4	17.4	5.9	4.5	5.0	8.2	6.1	
08/22/96	8	7.7	10.0	17.2	8.2	6.6	13.2	10.9	8.8	9.7	
1996 Total		60	34.5	50.1	48.5	30.1	35.4	31.1	41.9	34.2	40.6
05/23/97	8	9.1	4.8	3.0	4.5	3.6	6.6	1.8	11.1	4.7	
06/13/97	8	17.7	9.7	10.4	9.8	5.0	8.9	7.3	8.4	7.9	
07/10/97	8	8.4	3.9	17.2	10.6	2.7	8.9	9.8	9.7	8.1	
07/23/97	8	14.7	8.6	7.7	4.5	12.7	6.6	11.6	16.5	6.4	
08/13/97	8	12.7	12.7	7.5	9.8	9.1	9.8	13.2	14.7	7.3	
09/09/97	8	10.0	10.7	7.3	7.3	8.4	8.4	12.3	13.2	4.8	
1997 Total		72.6	50.4	53.1	46.5	41.5	49.2	56	73.6	39.2	53.6
5/7/98	8	8.8	13.0	12.3	12.1	12.8	8.8	10.4	2.9	14.7	
5/29/98	8		8.5	6.4	7.4	7.3	7.8	11.6	10.2	12.1	
6/19/98	8	17.1	4.2	11.4	11.8	10.0	11.6	9.3	9.2	7.4	
7/1/98	8	13.1	7.1	3.1	8.6	6.2	9.0	5.9	5.9	4.8	
7/21/98	8	9.5	10.0	6.7	6.4	8.6	11.1	10.7	10.6	4.3	
8/21/98	8	5.7	8.6	16.3	8.8	6.2	6.4	12.8	5.5	6.6	
1998 Total		54.2	51.4	56.2	55.1	51.1	54.7	60.7	44.3	49.9	53.1
Grand Total		371.9	288.8	365.1	295.1	285.4	296.7	296.6	315.3	344.3	

Table 4: Methoprene application rates in Wright Co. sites, 1994 - 1998. All values are in lb. per acre. Nominal rate is calculated by dividing the amount of methoprene sand dropped on each site by the total area of that site. Measured values were computed from the number of methoprene sand grains collected by particle collectors placed in the area where invertebrate samples were collected

Date	Nominal Application Rate (lb./ac)	Measured Application Rates in Study Areas						Mean lb./ac	
		Site 3	Site 9	Site 10	Site 21	Site 25	Site 27		Site 29
05/16/94	5	[REDACTED]							
06/02/94	5								
06/23/94	5								
07/14/94	5								
08/04/94	5								
08/25/94	5								
05/17/95	5	[REDACTED]							
06/08/95	5								
07/06/95	5								
07/20/95	5								
08/13/95	5								
09/07/95	5								
06/14/96	5	1.0	1.4	6.1	6.3	4.2	12.8	12.3	6.3
07/09/96	5	19.0	9.6	16.2	9.5	3.8	3.3	6.1	9.7
08/02/96	5	7.2	20.1	18.8	5.0	14.2	8.2	20.4	13.4
08/22/96	5	6.8	15.7	15.4	13.0	3.2	2.3	6.8	9.0
09/13/96	5	12.4	9.5	15.8	17.8	6.3	9.2	8.0	11.3
10/03/96	5	14.1	19.3	13.5	19.8	15.8	14.2	2.5	14.2
1996 Total		60.6	75.5	85.9	71.4	47.5	50.1	56.0	63.9
05/23/97	13	7.3	5.0	0.2	2.0	5.7	10.4	5.2	5.1
06/03/97	13	21.8	33.6	27.8	22.4	28.4	25.1	30.9	27.1
06/13/97	13	22.8	27.5	25.6	22.8	23.8	23.2	17.8	23.4
06/27/97	13	5.6	9.8	5.4	7.3	3.4	4.0	7.3	6.1
07/10/97	13	6.4	15.5	32.4	15.8	29.2	30.2	42.9	24.6
07/23/97	5	13.5	11.5	11.4	15.4	14.1	26.0	17.3	15.6
08/13/97	5	29.1	56.1	40.5	70.5	9.8	27.6	25.9	37.1
09/09/97	5	24.6	26.8	29.5	30.5	40.0	29.4	34.1	30.7
1997 Total		131.1	185.9	172.9	186.5	154.5	175.9	181.5	169.7
5/7/98	5	8.2	4.6	5.8	3.4	4.1	3.3	5.0	4.9
5/29/98	5	9.6	5.2	7.9	5.1	6.1	6.1	3.8	6.3
6/19/98	5	1.8	11.0	10.2	7.1	8.2	22.3	6.1	9.5
7/10/98	5	0.2	8.8	7.1	11.7	9.3	6.7	7.9	7.4
7/31/98	5	3.5	4.3	4.9	2.4	3.3	5.0	8.8	4.6
8/21/98	5	7.6	3.1	7.6	7.1	1.8	6.8	6.3	5.8
1998 Total		31.0	37.0	43.6	36.8	32.9	50.2	37.8	38.5
Grand Total		222.7	298.4	302.4	294.7	234.9	276.2	275.3	272.1

Table 5: Efficacy of Bti treatments Wright Co. sites, 1994-1998. The table indicates the number of larvae (no. lv.) collected (per 10 dips) from each site prior to Bti application and the percentage by which that number was reduced (% red.) after treatment. Positive numbers indicate an increase in the number of larvae present. Bti efficacy was not measured in 1996.

Date	Site 4		Site 6		Site 7		Site 11		Site 20		Site 22		Site 23		Site 24		Site 30		
	no. lv.	% red.	no. lv.	% red.	no. lv.	% red.	no. lv.	% red.	no. lv.	% red.	no. lv.	% red.	no. lv.	% red.	no. lv.	% red.	no. lv.	% red.	
05/17/94																			
06/03/94	2	-50.0	0	-	0	-	5	-20.0	2	50.0	14	-35.7	0	-	0	-	0	-	-13.9
06/24/94	3	-100.0	3	-100.0	0	-	7	-71.4	12	-91.7	21	-47.6	12	-66.7	0	-	12	-100.0	-82.5
07/15/94	11	-100.0	7	-42.9	0	-	7	-57.1	11	-45.5	3	-100.0	76	-75.0	6	-66.7	3	-100.0	-73.4
08/05/94	135	-93.3	5	-100.0	0	-	7	85.7	3	-66.7	8	-75.0	0	-	0	-	9	22.2	-37.9
08/26/94	6	-83.3	2	-100.0	0	-	8	-87.5	0	-	1	0.0	0	-	0	-	0	-	-67.7
1994 mean		-85.3		-85.7		-30.1		-38.5		-51.7		-70.9		-66.7		-59.3		-55.1	
05/18/95	1	-100.0	1	0.0	2	-100.0	4	-100.0	8	-100.0	12	-100.0	120	-98.3	6	16.7	2	-100.0	-75.7
06/06/95	11	-90.9	1	200.0	5	-100.0	21	-100.0	1	-100.0	37	-86.5	9	-100.0	37	-81.1	1	-100.0	-62.1
07/07/95	4	-50.0	30	-40.0	4	-75.0	1	-100.0	16	-68.8	1	-100.0	0	-	1	-100.0	0	-	-76.3
07/21/95	4	-100.0	6	116.7	4	150.0	3	-100.0	0	-	1	-100.0	0	-	0	-	0	-	-6.7
08/14/95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
08/25/95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1995 mean		-85.2		69.2		-31.3		-100.0		-67.2		-96.6		-99.2		-54.8		-100.0	
05/23/97	26	-92.3	4	-100.0	6	16.7	13	-92.3	8	-87.5	9	-44.4	18	-11.1	0	-	5	-40.0	-56.4
06/13/97	1	0.0	0	-	25	-84.0	2	0.0	1	0.0	7	57.1	0	0.0	0	-	0	-	-4.5
07/10/97	15	-100.0	9	-100.0	2	-100.0	6	-100.0	7	-100.0	34	-76.5	90	-96.7	17	-47.1	15	-93.3	-90.4
07/23/97	5	-100.0	3	-100.0	5	-60.0	7	-71.4	1	-100.0	6	-50.0	4	-100.0	0	-	3	-66.7	-81.0
08/13/97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
09/09/97	9	-44.4	16	-100.0	11	0.0	9	-66.7	7	-100.0	21	-14.3	11	-90.9	9	-66.7	3	-100.0	-64.8
1997 mean		-70.0		-100.0		-45.5		-69.7		-77.5		-21.3		-59.7		-56.9		-75.0	

Date	Site 4		Site 6		Site 7		Site 11		Site 20		Site 22		Site 23		Site 24		Site 30			
	no. lv.	% red.	no. lv.	% red.	no. lv.	% red.	no. lv.	% red.	no. lv.	% red.	no. lv.	% red.	no. lv.	% red.	no. lv.	% red.	no. lv.	% red.		
5/7/98	0		5	-80.0	12	-75.0	4	-100.0	16	-100.0	9	-88.9	2	-100.0	6	-16.7	2	-100.0	-82.6	
5/27/98	16	-100.0	13	-76.9	3	0.0	18	-72.2	1	-100.0	60	-68.3	0		4	-100.0	1	-100.0	-77.2	
6/19/98	7	0.0	4	50.0	1	300.0	2	-100.0	0		2	-100.0	0		0		0		30.0	
7/1/98	4	-75.0	3	-100.0	1	-100.0	9	-100.0	8	-100.0	18	-50.0	23	-100.0	30	-100.0	0		-90.6	
7/21/98	13	-84.6	18	-94.4	7	14.3	19	-73.7	7	-100.0	18	-33.3	29	-79.3	22	-100.0	0		-68.9	
8/20/98	1	-100.0	0		15	-100.0	3	-100.0	17	-100.0	10	-80.0	0		0		0		-96.0	
1998 Mean		-71.9		-60.3		6.5		-91.0		-100.0		-70.1		-93.1		-79.2		-100.0		-64.2
Overall Mean		-78.1		-44.2		-23.4		-72.7		-70.8		-59.9		-80.7		-64.4		-83.6		-64.2

Table 6: Efficacy of methoprene treatments in Wright Co. sites, 1994 - 1998. Values indicate the percentage of mosquito pupae collected from each site which successfully emerged as adults. Efficacy not measured in 1996.

Percent Emergence - Control Sites					
Site No	1994	1995	1997	1998	Mean
5	71	92	53	100.0	79.0
12	100	86	38	14.9	59.7
13	44	46		94.2	61.4
14	79	70	66	25.0	60.0
17	97	dry	94	90.1	93.7
18	90	79	94	24.6	71.9
19	92	87	94	24.6	74.4
26	98	46	100	97.5	85.4
51	99	93	78	79.2	87.3
Mean	85.6	66.6	77.1	61.1	74.7

Percent Emergence - Methoprene Sites					
Site No.	1994	1995	1997	1998	Mean
3	62	9		35.4	35.5
9	0	6	3	26.3	8.8
10	0	1	88	36.5	31.4
21	14	1	1	1.8	4.5
25	0	4	10	1.5	3.9
27	0	4	11	20.6	8.9
29	6	4	98	14.3	30.6
Mean	11.7	4.1	35.2	19.5	17.6

References

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Lyle94to98 data

Date	Nom. Rate (lb/ac)	Measured Application Rates									Mean	
		Site 4	Site 6	Site 7	Site 11	Site 20	Site 22	Site 23	Site 24	Site 30	Averag	2SE
5/17/94	5	15	8.9	14.3	13.4	16.3	16.6	11.1	7.9	9.8	12.59	2.17
6/3/94	5	17.4	9.5	16.1	5.7	17.5	10.6	11.6	12.9	19.7	13.44	3.03
6/24/94	8	16.6	12.9	27.7	27.4	25.4	22.9	15	14	22.4	20.48	3.93
7/15/94	8	25.6	26.3	32.9	22.2	13.8	26.5	20.6	15	37.8	24.52	5.17
8/5/94	8	22.4	23.3	32	6.1	27.6	14.9	17.7	22.2	29.9	21.79	5.36
8/26/94	8	14.3	19.3	23.8	10.9	1.6	14.5	14.1	30.2	28.5	17.47	6.02
1994 Average		18.55	16.7	24.47	14.28	17.03	17.67	15.02	17.03	24.68	18.38	2.11
5/18/95	8	13.2	7.5	8.8	18.3	19	13.8	14.7	10.4	11.6	13.03	2.63
6/6/95	8	15.6	8.2	8.6	12.2	8.1	4.1	10.2	10.2	17.5	10.52	2.73
7/7/95	8	11.5	4.7	7.9	1.1	10.4	8.1	5	7.9	5	6.844	2.14
7/21/95	8	7.9	7.2	3.2	7.2	6.6	8.6	7.7	4.8	12.7	7.322	1.75
8/14/95	8	4.5	9.8	11.1	7.5	6.4	6.3	10	12.5	6.1	8.244	1.8
8/25/95	8	21.1	14.9	19.3	13.1	10.2	10.6	11.1	7.5	20	14.2	3.27
1995 Average		12.3	8.717	9.817	9.9	10.12	8.583	9.783	8.883	12.15	10.03	1.22
6/14/96	5	4.7	3	5.4	7.9	4.8	3.9	5.2	8.1	8.2	5.689	1.28
6/28/96	5	8.4	4.7	3.9	5.5	3	5.7	2.5	6.8	3.6	4.9	1.27
7/9/96	5	8.1	3.9	5.9	7.3	7.3	4.8	3.9	3.2	5.7	5.567	1.16
7/25/96	5	9.1	2.3	7.3	2.1	2.3	3.2	3.6	6.8	0.9	4.178	1.89
8/9/96	5	22	10.6	10.4	17.4	5.9	4.5	5	8.2	6.1	10.01	4.01
8/22/96	8	7.7	10	17.2	8.2	6.6	13.2	10.9	8.8	9.7	10.26	2.16
1996 Average		10	5.75	8.35	8.067	4.983	5.883	5.183	6.983	5.7	6.767	1.08
5/23/97	8	9.1	4.8	3	4.5	3.6	6.6	1.8	11.1	4.7	5.467	1.99
6/13/97	8	17.7	9.7	10.4	9.8	5	8.9	7.3	8.4	7.9	9.456	2.33
7/10/97	8	8.4	3.9	17.2	10.6	2.7	8.9	9.8	9.7	8.1	8.811	2.76
7/23/97	8	14.7	8.6	7.7	4.5	12.7	6.6	11.6	16.5	6.4	9.922	2.75
8/13/97	8	12.7	12.7	7.5	9.8	9.1	9.8	13.2	14.7	7.3	10.76	1.77
9/9/97	8	10	10.7	7.3	7.3	8.4	8.4	12.3	13.2	4.8	9.156	1.77
1997 Average		12.1	8.4	8.85	7.75	6.917	8.2	9.333	12.27	6.533	8.928	0.99
5/7/98	8	8.8	13	12.3	12.1	12.8	8.8	10.4	2.9	14.7	10.64	2.34
5/29/98	8		8.5	6.4	7.4	7.3	7.8	11.6	10.2	12.1	8.913	1.5
6/19/98	8	17.1	4.2	11.4	11.8	10	11.6	9.3	9.2	7.4	10.22	2.35
7/1/98	8	13.1	7.1	3.1	8.6	6.2	9	5.9	5.9	4.8	7.078	1.93
7/21/98	8	9.5	10	6.7	6.4	8.6	11.1	10.7	10.6	4.3	8.656	1.57
8/21/98	8	5.7	8.6	16.3	8.8	6.2	6.4	12.8	5.5	6.6	8.544	2.47
1998 Average		10.84	8.567	9.367	9.183	8.517	9.117	10.12	7.383	8.317	9.011	0.87

Lyle94to98 data

Date	Nominal	Measured Application Rates in Study Areas							METHOPRENE	
Application Rate (lb./ac)	Mean lb./ac	Site 3	Site 9	Site 10	Site 21	Site 25	Site 27	Site 29		
5/16/94	5									
6/2/94	5									
6/23/94	5	Data not available								
7/14/94	5									
8/4/94	5									
8/25/94	5									
5/17/95	5									
6/8/95	5									
7/6/95	5	Data not available								
7/20/95	5									
8/13/95	5									
9/7/95	5								Average	2SE
6/14/96	5	1.0	1.4	6.1	6.3	4.2	12.8	12.3	6.30	3.58
7/9/96	5	19.0	9.6	16.2	9.5	3.8	3.3	6.1	9.64	4.55
8/2/96	5	7.2	20.1	18.8	5.0	14.2	8.2	20.4	13.41	4.97
8/22/96	5	6.8	15.7	15.4	13.0	3.2	2.3	6.8	9.03	4.25
9/13/96	5	12.4	9.5	15.8	17.8	6.3	9.2	8.0	11.29	3.20
10/3/96	5	14.1	19.3	13.5	19.8	15.8	14.2	2.5	14.17	4.33
1996 Average		10.1	12.6	14.3	11.9	7.9	8.3	9.4	10.64	1.81
5/23/97	13	7.3	5.0	0.2	2.0	5.7	10.4	5.2	5.11	2.52
6/3/97	13	21.8	33.6	27.8	22.4	28.4	25.1	30.9	27.14	3.28
6/13/97	13	22.8	27.5	25.6	22.8	23.8	23.2	17.8	23.36	2.27
6/27/97	13	5.6	9.8	5.4	7.3	3.4	4.0	7.3	6.11	1.66
7/10/97	13	6.4	15.5	32.4	15.8	29.2	30.2	42.9	24.63	9.46
Average, 10d sand		12.8	18.3	18.3	14.1	18.1	18.6	20.8	17.27	3.86
7/23/97	5	13.5	11.5	11.4	15.4	14.1	26.0	17.3	15.60	3.81
8/13/97	5	29.1	56.1	40.5	70.5	9.8	27.6	25.9	37.07	15.47
9/9/97	5	24.6	26.8	29.5	30.5	40.0	29.4	34.1	30.70	3.83
Average, 20d sand		22.4	31.5	27.1	38.8	21.3	27.7	25.8	27.79	6.56
5/7/98	5	8.2	4.6	5.8	3.4	4.1	3.3	5.0	4.91	1.28
5/29/98	5	9.6	5.2	7.9	5.1	6.1	6.1	3.8	6.26	1.46
6/19/98	5	1.8	11.0	10.2	7.1	8.2	22.3	6.1	9.53	4.83
7/10/98	5	0.2	8.8	7.1	11.7	9.3	6.7	7.9	7.39	2.70
7/31/98	5	3.5	4.3	4.9	2.4	3.3	5.0	8.8	4.60	1.57
8/21/98	5	7.6	3.1	7.6	7.1	1.8	6.8	6.3	5.76	1.76
1998 Average		5.2	6.2	7.3	6.1	5.5	8.4	6.3	6.41	1.12