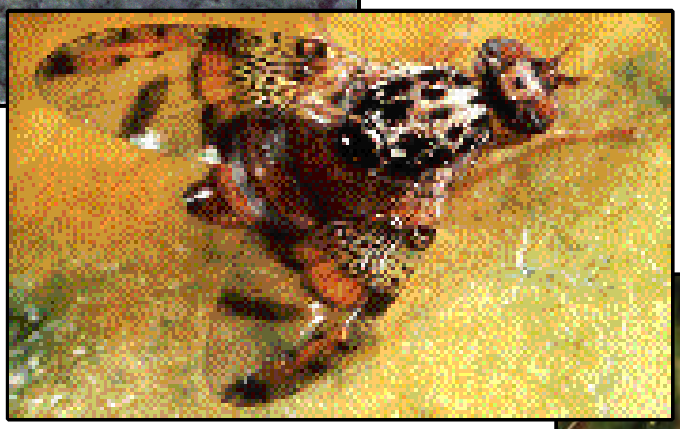
Biological Assessment of Five Lakes in the Umatilla, Florida Area in Response to Application of Malathion for the Control of the Mediterranean Fruitfly (*Ceratitis capitata*)







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BIOLOGICAL ASSESSMENT OF FIVE LAKES IN THE UMATILLA, FLORIDA AREA IN RESPONSE TO APPLICATION OF MALATHION FOR THE CONTROL OF THE MEDITERRANEAN FRUIT FLY (C*eratitis capitata*)

INTRODUCTION

The Mediterranean Fruit Fly (C*eratitis capitata*), also commonly referred to as the Medfly, is one of the world's most destructive fruit pests, infesting over 250 different plants of commercial importance. The adults deposit eggs through holes in the rind of the host fruit. These eggs hatch into 1/4 inch long larvae (maggots) which feed on the fruit pulp (Florida DOACS, 1998). Eradication efforts generally include the treatment of the infested area (in this case an approximately 35 square mile area within Lake and Marion counties) with malathion bait spray at 5 to 10 day intervals until eradication is declared. Application of bait is usually accomplished by a combination of ground and aerial spraying.

Malathion is a fairly broad spectrum insecticide, which means that it is toxic to a wide variety of organisms. Therefore, preventing contamination of surface water bodies is a concern due to the potential impacts on the aquatic communities. To this end the Florida Department of Agriculture and Consumer Services (DOACS) or any other entity spraying malathion with helicopters is required to observe a 100 foot buffer zone around all water bodies within the treatment area which are named on USGS Quadrangle map(s) for that particular area.

A Medfly outbreak in the Umatilla, Florida area prompted the initiation of ground and aerial application of malathion bait beginning May 3, 1998. The final (seventh) aerial application of malathion occurred on June 13th, and eradication of the Medfly for this area was declared on August 7, 1998. Macroinvertebrate communities were sampled in five lakes in this area between April 30 and August 4, 1998 (see Table 1). The purpose of this effort was to determine the potential impacts of malathion application on the biota of selected lakes around which a buffer zone was to be observed. The following lakes were sampled: South Twin Lake (81 Acres), Lake Gibson (76 Acres), Lake Umatilla (161 Acres), East Lake (83 Acres) and Crescent Lake (74 Acres). (See map, Fig. 1)

METHODS

The shallow (littoral zone) areas of each lake were sampled using an experimental method which employs the collection of six one-half meter long sweeps using a standard D-frame dipnet with a 0.30 meter wide opening and a U.S. #30 bag (595 μm mesh). Sweeps were performed in what was considered to be the best or most productive habitats which when sampled would provide an estimate of the site's maximum biological diversity. Sweep samples were placed in 1/2 gallon Nalgene containers, labeled and returned to the laboratory for sorting. In the laboratory the entire contents of each sample container were sorted, and the organisms thus obtained were placed in vials of 95% ethanol for later identification. All organisms were identified to the lowest practicable taxonomic level (species in most cases) and enumerated.

The sublittoral (2 to 4 meter depth) areas of Lake Gibson and South Twin Lake were also sampled using the Department's current protocol for benthic macroinvertebrate composite grab sample collection for lakes (FDEP, 1996), as follows. For lakes less than 1000 acres, the lake was divided into 12 sampling units or sections. One grab sample was taken in the sublittoral zone from each of these sections using a Petite Ponar dredge. The twelve dredge grabs thus obtained were composited into a sample container and returned to the laboratory for processing. In the laboratory the contents of the sample container were transferred to an enamel pan which was gridded into 24 sections roughly 5cm x 5cm each. Eight of these grids were randomly selected and their material removed and transferred to a second gridded pan of the same dimensions. Individual grids were randomly selected from the second pan and their contents completely sorted to remove all macroinvertebrates. This process continued until a minimum of 100 organisms were obtained. All organisms were identified to the lowest practicable taxonomic level (species in most cases) and enumerated.

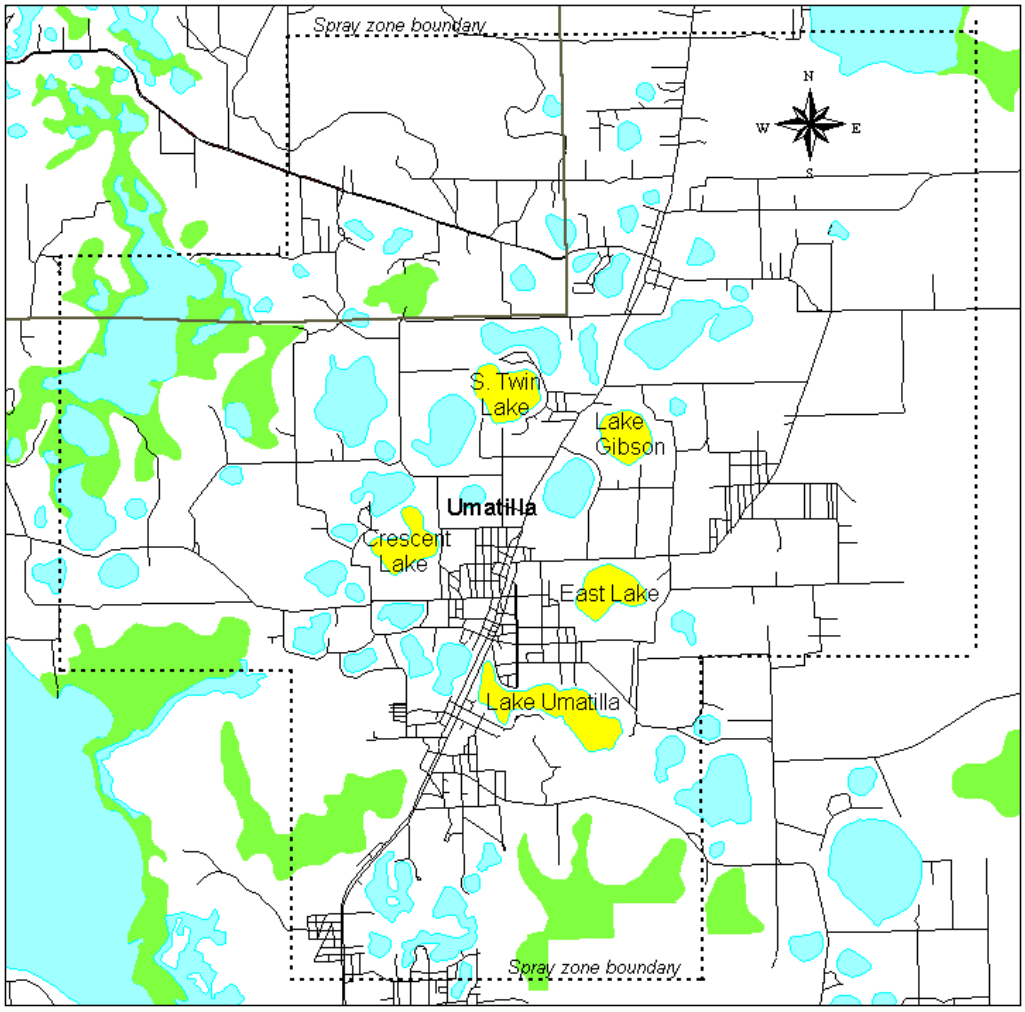


Figure 1. Map of Umatilla, FL lakes where macroinvertebrate sampling was carried out.

Metrics which were reviewed as part of this study include the following:

- Number of macroinvertebrate taxa
- Number of individuals
- Shannon-Weaver Diversity Index
- Equitability
- Dominant functional feeding group
- Number of Ephemeroptera, Trichoptera and Odonata taxa
- Hulbert's Lake Condition Index (LCI), biotic component only (Hulbert 1990)
- Index of Similarity (Odum 1971)
- Quantitative Stability Index (FDEP Fifth Year Inspection Program)

It should be noted that the Department has not as yet completed the process of developing and standardizing lake bioassessment methods and metrics.

For each lake, the percentages of samples represented by each major taxonomic group were compared between the initial (pre-treatment) sample and subsequent (post-treatment) samples. Additionally, the Quantitative Stability Index was calculated. This metric was devised by the Department for comparing the macroinvertebrate communities at sites upstream and downstream of point source discharges. It is determined using a two step process. First, the relative proportions of the major taxonomic groups are calculat-ed for each site (data set). For each pair of data sets being compared, the lesser of the two percentages for each major taxonomic group are totaled to determine the QSI value. A QSI (% composition) of 100% means the two sites (data sets) being compared are identical. Values between 50% and 75% indicate slight to moderate degradation. Values below 50% would indicate more severe degradation. In this study, the QSI was used to compare results within each lake before and after malathion treatments.

As part of the sublittoral benthic sampling process for Lakes Gibson, Umatilla and South Twin, water samples were collected from the center of each lake along with field measurements for temperature, conductivity, dissolved oxygen and pH. A Hydrolab Scout II unit was used for the field measurements. Water samples were collected at 0.5 meter depth. They were analyzed in the DEP Central District Laboratory in Orlando for ortho-phosphorus, alkalinity, turbidity, color, chlorophyll a and total and fecal coliforms. The DEP Central Laboratory in Tallahassee performed analyses for total phosphorus, total Kjeldahl nitrogen, ammonia nitrogen, nitrate/nitrite, and algal growth potential. Phytoplankton identification and enumeration, sediment particle size analysis, and sediment percent organic content determination were also carried out in the Central Lab. While much of this information was not necessary to answer the question of toxic effects of malathion, these data were collected as part of the Department's lake bioassessment methods development effort.

Water samples for malathion concentration determination were collected by DOACS personnel typically within 30 minutes to two hours of the completion of each spray event. These samples were collected near the surface in shallow nearshore areas of each lake. Summary data from these analyses were made available to DEP by DOACS (Table 3).

In reviewing the macroinvertebrate data, it was taken into consideration that the littoral sweep samples are not quantitative, but at best semi-quantitative. Therefore, metrics

which rely more on quantitative information were given less significance, whereas measures of relative abundance or of a comparative nature were more closely evaluated for the sweep samples.

The malathion spraying and biological monitoring activities as they occurred from April 30, 1998 through July 6, 1998 are shown below in Table 1. Activities listed for April 30 and May 1, 1998 occurred prior to the initial malathion treatment.

TABLE 1 - Chronology of spraying and monitoring events, 4/30/98 through 7/6/98

DATE	LAKE NAME	LITTORAL SWEEPS	SUBLITTORAL PONAR	WATER SAMPLES	FIELD METER READINGS
4/30	**South Twin**	**X**	**X**		**(meter inoperable)**
	Gibson	**X**	**X**		**(meter inoperable)**
5/1	**East**	**X**			**(meter inoperable)**
	Umatilla	**X**			**(meter inoperable)**
	Crescent	**X**			**(meter inoperable)**
5/3-5/5	**MALATHION TREATMENT**				
5/11-5/12	**MALATHION TREATMENT**				
5/12	**S. Twin**	**X**	**X**		**X**
	Gibson	**X**	**X**		**X**
	East	**X**			**X**
	Umatilla	**X**			**X**
	Crescent	**X**			**X**
5/16	**MALATHION TREATMENT**				
5/23	**MALATHION TREATMENT**				
5/30	**MALATHION TREATMENT**				
6/6	**MALATHION TREATMENT**				
6/13	**MALATHION TREATMENT**				
6/16	**S. Twin**	**X**			
	Gibson	**X**			
	East	**X**			
	Umatilla	**X**			
	Crescent	**X**			
7/6	**S. Twin**		**X**	**X**	**X**
	Gibson		**X**	**X**	**X**

It should be noted that DEP became aware of plans to begin treatment of the Umatilla area less than three days prior to commencement. Lake selection, number of lakes and methods used were somewhat limited by the monitoring resources of the Central District available at that time. Furthermore, it was not known if the initial treatment area

would be expanded and if so to what extent. Unfortunately, due to these factors no lake was located and sampled to serve as a control for comparison purposes.

RESULTS

The table below summarizes the metrics of interest for all the macroinvertebrate sample results. Malathion sample results for each lake over the total treatment period are shown in Table 3. The results for each lake are discussed separately below.

Table 2. Macroinvertebrate sampling data from Umatilla lakes. Pre-spray sampling events are indicated by italics. (LCI=Lake Condition Index, biotic component; QSI=Qualitative Stability Index)

LITTORAL SWEEPS	Date	No. of Taxa	Number of Individuals	Diversity	LCI	QSI
South Twin Lake	*4/30/98*	*34*	*349*	*3.37*	*16*	*Reference*
South Twin Lake	5/12/98	45	808	3.39	24	91.07%
South Twin Lake	6/16/98	32	260	2.88	14	**41.52%**
Lake Gibson	*4/30/98*	*30*	*326*	*3.37*	*12*	*Reference*
Lake Gibson	5/12/98	35	288	3.57	12	73.40%
Lake Gibson	6/16/98	27	222	2.96	10	72.42%
East Lake	*5/1/98*	*26*	*324*	*2.48*	*10*	*Reference*
East Lake	5/12/98	62	397	4.68	20	**27.27%**
East Lake	6/16/98	28	84	4.15	10	**37.70%**
Lake Umatilla	*5/1/98*	*36*	*435*	*3.95*	*11*	*Reference*
Lake Umatilla	5/12/98	36	562	2.4	8	**48.02%**
Lake Umatilla	6/16/98	51	953	3.58	13	65.14%
Crescent Lake	*5/1/98*	*36*	*1259*	*2.78*	*9*	*Reference*
Crescent Lake	5/12/98	32	206	3.83	6	64.19%
Crescent Lake	6/16/98	30	138	3.94	8	**40.31%**

12 GRAB PONARS	Date	No. of Taxa	Number of Individuals/m2	Diversity	LCI	QSI
South Twin Lake	*4/30/98*	*17*	*3279*	*2.55*	*8*	*Reference*
South Twin Lake	5/12/98	24	4107	3.35	13	91.01%
South Twin Lake	7/6/98	23	616	3.24	14	75.98%
Lake Gibson	*4/30/98*	*26*	*4456*	*3.96*	*11*	*Reference*
Lake Gibson	5/12/98	19	3651	3.25	11	79.95%
Lake Gibson	7/6/98	16	1557	2.73	11	71.82%

Table 3. Malathion concentrations in water samples taken from the five lakes during the Medfly eradication effort.

Spray event ---------->	1	1	2	2	3	4	5
Date ---------->	5/3/98	5/9/98	5/11/98	5/12/98	5/22/98	5/23/98	5/30/98
Lake							
Umatilla	BDL	BDL	BDL	-	BDL	0.3*	BDL
Gibson	4.5	0.3*	2.5	-	BDL	1.8	0.9
South Twin	0.56	BDL	3.4	-	BDL	1.7	0.3*
East	0.13*	0.46	-	0.3*	0.3*	0.3*	0.4
Crescent	0.26*	0.32	-	1.9	0.3*	0.3*	BDL

Spray event ---------->	6	6	7
Date ---------->	6/6/98	6/12/98	6/13/98
Lake			
Umatilla	0.3*	BDL	BDL
Gibson	0.9	BDL	0.4
South Twin	0.3*	BDL	BDL
East	0.3*	BDL	BDL
Crescent	0.3*	BDL	0.3*

Note: All values shown are in mg/l.

NOTES:

- The state standard for malathion in Class III fresh waters is 0.1 μg/l, which is the method detection limit (MDL) for the analyses performed.
- BDL indicates that samples taken on these dates had levels of malathion that were below the method detection limit of 0.1 μg/l.
- Values with an asterisk (*) are for samples which had levels above the detection limit, but below the practical quantification limit of 0.3 μg/l.
- Lakes Umatilla, Gibson, and South Twin were sampled for malathion on 5/11/98, whereas lakes East and Crescent were sampled on 5/12/98.

South Twin Lake

The highest concentration of malathion in this lake (3.4 μg/l) was detected on May 11. The quantitative (ponar) data show varying results when comparing pre and post (final) treatment data. Total number of organisms per square meter decreased from 3279 to 616, but Shannon-Weaver Diversity Index, number of taxa and Lake Condition Index (LCI) increased. The improvement in the diversity index value was due in part to the increased number of taxa with a simultaneous decrease in the percent contribution of the dominant taxon (the midge larvae *Polypedilum halterale* group).

Community composition measured at the major taxonomic group level showed some changes between pre and post-treatment data. Comparing the pre-treatment sweep samples to those collected after the first two treatments, the QSI was 91%. When comparing the pre-treatment samples to the final samples (following seven treatments) the QSI dropped to 41.5%. All data sets (sweeps and ponars) following malathion treatment showed reduced percentages in the contributions of oligochaete worms and turbellarians (flatworms). After the initial treatment the turbellarians were totally absent from all subsequent samples. Water mites (Acariformes) exhibited increased percent contribution in all post-treatment samples at South Twin Lake compared to pre-treatment samples.

Lake Gibson

The highest concentration of malathion in this lake (4.5 μg/l) was detected on May 3. The following comparisons are between the first (pre) and third (final) macroinvertebrate sample events. For the ponar samples, the total number of organisms per square meter decreased from 4456 to 1557, the total number of taxa dropped from 26 to 16, the diversity index decreased from 3.96 to 2.73, and the LCI remained stable. The same patterns were observed for the sweep samples, with total numbers of organisms, number of taxa and diversity index declining while the LCI remained stable.

For both the ponar and sweep samples, the QSI was stable when comparing the first sample event with each of the subsequent events. However, other community structure differences were observed. As was the case with South Twin Lake, turbellarians were absent following the onset of malathion treatment. Oligochaetes were also absent by the final treatment.

The percent contribution of water mites was variable throughout the sampling events, with no apparent trend for either the ponar or sweep samples.

East Lake

A maximum concentration of 0.46 μg/l malathion was detected in this lake on May 9. Sweep samples showed mixed results between initial and final macroinvertebrate sampling events. The total number of organisms decreased from 324 to 84; the total number of taxa increased slightly from 26 to 28; the diversity index increased from 2.48 to 4.15 and the LCI remained the same at 10. Community structure appeared to have changed as evidenced by the low QSI value when comparing initial and final data sets for this lake.

Once again, turbellarians were absent soon after the initiation of malathion treatment. The diversity index value for the second macroinvertebrate sampling event increased substantially over the initial event. This was largely the result of an increase in the number of taxa along with a drastic decrease in the number of turbellarians, which had previously made up over 50% of the total number of organisms in the sample. Concurrent with the decrease in turbellarians there was an increase in the percent contribution of water mites in the second sampling from 0.9% to over 18%. Nearly half of the water mites collected in the second sampling were representatives of the genus *Hydrodroma*. Another change in community composition was noted for the oligochaetes. Initially they made up nearly 25% of the total number of organisms. Following the initial treatments, only 2.5% of the total number of individuals were oligochaetes.

Lake Umatilla

The maximum post-treatment concentration of malathion in this lake was 0.3 μg/l, on May 23. Comparing the initial sample event to the final sample event for the sweep samples, the number of taxa increased from 36 to 51; total number of organisms increased from 435 to 953; diversity index decreased slightly 3.95 to 3.58 and the LCI increased slightly from 11 to 13.

The results from the intermediate sampling showed a total disappearance of turbellarians, as in the other lakes previously discussed. Also as seen several times before, the number of water mites increased dramatically, in this case from 61 individuals (14.02 % of the sample) to 354 individuals (62.99% of the sample). The number of oligochaetes also decreased markedly between the first and the second sample dates. Before spraying began, they made up about 14% of the sample. After spraying began, however, the oligochaetes accounted for only 0.18% of the sample. These shifts in community composition between the initial and second sample dates are reflected in the low QSI value of 48%.

Crescent Lake

The maximum post-treatment concentration of malathion in this lake, 1.9 μg/l, was found on May 12. Results of the sweep samples for this lake were mixed. Number of taxa progressively decreased from 36 to 30 and total number of organisms decreased from 1259 to 138. Diversity index progressively increased from 2.78 to 3.94, while the LCI remained relatively stable.

Comparing initial to final macroinvertebrate samples, the turbellarian and oligochaete populations were absent following all malathion treatments. Community structure shifts were indicated by the low QSI value of 40.31%.

DISCUSSION

While there was no obvious indication of mass eradication of organisms sampled by these procedures, a summary review of the data reveals the following regarding the sweep samples in the five lakes:

- Total numbers of organisms collected declined in four lakes.
- Diversity index values declined in three lakes.
- Numbers of different species collected declined in three lakes.
- The QSI suggested moderate degradation at two lakes and more severe degradation at three lakes when comparing samples from pre-application to post-(final) application.

Data from the benthic grab (Petite Ponar) analyses shown below indicate mixed results and somewhat less negative change when comparing pre-application and post- (final) application samples.

South Twin Lake ponar data show the following:

- 81% reduction in the total number of organisms.
- 27% increase in the diversity index.
- 35% increase in the numbers of different species collected.
- QSI value was just within the range for little or no degradation.

Lake Gibson ponar data show the following:

- 65% reduction in the total number of organisms.
- 24% reduction in the diversity index.
- 38% reduction in the numbers of different species collected.
- QSI value within the moderate degradation range.

In each of the lakes sampled, there was a reduction or total absence of turbellarians and oligochaetes following malathion treatment (see Fig. 2). The Environmental Protection Agency maintains an aquatic toxicity information and retrieval database (AQUIRE) which lists results of toxicity testing for various aquatic organisms. A review of AQUIRE for toxicity of malathion to aquatic invertebrates was performed. No references were listed for the effects of malathion on turbellarians. There were, however, a number of references which listed the toxicity to various species of oligochaetes. These values appeared very high, ranging from 4000 to 26,500 µg/L for concentrations of malathion in the water column. It should be noted that these were short term (1 to 3 day duration) tests. The tendency of malathion to accumulate rapidly and degrade slowly in aquatic sediments, and to have lethal and sublethal effects on invertebrates has been documented (Jewell and Johnson 1991, Spectrum Laboratories 1998, Wurgler and Kramers 1992) . Since oligochaetes are closely associated with bottom sediments and ingest varying amounts of organic material from that habitat, it is possible that malathion can become toxic to oligochaetes in the natural environment at much lower water column concentrations.

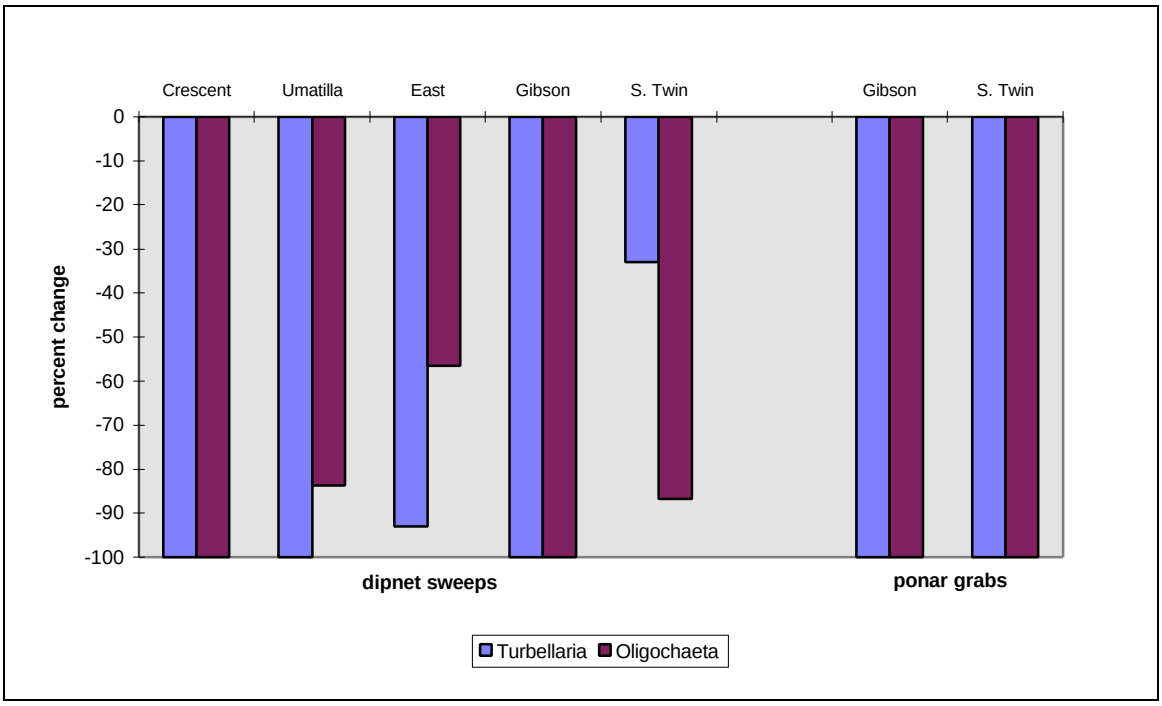


Figure 2. Percent change in turbellarian and oligochaete communities in lakes sampled: background condition versus post-malathion spraying.

Of the 354 water mite individuals encountered in Lake Umatilla on the second sample date, 339 were members of the soft-bodied genus *Hydrodroma*. Also of potential importance was the observation of numerous imagochrysalis (sedentary stage) specimens of *Hydrodroma* in the second sample. This might be the result of the absence of flatworms, which are known to be predators of various different types of small aquatic invertebrates (Kolasa 1991). The sedentary imagochrysalis stage of water mites would be a particularly vulnerable target for turbellarians. The fact that such large numbers of these sub-adult *Hydrodroma* were encountered in some samples might be a reflection of the absence of turbellarians. Also, the fact that this genus of mites is soft bodied may make it a more vulnerable prey organism than other more heavily sclerotized mite taxa.

SUMMARY

- Some alteration of the macroinvertebrate community was noted in all of the lakes sampled. This was especially apparent in those organism groups which are closely associated with bottom sediments (*i.e.*, the turbellarians and oligochaetes).

- The most apparent negative effect was seen in the turbellarians (flatworms), which nearly or completely disappeared in all five lakes after malathion spraying began. A similar but less drastic phenomenon was noted with the oligochaete populations.

- In some cases, the dramatic reductions in numbers of flatworms and oligochaetes that took place after malathion spraying began were accompanied by dramatic increases in numbers of water mites, most notably the soft-bodied genus *Hydrodroma*. This might have been due to the absence of turbellarians, which may be predatory on immature and adult mites.

RECOMMENDATIONS

- The 100 foot buffer zone around named water bodies should be maintained, or preferably increased. Any decrease in the width of this buffer zone could increase the severity of the ecological effects noted in this study.

- These results indicate that malathion spraying might cause a more profound and measurable effect on the organisms inhabiting lake sediments than those present in the water column. It is therefore suggested that aquatic sediment sampling for malathion be included as a standard portion of the monitoring carried out during any future Medfly eradication efforts which involve aerial application of malathion.

- For any future studies of this nature, it would be beneficial to include sampling at an appropriate control lake outside of the spray zone before, during and after malathion treatment. This would be done for the purpose of recognizing any effects of natural temporal variability on the study results.

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