CONTENTS

LIST OF TABLES

SECTION 7.0

MOSQUITO CONTROL

BACKGROUND

Mosquitoes are common in any wetland or open water environment. Because of the potential public health threat of mosquito-borne disease transmission, the monitoring and management of the mosquito population at the SCWDP was considered an essential component of this five-year pilot project. The program included biological control measures, physical source manipulation (i.e., vegetation thinning), and weekly monitoring during the mosquito season. The program steadily evolved over the life of the pilot project, becoming more efficient and effective each year. A combination of vegetation management, biological larvacide applications, and predator populations of sufficient size to be effective provided a level of control acceptable to the Sacramento-Yolo Mosquito and Vector Control District (SYMVCD).

MONITORING

The foundation of the control program was a weekly monitoring program, which took place from March through October of each year.

Sampling Procedures

Between 0600 and 1100 hours, twelve random dips were taken from each half-cell with a standard 250-mL dipper. Each dip was filtered through a fine mesh strainer to concentrate the mosquito larvae and other suspended matter. The sample was then back flushed with clear water. In the laboratory, the larvae were sorted from the other aquatic organisms and debris before being preserved in isopropyl alcohol. The larvae were then keyed with the aid of a microscope to the genus level except for *Culex tarsalis*, which were keyed to species because of their importance as a vector of encephalitis. Larvae were also sorted by growth stage into three groups, with first, second and third instar larvae forming one group; fourth instar larvae a second; and pupae comprising the third group. Due to maintenance activities resulting in periodic shut downs, any cells found dry at sample time were not dipped.

Mosquito Monitoring Results, 1994-1998

During the first full season of operation in 1994, the only control measure in effect was the introduced population of mosquito fish (*Gambusia affinis*). The monitoring results from 1994 indicated the potential of the wetlands to produce mosquitoes without additional control measures. Weekly counts in individual half-cells ranged from 0.00 to 46.12 per dip. Counts averaged over the entire wetland system ranged from 0.07 to 12.33 larvae per dip. The accepted threshold limit for the SYMVCD before treatment with larvacide must be implemented is 0.1 larvae per dip. In 1994, the wetlands averaged 1.98 larvae per dip. With mosquito fish alone, the mosquito population could not be controlled.

Adult mosquito trapping was also performed by SYMVCD during the initial season of operation in 1994. Carbon dioxide traps were set out for one night each week and mosquitoes were counted and identified the following morning. The adult populations were a precursor to the rapid growth of the larval populations. Only 50 mosquitoes per trap were captured during the first week of sampling before peaking with an average of over 1300 mosquitoes per trap. The high numbers and exponential population growth coupled with the close proximity of the wetlands to residential areas prompted SRCSD to seek more effective control methods. Western Equine Encephalitis (WEE) was found in one of the adult mosquitoes.

Beginning in 1995, the mosquito management program was bolstered with vegetation management, mosquito fish and guppy (*Poecilia reticulata*) stocking, exclusion techniques and regular applications of biological larvacides. After implementation of these measures, larval counts for the entire wetland system were significantly lower.

During both the 1996 and 1997 seasons, the influent, or "B" half-cells consistently yielded higher counts than the effluent, or "A" half-cells. Larvae counts from 1998 also demonstrated a significant difference between half-cells ($p = 0.01$), with the "B" half-cells averaging 0.34 larvae per dip for the season and the "A" half-cells recording an average of 0.17 larvae per dip. However, due to the varied maintenance and larvacide application schedules for each half-cell, statistical analysis of these numbers should be used with caution. Several factors could account for this difference, including elevated water temperature and nutrient content on the influent side, and higher vegetation density.

During the 1998 season, the average number of mosquito larvae per dip at the wetlands was 0.25. Weekly counts for the entire wetland system ranged from a low of 0.01 mosquitoes per dip on April 14 to a high of 0.76 per dip on September 22. Values in individual half-cells ranged from 0.00 to 9.25 per dip in cell 7B on June 9. The complete weekly data for each half-cell throughout the entire season can be found in Table 7-1.

The four-year average during the active management period from 1995-1998 was 0.34 mosquito larvae per dip. In contrast, counts for the 1994 season had averaged 1.98 per dip. Average dip counts and management activities for each half-cell from 1994 through 1998 are summarized in Table 7-2.

MANAGEMENT METHODS

During the five-year project, several biological and physical control techniques were implemented to aid in suppressing larvae populations. Mosquito fish and guppy stocking, and treatments with the bacterial larvacides *Bacillus thuringensis* var. *israelensis* (Bti) and *Bacillus sphaericus* (Bs) comprised the biological control component of the program.

The physical control measures involved several vegetation harvest techniques and a two-month trial to determine if the application of water via overhead sprinklers from dusk until dawn would reduce oviposition by gravid females.

Biological Control

Fish. Each season from 1994 through the 1997 season, mosquito fish were stocked at the wetlands at a rate of 1 pound (~ 1500 fish) per half-cell. No fish were planted in 1998, due to high demand for fish from SYMVCD at other sites. After the 1994 season, it was apparent that fish alone could not control the growth of the mosquito population. Factors inhibiting the control provided by the fish were high vegetation density which limited access by the fish to the interior area of the cells and low dissolved oxygen content which probably accounted for low winter fish survival rates.

Due to the low survival rates of the mosquito fish during the initial winter season, 4,000 guppies were stocked in half-cells 9A and 9B and 1,000 were planted into cell 11B and the habitat cell. These fish were thought to be hardier than mosquito fish and be able to overwinter more successfully due to a greater tolerance for low dissolved oxygen conditions. No follow-up study was performed on the guppies to test this hypothesis, although these fish were observed in subsequent seasons.

Although the fish alone did not maintain mosquito populations below the accepted threshold level independently, they did aid in controlling larval abundance.

***Bacillus thuringensis* var. *israelensis* (Bti)**. In 1994, SYMVCD applied Bti from the ground using a backpack sprayer to 18 half-cells during the course of the season. Although these treatments reduced larvae totals, they were not always sufficient to lower levels below the 0.1 per dip threshold. Probable reasons for the ineffectual treatments were the dense vegetation canopy which did not allow all the insecticide to contact the water surface, and high levels of organic matter in the water column. In waters with an elevated organic content, mosquito larvae will not always ingest a lethal dose of Bti before the bacteria settles out of the water column.

To achieve better penetration of Bti in 1995, a spray system was developed to apply liquid Bti (Vectobac 12AS) with a large water volume from directly above the vegetation canopy. By spraying down through the mostly vertical canopy, less of the total spray volume was intercepted by the vegetation. The high spray volume was also used to help transport more of the active ingredient through the canopy.

The system was comprised of a tractor mounted 110-gallon sprayer with an 11.5-foot boom equipped with three spray nozzles. The high volume nozzles were spaced 18 inches apart. Two Tee-Jet #4 D nozzles were placed closest to the tractor where they would spray near the edge of the water and the third nozzle, a Tee-Jet OC80 sprayed over 15 feet out into the cell. The coverage obtained was almost 30 feet, and by circling the entire half-cell, complete coverage could be obtained. Hydraulic controls to raise and lower the boom allowed the spray to be applied from above the emergent marsh canopy. The sprayer employed a PTO-driven pump with an output of 40 gallons per minute at 40 pounds per square inch of pressure. A loading rate of 40 gallons per acre was used. Coupled with this spray system was the vegetation management program, which also aided contact of the larvacide with the water surface, especially early in the season prior to active regrowth.

During 1995, a total of 128 half-cells were treated with Bti, and in 1996, 139 Bti applications were made. All Bti applications were made at a rate of two pints per acre. Although dip counts averaged greater than 0.1 for these two seasons, most of the larvae were early instars, indicating that the Bti applications had disrupted the breeding cycle and few larvae were progressing to maturity. Thus, despite the high dip counts, an acceptable level of control was being achieved.

In 1997, the weekly monitoring began to yield later instar larvae in half-cells which had been treated during the previous week. The decision was made to increase the spray solution volume from 40 gallons per acre to 80 gallons per acre and to sample the treated cells one day post-treatment. If numbers remained above 0.1 larvae per dip, the half-cell was retreated during the same week. During four weeks of biweekly sampling and Bti treatments, ten half-cells were treated twice in the same week and by the end of the first thirteen weeks of the season, 107 Bti applications had been made. At this pace, during a 32-week season, approximately 263 treatments would have been required, at a substantial cost for both materials and labor. At this point, a decision was made to switch to an alternate product. All subsequent treatments were made using Bs, the recently registered biological larvacide.

***Bacillus sphaericus* (Bs)**. During the 1995 season, biologists with SYMVCD received a research authorization permit to apply Bs, a then experimental larvacide. This allowed SYMVCD to treat up to six half-cells at rates of 10 pounds per acre. These trials produced excellent results, providing residual control for up to four weeks (Yoshimura et al., 1996). Bs was registered in California for use as a mosquito larvacide under the trade name Vectolex prior to the 1997 season.

The entire mosquito control season in 1998 necessitated only 46 total Bs applications. Part of this increased efficiency is due to the residual activity of Bs, but another factor adding to the effectiveness of the Vectolex treatments was the use of a granular formulation, rather than liquid formulation. The use of a granular material improved penetration of the larvacide through the vegetation canopy.

The Vectolex CG granular formulation of Bs was applied with a Maruyama MD 150DX backpack mister (purchased through Target Specialty Products, 1-800-767-0719) at a rate of 20 pounds per acre. A worker on foot circled the cell, while broadcasting the corncob granules with the backpack blower over the vegetation and into the water, distributing the material as evenly as possible. Using this method, each 0.75-acre half-cell required less than ten minutes to complete.

The switch to Bs also required the use of slightly different monitoring methods. Bs has been shown to provide residual control for up to 60 days in waters containing suspended organic material. Bs also acts slower than Bti, typically requiring 2-3 days to kill mosquito larvae (Yoshimura et al., 1996) Because of this residual activity, there may be larvae present in the cells even while Bs is still effectively controlling the population. Therefore, the threshold level at which retreatment is required is based not only on the number of larvae present, but also on the age or instar of the larvae. Retreatment of a half-cell occurred only when fourth instar and/or pupae were present at a density of at least 0.1 per dip. These later instars are an indication that the treatment is beginning to lose effectiveness and the larvae are completing their life cycle.

During 1997, after switching from Bti, a total of 43 half-cell applications were made using Bs at 20 pounds per acre. An average of 5.6 weeks elapsed between treatments while using Bs; Bti treatments averaged only 1.25 weeks between applications.

For the entire 1998 season, regular Bs treatments were the primary control measure utilized at the Demonstration Wetlands. Due to the high demand for mosquito fish from SYMVCD, none were available for additional stocking in 1998. The overwintering fish population from the 1997 season provided the fish component of the control program. In addition, vegetation harvest, a technique which improves the efficacy of larvacide applications and access to the interior of the cell for fish, was not conducted.

In 1998, a total of 46 half-cell applications of Vectolex CG were performed and an average of 5.6 weeks elapsed before retreatment was required. The cost comparison in Table 3 shows that Bs was more cost effective compared to Bti. Additionally, it is important to note that some factors were not considered in the cost comparison such as the time required to transport the Bti spray equipment to the Demonstration Wetlands and the extra time required to monitor the larvae counts 24 hours post-treatment. During the 1997 and 1998 seasons, Bs proved to be an effective and economical option for control of mosquitoes.

One of the possible dangers of relying solely on Bs to control mosquitoes is the potential for mosquitoes to develop resistance to the product. There have been several documented cases of populations developing resistance to Bs both in the laboratory and under field conditions. This resistance, however, has also been shown to be reversible by subsequently treating populations resistant to Bs with Bti (Silva-Filha et al., 1997). Although there was no evidence of the population of mosquitoes at the Demonstration Wetlands becoming resistant to Bs in 1998, management in the future should include treatments with Bti on a rotational basis. This would eliminate low levels of resistance to Bs which may not be evident from the monitoring data collected. These treatments would probably be most effective if a granular formulation, either corncob or silica sand, was used to enhance penetration through the thick vegetation.

Lagenidium. In 1994, experimental culturing of *Lagenidium*, a fungus which attacks mosquito larvae, was attempted in Demonstration Wetlands effluent, however, the limited attempts were unsuccessful. This fungus, which is currently registered for use as a mosquito control agent as Laginex®, should be studied in the future to evaluate its potential at the treatment wetlands. One possible advantage of this product is that if conditions are favorable to support this fungus, control may continue indefinitely.

Physical Control Measures

Vegetation Management. In 1995, several vegetation management techniques were applied to some of the wetland half-cells. Combing, thatching and channelization were all performed in order to provide better access for fish populations to all parts of the cell, decrease breeding, harborage, and overwintering habitat for mosquitoes, and to aid the effectiveness of larvacide applications by improving the insecticide contact with the water surface.

Combing consists of the removal of all dead vegetation above and slightly below the water surface with a backhoe, while thatching refers to the removal of all dead vegetation from the water surface down to the bottom of the cell. A substantial portion of live vegetation is also removed during both of these procedures. Channelization involves the digging of open water channels three feet deep and four feet wide along the entire edge and at 50-foot intervals throughout the cell. This technique was used primarily to improve fish distribution throughout the cell, and to reduce mosquito breeding and harborage in overhanging vegetation.

In 1996, combing and channelization were again performed on selected cells. In addition, cell 8A/B was replanted with California bulrush (*Scirpus californicus*).

Prior to the 1997 season, combing and channelization were the primary vegetation harvest techniques employed. Additionally, cell 9A/B was turned into a hemi-marsh, with patches of open water and emergent marsh alternating every 50 feet. A complete vegetation harvest history for each half-cell is contained in Table 7-2.

There is not enough valid data to scientifically analyze which of these techniques provided the best results concerning mosquito control. The combing and thatching treatments appeared to provide the best access for fish as well as for the larvacide applications. Due to the large amounts of dense emergent marsh under both the channelization and hemi-marsh techniques, it is doubtful whether enough fish access was provided to actually improve the control provided by mosquito fish. At the very least, the hemi-marsh treatment reduces the attractive mosquito breeding habitat by 50 percent.

The replanting of cell 8A/B with *S. californicus* also appeared to provide benefits to the mosquito management activities. The quantity of thatch and decomposing plant matter in cell 8 appeared to be much less than those cells dominated by *S. acutus*. The reduced density of thatch provided improved access for both fish and larvacide applications. Also, the lower amount of decomposing matter probably made the cell less attractive to gravid females. The lower amount of senescent vegetation in cell 8 is most likely related to the relative youth of the vegetation communities in comparison to the other cells. Cell 8A/B recorded an average of 0.015 larvae per dip in 1998, and required only one treatment the entire season. In comparison, the remaining cells at the Demonstration Wetlands averaged 0.25 larvae per dip, and over four treatments per cell. The influence of the vegetation community on mosquito populations would be an excellent area of study in future seasons.

Overhead Sprinkler Application, 1995

During the 1995 season, the use of overhead sprinklers was tested as a means to prevent mosquitoes from accessing the cell to lay eggs. Bufferlands staff constructed a sprinkler system running the entire length of cell 10 B, with risers capable of clearing the tallest vegetation. Water was pumped directly from the cell by a gas-powered pump. Sprinklers were run from dusk until dawn to deter adult mosquitoes from entering the half-cell during peak activity periods. Not enough data was gathered to perform a rigorous analysis, but results indicated that the sprinklers were able to suppress larvae populations below harmful levels. Although this manual sprinkler system was not cost-effective during the two-month period it was in operation, an automatic, built-in system could have the potential to be cost-effective over the life of a project.

Demonstration Wetlands Effluent vs. Freshwater Mosquito Production Study, 1997

The following results are condensed from the 1997 Annual Report (Nolte, 1998). The full report including methods and results can be found in the original report.

During the 1997 season, in anticipation of utilizing the Demonstration Wetlands effluent on-site to create wildlife habitat and improve water quality, a study was conducted to determine if the effluent provided greater mosquito production potential than water occurring on-site in nearby Laguna Creek. The habitat cell, the location where all Demonstration Wetlands effluent collects prior to being returned to the plant, had produced few mosquitoes during the five-year project, indicating that any increased breeding potential due to effluent water quality parameters would be low.

For the study, two identical cells were created adjacent to each other and one was filled with effluent while the other was supplied with water from Laguna Creek. The cells were managed to minimize the differences of other variables such as vegetation composition and density, predator populations, and water depth. Twenty random dips were taken bi-weekly from each cell using the same procedures as those for the Demonstration Wetlands monitoring program.

From June 6, 1997, to September 23, 1997, a total of 29 sample events occurred. *Culex tarsalis* was the dominant species found within the constructed wetlands (CW) test cell, while *Anopheles* spp. were dominant within the Laguna Creek (LC) test cell. Mosquito larvae were most abundant in samples taken during the first three weeks of the sampling phase. Between June 6, and July 3, eighty (80) larvae were detected in the CW test cell while 42 larvae were collected from the LC test cell. Only six larvae were found in the CW test cell during the following 14 weeks of sampling, and during the same period six larvae were found in the LC test cell. Larvae were detected in the CW test cell during 8 of 29 sampling events, and in the LC test cell during 13 of 29 sampling events.

The average number of larvae per dip at the CW test cell was almost twice that of the average number per dip at the LC test cell, with 0.15 larva per dip and 0.08 larva per dip respectively. These means, however, were not significantly different ($p = 0.29$). This study provided preliminary evidence that there would be no greater potential for mosquito production using Demonstration Wetlands effluent instead of on-site surface water to create wetland habitat.

Summary

The research at the SRWTP Demonstration Wetlands not only produced results on the ability of a constructed wetlands system to polish secondary effluent, it also provided a wealth of information relating to the control of mosquitoes under near ideal breeding conditions. The program was an excellent example of an integrated pest management system, combining physical source manipulation, biological control, and research. Only when several practices were utilized concurrently was acceptable control achieved. During the five-year pilot project, this ancillary program used over 1,440 pounds of Vectolex CG and 748 gallons of Vectobac 12AS. Also, over 88 pounds of mosquito fish (approximately 133,000) and 10,000 guppies were stocked. Over 26,000 mosquito larvae were captured and identified in just under 40,000 dips. Each dip removed approximately 250 mL of water for a total of 2,615 gallons removed. To collect this data, staff covered over 450 miles on foot. The end result of these efforts was an economical, effective and environmentally safe mosquito management program.

REFERENCES

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TABLE 7-1
SUMMARY OF 1998 WEEKLY MOSQUITO MONITORING DATA
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

CELL	Total Mosquito Larvae Per Dip															
	03/10/98	03/17/98	03/24/98	04/01/98	04/07/98	04/14/98	04/21/98	04/28/98	05/05/98	05/12/98	05/19/98	05/26/98	06/02/98	06/09/98	06/16/98	06/23/98
HAB CELL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	---	0.00	0.00	0.00	0.00	0.00	0.00
CELL 1A	0.00	0.00	0.25	0.50	0.00	0.00	0.00	0.17	0.00	---	0.08	0.33	0.33	1.08	0.00	0.25
CELL 1B	0.08	0.08	0.50	0.00	0.17	0.00	0.17	1.92	0.17	---	1.50	3.25	1.08	1.58	0.58	2.67
CELL 2A	0.00	0.00	0.00	0.00	---	0.00	---	0.00	0.00	---	---	---	0.08	0.08	0.00	0.00
CELL 2B	0.00	0.00	0.17	0.00	---	0.00	0.00	0.00	0.33	---	0.17	0.08	0.00	0.25	0.00	0.08
CELL 3A	0.08	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	---	0.00	0.00	---	0.08	0.33	0.00
CELL 3B	0.00	0.08	0.25	0.00	0.00	0.08	0.00	0.00	0.50	---	0.08	0.08	0.00	1.33	1.92	1.67
CELL 4A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	---	0.00	0.17	0.00	0.42	0.00	0.00
CELL 4B	0.00	0.00	0.08	0.00	0.00	0.08	0.00	0.08	0.42	---	0.00	0.00	0.33	1.25	0.00	0.08
CELL 5A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	---	0.00	0.00	0.00	0.00	0.00	0.00
CELL 5B	0.17	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	---	0.00	0.00	0.00	0.00	0.00	0.00
CELL 6A	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	---	0.00	0.00	0.00	0.00	0.75	0.00
CELL 6B	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	---	0.00	0.00	0.00	0.00	0.08	0.00
CELL 7A	0.08	0.00	0.08	0.33	0.08	0.00	0.00	0.08	0.00	---	0.33	0.08	0.00	0.00	1.58	0.17
CELL 7B	0.00	0.08	0.25	0.33	0.17	0.00	0.00	0.83	3.17	---	0.17	0.42	0.50	9.25	3.42	0.00
CELL 8A	---	---	0.00	0.00	0.00	0.00	0.00	0.00	0.00	---	0.00	0.00	0.00	0.00	0.00	0.00
CELL 8B	---	---	0.00	0.00	0.33	0.00	0.00	0.00	0.00	---	0.00	0.00	0.00	0.17	0.17	0.00
CELL 9A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	---	0.00	0.00	0.00	0.00	0.00	0.00
CELL 9B	0.17	0.33	0.25	0.08	0.00	0.00	0.17	0.08	0.17	---	0.00	0.17	0.83	1.25	0.00	0.17
CELL 10A	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	---	0.00	0.00	0.00	0.00	0.00	0.00
CELL 10B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.08	---	0.00	0.00	0.17	0.33	0.08	0.08
CELL 11A	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	---	0.00	0.08	0.00	0.08	0.08	1.75
CELL 11B	0.33	0.17	0.67	0.00	0.00	0.00	0.00	1.83	0.00	---	0.00	1.08	0.00	0.00	1.25	0.08
AVG	0.05	0.03	0.13	0.06	0.04	0.01	0.02	0.22	0.21	---	0.11	0.26	0.15	0.75	0.47	0.30

TABLE 7-1 (continued)
SUMMARY OF 1998 WEEKLY MOSQUITO MONITORING DATA
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

CELL	Total Mosquito Larvae per Dip															
	07/01/98	07/07/98	07/14/98	07/21/98	07/28/98	08/05/98	08/11/98	08/18/98	08/25/98	09/01/98	09/08/98	09/15/98	09/22/98	09/29/98	10/06/98	AVERAGE
HAB CELL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CELL 1A	1.75	0.00	0.92	0.00	---	1.08	0.00	0.08	1.08	0.00	0.00	0.17	0.50	1.17	1.67	0.39
CELL 1B	0.00	1.83	2.50	0.00	---	3.58	0.17	0.00	2.42	1.42	2.25	0.25	0.42	1.17	2.00	1.09
CELL 2A	---	---	---	---	---	---	0.00	0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.02
CELL 2B	0.25	0.00	---	---	---	1.00	0.00	0.00	0.00	0.00	0.00	0.00	5.75	0.00	0.08	0.31
CELL 3A	0.33	0.00	0.17	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.08	0.00	0.06
CELL 3B	0.00	0.17	0.42	0.58	0.25	0.00	0.00	0.00	0.17	0.00	0.00	0.00	3.33	0.00	0.42	0.38
CELL 4A	0.25	0.25	0.08	0.33	---	0.33	0.58	0.00	0.17	0.00	2.67	0.50	3.83	0.42	1.75	0.41
CELL 4B	0.17	0.33	0.00	0.58	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.42	0.00	0.14
CELL 5A	0.00	0.00	0.00	0.00	---	---	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CELL 5B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
CELL 6A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
CELL 6B	0.00	0.00	0.00	0.00	---	---	0.00	0.00	---	0.00	0.00	0.00	0.00	0.00	0.00	0.01
CELL 7A	0.25	0.42	8.83	1.75	0.00	0.00	0.08	0.00	0.00	0.33	0.00	0.50	0.00	0.17	0.00	0.51
CELL 7B	0.00	0.25	1.33	0.25	---	0.17	0.25	1.67	0.25	1.17	0.00	1.50	2.08	0.00	2.00	1.02
CELL 8A	0.00	0.00	0.00	0.00	---	---	0.08	0.00	---	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CELL 8B	0.00	0.00	0.00	0.00	---	---	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.03
CELL 9A	0.00	0.00	0.17	0.08	0.00	0.08	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.02
CELL 9B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.08	0.75	0.00	0.00	0.17
CELL 10A	---	0.00	0.00	0.08	---	0.08	0.75	0.25	---	0.25	0.00	1.92	0.00	0.25	0.00	0.14
CELL 10B	0.17	0.33	0.00	0.00	---	5.58	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.92	0.28
CELL 11A	0.25	0.25	0.83	1.58	1.00	0.25	0.00	0.25	0.00	0.50	0.08	0.83	0.92	0.00	0.00	0.29
CELL 11B	1.42	0.08	0.00	0.00	0.33	0.00	0.00	0.00	0.33	0.00	0.00	0.08	0.00	1.00	0.42	0.30
AVG	0.23	0.18	0.73	0.25	0.16	0.68	0.09	0.10	0.24	0.17	0.26	0.26	0.76	0.20	0.40	0.25

TABLE 7-2
SUMMARY OF MOSQUITO MANAGEMENT ACTIVITIES, 1994-1998
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

Cell	Wastewater Treatment	1994 May-October		1995 March-October			1996 March-October			1997 March-October			1998 March-October			Totals 1994-1998	
		Avg. larvae/ dip[b]	*B.t.i.*[c]	Veg. harvest[a]	Avg. larvae/ dip[b]	*B.t.i./ B.s.*[c]	Veg. harvest[a]	Avg. larvae/ dip[b]	*B.t.i./ B.s.*[c]	Veg. harvest[a]	Avg. larvae/ dip[b]	*B.t.i./ B.s.*[c]	Veg. harvest[a]	Avg. larvae/ dip[b]	*B.t.i./ B.s.*[c]	Avg. larvae/ dip	*B.t.i./B.s.*
1A	fill/draw	1.31	3	C	0.10	4/0	C	0.01	2/0	N	0.27	3/2	N	0.39	0/3	0.42	12/5
1B	fill/draw	0.91	3	N	0.17	6/0	C	0.25	14/0	N	0.64	10/5	N	1.09	0/7	0.61	33/12
2A	fill/draw	0.65	0	T	0.08	5/0	C	0.03	4/0	C	0.22	4/2	N	0.02	0/0	0.20	13/2
2B	fill/draw	2.08	0	T	0.20	7/0	C	0.08	8/0	C	0.37	8/2	N	0.31	0/3	0.61	23/5
3A	recycle	9.07	3	T	0.05	2/0	N	0.07	7/0	C	0.17	7/1	N	0.06	0/1	1.88	19/2
3B	recycle	7.80	3	T	0.13	4/0	N	0.13	12/0	C	0.22	9/3	N	0.38	0/4	1.73	28/7
4A	recycle	6.06	0	C	0.17	11/0	C	0.01	1/0	C	0.86	5/4	N	0.41	0/3	1.50	17/7
4B	recycle	1.15	0	C	0.75	10/0	C	0.04	5/0	C	0.21	6/2	N	0.14	0/3	0.46	21/5
5A	control	0.12	0	N	0.02	2/0	N	0.00	0/0	N	0.01	1/0	N	0.00	0/0	0.03	3/0
5B	control	0.06	0	N	0.04	2/0	N	0.01	1/0	N	0.01	0/0	N	0.01	0/0	0.02	3/0
6A	overland flow	0.27	0	Ch	0.01	2/0	Ch	0.03	1/0	Ch	0.07	2/0	N	0.03	0/0	0.08	5/0
6B	overland flow	0.26	0	N	0.03	1/0	C	0.08	3/0	C	0.13	6/0	N	0.01	0/0	0.10	10/0
7A	plug flow	1.96	0	N	0.92	9/2	N	0.00	0/0	N	0.36	3/2	N	0.51	0/2	0.75	12/6
7B	plug flow	1.09	0	N	0.32	8/2	N	0.45	23/0	N	1.27	8/5	N	1.02	0/6	0.83	39/13
8A	plug flow	0.32	0	T	0.76	8/0	R	5.71	2/0	N	0.03	1/0	N	0.00	0/0	1.36	11/0
8B	plug flow	1.99	0	T	0.52	9/0	R	3.24	4/0	N	0.01	1/0	N	0.03	0/1	1.16	14/1
9A	plug flow	3.28	3	Ch	0.07	6/0	Ch	0.01	1/0	H	0.11	3/1	N	0.02	0/1	0.70	13/2
9B	plug flow	4.07	3	T	0.24	7/0	Ch	0.25	17/0	H	0.81	10/4	N	0.17	0/4	1.11	37/8
10A	plug flow	0.23	0	C	0.86	9/2	C	0.08	4/0	C	0.12	4/1	N	0.14	0/1	0.29	17/4
10B	plug flow	0.10	0	N	0.89	9/1	C	0.29	14/0	C	0.25	7/2	N	0.28	0/1	0.36	30/4
11A	plug flow	0.42	0	T	0.05	4/0	Ch/C	0.02	1/0	Ch	0.07	1/3	N	0.29	0/2	0.17	6/5
11B	subsurface	0.39	0	Ch	0.12	3/0	Ch/C	0.23	15/0	Ch	0.90	8/4	N	0.30	0/4	0.39	26/8
Total		1.98	18		0.30	128/7		0.50	139/0		0.32	107/43		0.25	0/46	0.67	392/96

[a] Key to harvest methods: C=Comb, Ch=Channelize, H=Hemi-marsh, N=No harvest, R=Replant, T=Thatch
[b] Average number of mosquito larvae per dip for the entire season
[c] Total number of *B.t.i.* and *B.s.* treatments for the entire season

TABLE 7-3
COST COMPARISON OF Bs AND Bti MOSQUITO CONTROL
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

Parameter	Units	Mosquito Control Agent Vectolex CG (Bs)	Mosquito Control Agent Vectobac 12AS (Bti)
Material Cost	$/ac	80.00	6.88
Application Time	min/ac	8	15
Labor Cost	$/hr	28.50	28.50
Equipment Cost	$/hr	2.00[a]	50.00[b]
Total Application Cost	$/ac	83.60	26.51
Average Time Between Applications	wk	5.63	1.25
Total Cost	$/ac·wk	14.93	21.21

[a]Assumes backpack sprayer
[b]Assumes use of tractor