TABLE 2. SURFICIAL SEDIMENT PHOSPHORUS FRACTIONS FOR THE CONTROL AREA (C) AND HARVESTED AREA (H) FROM 1979 TO 1984. PHOSPHORUS CONCENTRATIONS ARE IN µg/gDW. CDB-P IS CITRATE-DITHIONATE-BICARBONATE EXTRACTABLE PHOSPHORUS. NaOH-P IS 1 N SODIUM HYDROXIDE EXTRACTABLE PHOSPHORUS. TOTAL P IS 1 N HCl EXTRACTABLE PHOSPHORUS ON AN ASHED SAMPLE. TIP IS TOTAL INORGANIC PHOSPHORUS. BAP IS BIOLOGICALLY-AVAILABLE PHOSPHORUS EXTRACTED WITH 0.1 N NaOH. 1 S.E. = 13.7%.

	CDB-P		NaOH-P		Apatite-P		Total P		TIP		BAP	
	C	H	C	H	C	H	C	H	C	H	C	H
79	90	—	23	—	140	—	1113	—	415	—	—	—
80	49	—	78	—	105	—	1176	—	381	—	—	—
81	318	—	85	—	103	—	1581	—	489	—	212	—
82	178	298	81	61	110	76	1543	1528	395	477	183	175
83	95	111	74	71	75	92	1586	1307	422	289	453	219
84	330	181	90	70	105	105	1262	1136	431	260	303	218

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Residues and Efficacy of Two Formulations of 2,4-D on Aquatic Macrophytes in Buckhorn Lake, Ontario

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ABSTRACT

Efficacy studies and monitoring of 2,4-D residues in sediments, water and plants in Buckhorn Lake, Peterborough County, Ontario, (1977-79) indicated no significant differences in the effectiveness of the use of BEE 2,4-D or DMA 2,4-D. Early season treatments with either herbicide, seemed to offer slightly better control of aquatic macrophytes than treatments later in the season. Herbicide treatments coupled with harvesting (1977 only) did not show significant differences to treatments without the harvesting carried out at the same time. Residues persisted throughout the summer months in all of the plots tested. The problems of unauthorized use of 2,4-D prior to treatment and/or the effects of land drainage were indicated. Lateral movement or dilution of the chemical through the water was established.

Key words: Aquatic weeds, harvesting, lateral movement, persistence, 2,4-D amine, Myriophyllum, Potamogeton.

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INTRODUCTION

Throughout the mid to late 1970's, aquatic macrophyte growth in the Kawartha Lakes district of Central Ontario was extremely high, covering an estimated 80% to 90% of the surface area of these highly used recreational bodies of water. Extensive aquatic macrophyte growth creates problems for shoreline residents and transient boaters over most of the Kawartha Lakes district in the Province of Ontario. The exotic macrophyte, Eurasian Water Milfoil (*Myriophyllum spicatum* L.), hereafter called milfoil, is of increasing concern.

Studies on the control of milfoil have been conducted in North America (Stanley 1974, Smith 1970, and Tennessee Valley Authority Environmental Statement, 1972) and in particular Canada (Scott et al. 1981 and Lim 1976).

The objectives of this study were: (1) to compare the degree of control achieved by a liquid formulation of a dimethylamine salt of 2,4-dichlorophenoxy acetic acid (=DMA) and the currently registered 20% granular formulation of 2,4-D (butoxyethanol ester of 2,4-dichlorophenoxy acetic acid) (=BEE) applied as early or late treatments; (2) to determine the persistence of 2,4-D residues in plant, water and sediment; and (3) to evaluate the compound effects of DMA 2,4-D applied at different times to a recently harvested area.

The study was conducted over a three year period. Site locations and parameters were modified on a yearly basis as environmental conditions dictated.

METHODS AND MATERIALS

Buckhorn Lake, situated in Peterborough County, was chosen for study due to its heavy population of milfoil and its importance as a recreational lake. Physical and chemical details of the lake were previously published by the Ontario Ministry of the Environment (Kawartha Lakes Water Management Study—Water Quality Assessment (1972-1976), 1976). In general, the lake is a mesotrophic lake, 14 km long and averaging 4.5 km wide, with a mean depth of 3 meters and a total surface area of 33 square kilometers (Report on Water Quality in Buckhorn Lake, 1972).

Within Buckhorn Lake different sites were chosen each of the three study years. Certain basic criteria were sought in the site selection process. The area had to be infested with aquatic macrophytes, away from the main boat channels and excessive human activity, free from currents and extensive wave action, and isolated from prior herbicide applications. In each of the three years, plots were established and marked from shoreline benchmarks. The plots, each approximately 30.5 by 30.5 meters, were marked with colour coded poles.

In 1977, seven plots, each 0.1 hectares, were established in a quiet bay east of Fox Island in Buckhorn Lake (part lots 14 and 15, concession IX, Harvey Township) (Figure 1). This bay was approximately 64.8 hectares in area, with an average depth of 1.5 meters. Prevailing winds were from the northwest. The existing current was extremely slight and ran in a north-south direction.

In 1978, ten 0.1 hectare plots were established in three small bays east of Nichol Island in Buckhorn Lake (part lot B, concession XIV, Harvey Township) (Figure 1). The bays were, in total, approximately 23.2 hectares in area, with an average depth of 1.5 meters. Prevailing winds were from the northwest. No current was evident in the trial area.

In 1979, eight 0.1 hectare plots were established west of McKenty Island in Buckhorn Lake (part lot 1, concession XIII, Harvey Township) (Figure 1). This bay was approximately 13.5 hectares in area, with an average depth of 1.5 meters. Prevailing winds were from the northwest. The existing current was extremely slight and ran through the study area in a north-south direction.

FIELD STUDIES

Plant species composition was determined for each plot for the three years of the study. Percentage composition of each species in the community was determined from a visual assessment, as was the percentage of coverage of the plots by macrophytes, in general.

Two herbicides were used in the trials in all three years. Treatment dates were established to coincide with early or late treatments in the area, and varied slightly from year to year to accommodate local growing conditions. A liquid concentrate of DMA 2,4-D which contained 400 gms/L w/v 2,4-D acid equivalent was applied at a rate of 44.8 kg/ha acid equivalent. The BEE 2,4-D 20% w/w granular formulation on 8-13 mesh "Attaclay" granules was applied at a rate of 44.8 kg/ha acid equivalent.

The DMA 2,4-D was applied, in all cases, using a 9.1 L hand pump sprayer with sufficient pressure to produce a coarse, uniform spray pattern over the water surface. The BEE 2,4-D was applied using a "Cyclone Seeder" with a hopper capacity of 2.5 kg. The rotary action of this equipment threw the granules uniformly over a distance of about 1.5 meters. In all cases, split applications of either herbicide were made in a north-south direction, followed by applications in an east-west direction to ensure even coverage.

An Aquamarine series 650 Weed Harvester was used in the harvesting part of the study (1977 only). It is constructed on a barge 7.3 meters long, 2.7 meters wide and 0.6 meters deep. A gas driven 35 hp power plant mounted on the barge drives three hydraulic pumps that, in turn, power the cutting and propulsion systems. Propelled by two side-mounted, reversible variable speed paddle wheels, the harvester is capable of cutting a swath 2.4 meters wide. Reciprocating cutting bars (2 vertical 1.5 meter bars and one horizontal 2.4 meter cutting bar) mounted on a porous elevating conveyor are adjustable to a maximum 1.5 meter cutting depth (Wile and Hitchin, 1977).

Samples of water, sediment and plant material were collected at specific times before and after treatments and analyzed for 2,4-D residues. All analyses of samples were conducted by the Pesticide Residue Testing Laboratory, Ontario Ministry of Agriculture and Food at the University of Guelph, using standard analytical methods previously described.

Composite water samples were collected as grab samples through the top 0.5 meters of the water column. Four samples were collected from each plot on each sampling date. One litre samples were placed in clean pre-washed bottles.

Sediment samples from the upper 10 to 21 centimeters of the hydrosoil were collected with an Ekman Dredge from four locations within each plot on each sampling date. Water was decanted from each sample and root and plant fragments were removed. Samples were double-bagged in polyethylene.

Single entire milfoil plants were collected as grab samples of approximately 1.1 kg in weight, from each plot on each sampling date, washed with lake water to remove sediments adhering to the roots and double-bagged in

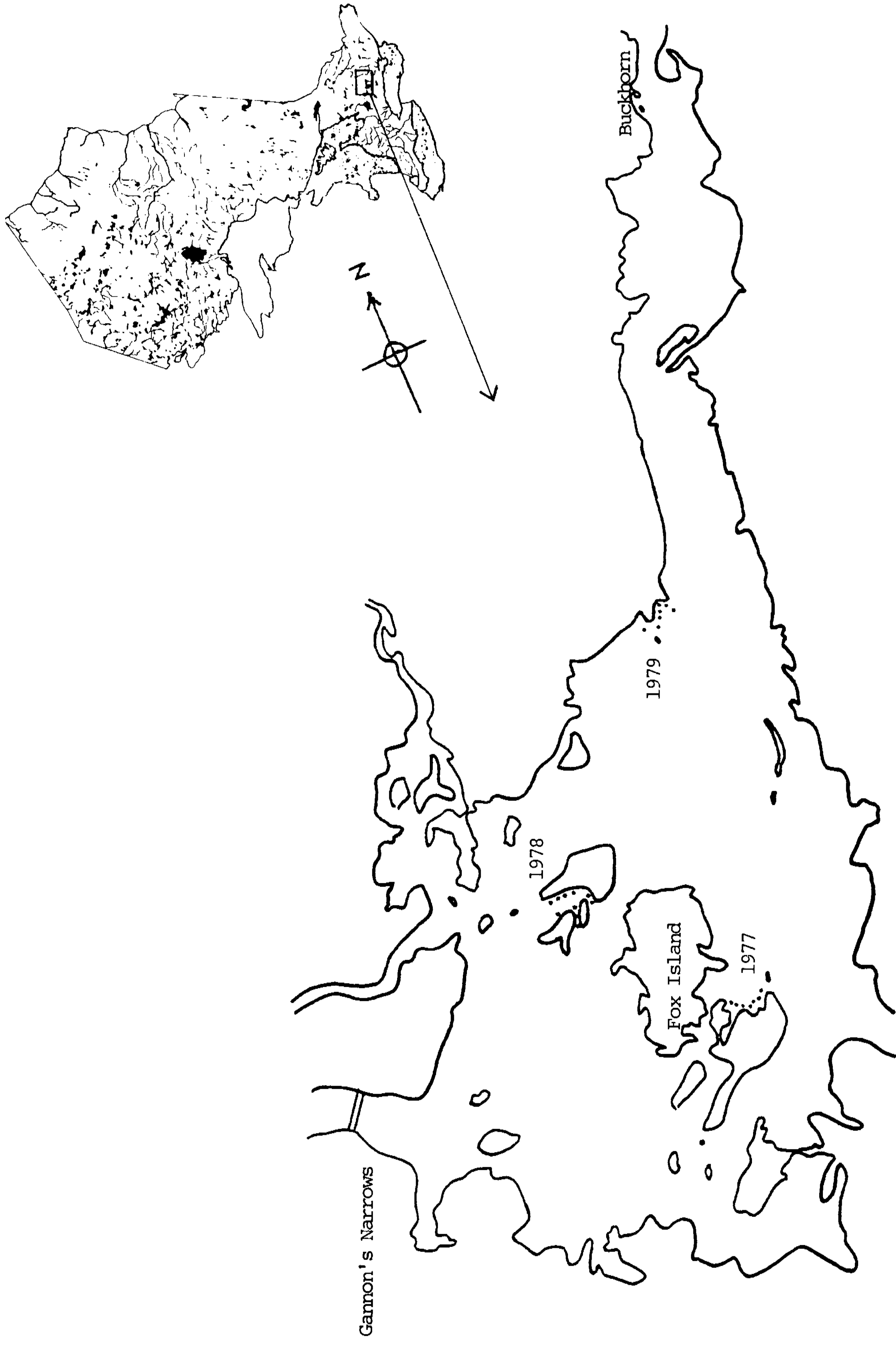

Figure 1. Study Locations in Buckhorn Lake, Peterborough County (1977-1979).

polyethylene. All water, soil and plant samples collected for residue analysis were immediately chilled and shipped within 24 hours to the Laboratory.

Biomass determinations were carried out throughout the trials. All plant species from 10 random 0.25 m^2 samples per plot were collected on each sampling date, shaken dry and weighed. Control plots (at least one/year) were established and sampled exactly as the treated sites throughout.

RESULTS

The treatments for each test plot, for each of the three years of the study are indicated in Table 1. Treatment dates and the herbicide, if any, used are included in the table.

The plant species composition for the test plots over the three year period is presented in Table 2. The percentage of each species of the total plant community was assessed on a visual basis. In virtually all cases the plants covered between 80 and 100% of the water surface, at some time during the sampling period.

The 2,4-D residue data for the test plots for water, sediments and plants during the 1977, 1978 & 1979 periods is presented in Tables 3, 4 & 5 respectively.

TABLE 1. DATES OF TREATMENT AND HERBICIDES USED IN 1977-1979 IN BUCKHORN LAKE, CANADA.

Plot	Date Control Applied	Treatment Used
	1977	
1	June 21	Harvested
	June 28	DMA
2	May 30	BEE
3	June 21	DMA
4	Control	None
5	June 21	BEE
6	May 30	DMA
7	June 21	Harvested
	June 21	DMA
	1978	
1	Control	None
2	July 6	Diquat[1]
3	July 6	BEE
4	July 19	Diquat[1]
5	Control	None
6	July 19	DMA
7	Control	None
8	July 24	Diquat[1]
9	July 19	BEE
10	July 6	DMA
	1979	
1	July 4	DMA
2	June 20	Diquat[1]
3	Control	None
4	June 20	BEE
5	July 4	Diquat[1]
6	June 20	DMA
7	July 4	BEE
8	Control	None

[1]Diquat analyses were not completed and no further mention of these treatments will appear in the text.

TABLE 2. PLANT SPECIES (FASSETT 1957) COMPOSITION FOR TEST PLOTS (1977-1979) IN BUCKHORN LAKE, CANADA.

	% of Total Plant Community by Area			No. of Plots Containing This Species		
Species	1977	1978[1]	1979	1977	1978[1]	1979
Ceratophyllum demersum	—	1	4	—	5	7
Chara sp.	—	1	—	—	1	—
Elodea canadensis	4	5	4	4	7	6
Heteranthera dubia	—	—	1	—	—	2
Juncus sp.	—	1	—	—	1	—
Myriophyllum exalbescans	5	3	1	5	7	1
M. heterophyllum	—	—	1	—	—	3
M. spicatum	75	1	66	7	4	8
Najas flexilis	—	—	2	—	—	4
Nuphar sp.	2	3	1	2	6	3
Nymphaea sp.	1	2	1	4	7	1
Potamogeton alpinus	1	—	—	1	—	—
P. amplifolius	1	1	3	1	2	5
P. confervoides	—	—	1	—	—	2
P. crispus	—	1	4	—	6	6
P. natans	—	1	—	—	5	—
P. pectinatus	1	1	—	2	1	—
P. praelongus	5	1	—	7	1	—
P. richardsonii	3	1	1	6	3	3
P. robinsii	—	—	1	—	—	2
P. zosteriformis	2	15	5	6	10	8
Sagittaris cristata	—	1	1	—	2	1
Utricularia sp.	—	1	—	—	1	—
Vallisneria americana	1	60	3	1	10	7

[1]By early August, 1978, *Sparganium* sp. had "taken over" plots 3, 4 and 5, virtually replacing all other species. Similarly, *Myriophyllum spicatum* L. moved into plots 8, 9 and 10 eventually making up 80% of the macrophyte population in these areas.

Water—1977

In three of the treated plots, the highest residue levels found in water were noted twenty-four hours after treatment (42.5 μg/L DMA 2,4-D, 22.7 μg/L DMA 2,4-D and 80.5 μg/L BEE 2,4-D). In the other three treated plots, highest residue levels were detected forty-eight hours after treatment (147.8 μg/L DMA 2,4-D, 60.5 μg/L DMA 2,4-D and 115.5 μg/L BEE 2,4-D). Significant decreases in residue levels occurred 21 to 30 days after treatment (student t-test, 95% confidence levels). The control plot showed significant increases in 2,4-D levels after 24 days and declined significantly after 60 days.

Sediment—1977

One plot showed highest residue levels after twenty-four hours (0.64 mg/L DMA 2,4-D) and two plots after forty-eight hours (0.33 mg/L DMA 2,4-D and 7.46 mg/L BEE 2,4-D). This latter plot showed another peak of 9.77 mg/L 63 days after treatment. The other three treated plots showed highest residues 16 days (20.5 mg/L BEE 2,4-D), –3 days (0.52 mg/L DMA 2,4-D) and –8 days (0.14 mg/L DMA 2,4-D) after treatment. Twenty-one to 40 days later, most levels had dropped significantly. Peak levels of 0.53 mg/L (day 24) and 0.55 mg/L (day 0) were detected in the control plot.

TABLE 3. RESIDUES OF 2,4-D IN WATER (μg/L), SEDIMENT (mg/L) AND PLANT (mg/L) SAMPLES IN BUCKHORN LAKE (1977). EACH VALUE IS MEAN OF FOUR SAMPLES COLLECTED FOR EACH DATE.

Treatment Plot No. Sample	Days After Treatment																											
	−8	−3	−1	0	1	2	4	16	19	21	24	29	31	33	35	36	39	42	46	51	57	60	63	67	74	77	82	88
2,4-D BEE Plot 2																												
Water		0.1			80.5			5.3								6.5									0.2			
Sediment		0.25			7.73			20.50								4.25									0.01			
Plant		0.01			0.10			0.21								0.10									0.01			
2,4-D BEE Plot 5																												
Water			1.2			115.5				7.3								0.6					0.1					
Sediment			0.52			7.46				6.90								2.47					9.77					
Plant			0.01			0.75				0.02								0.06					0.02					
2,4-D DMA Plot 1																												
Water	2.2		15.4		42.5							1.3								0.2								
Sediment	0.14		0.01		0.01							0.01								0.01								
Plant	0.39		0.02		0.04							0.01								0.02								
2,4-D DMA Plot 3																												
Water			3.2			147.8				3.4								0.5					0.1					
Sediment			0.15			0.33				0.09								0.01					0.01					
Plant			0.05			1.13				0.02								0.04					0.02					
2,4-D DMA Plot 6																												
Water		0.5			22.7			4.0								4.1									0.2			
Sediment		0.52			0.32			0.08								0.01									0.01			
Plant		0.05			0.26			0.04								0.09									0.01			
2,4-D DMA Plot 7																												
Water			0.6		60.5										0.7						0.2							
Sediment			0.16		0.64										0.01						0.01							
Plant			0.01		9.10										0.02						0.01							
Control Plot 4																												
Water				0.1			0.1		5.2	2.8	16.6			21.6	8.8		4.9		5.1			0.6		0.4		0.2	0.2	0.1
Sediment				0.55			0.06		0.70	0.10	0.53			0.01	0.02		0.02		0.05			0.02		0.01		0.01	0.10	0.01
Plant				0.02			0.03		0.10	0.10	3.02			0.02	0.05		0.02		0.04			0.01		0.01		0.01	0.10	0.01

Plant—1977

Highest residues of 2,4-D were found one day (0.26 mg/L DMA 2,4-D and 9.1 mg/L DMA 2,4-D), two days (0.75 mg/L BEE 2,4-D and 1.13 mg/L DMA 2,4-D), 16 days (0.21 mg/L BEE 2,4-D) and −8 days (0.39 mg/L DMA 2,4-D) after treatment. Levels declined significantly 16 to 33 days after treatment. A peak of 3.02 mg/L was found in the control plot 24 days after the start of the study, indicating lateral movement of the herbicides.

Water—1978

Two plots showed their highest residue levels twenty-four hours after treatment (5.5 μg/L DMA 2,4-D and 4.6 μ/L BEE 2,4-D). The other two treated plots showed their highest levels eight (6.6 μg/L DMA 2,4-D) and 14 (7.1 μg/L BEE 2,4-D) days after treatment. The plots treated only with diquat showed peaks of 2,4-D at nine days (0.8 μg/L), 14 days (45.3 μg/L) or −8 (i.e. 8 days before treatment) days (1.8 μg/L) indicating lateral movement of the chemical from adjacent plots. Significant decreases in residue levels occurred 20 to 27 days after treatment, in all plots. The control plots showed no detectable 2,4-D levels until 63 days after the start of the study when two plots showed residues of 6.2 μg/L and 73.5 μg/L. Seven days later the levels had dropped significantly.

Sediment—1978

Peak residue levels were attained five days (43.8 mg/L BEE 2,4-D), eight days (8.13 m/L BEE 2,4-D), −28 days (0.33 mg/L DMA 2,4-D) and −41 days (0.43 mg/L DMA 2,4-D) after treatment, in the 2,4-D treated plots. In the diquat treated plots, peak levels were detected −28 days (0.47 mg/L), −42 days (0.48 mg/L) and −46 days (0.37 mg/L) after treatment. Six to nine days after treatment the levels had dropped significantly. The highest levels found in the control plots were found on day 16 (0.56 mg/L and 0.51 mg/L), day 63 (0.57 mg/L) and day 0 (1.13 mg/L). Fifty days later all levels had declined significantly.

Plant—1978

Twenty-four hours (0.37 mg/L DMA 2,4-D and 4.81 mg/L BEE 2,4-D), five days (2.6 mg/L BEE 2,4-D) and 21 days (0.13 mg/L DMA 2,4-D) after treatment, highest residue levels were detected. In the diquat treated plots, peaks were noted 14 (0.21 mg/L and 0.05 mg/L and 16 (trace) days after 2,4-D application. Levels dropped significantly

TABLE 4. RESIDUES OF 2,4-D IN WATER (μg/L), SEDIMENT (mg/L) AND PLANT (mg/L) SAMPLES IN BUCKHORN LAKE (1978). EACH VALUE IS MEAN OF FOUR SAMPLES COLLECTED FOR EACH DATE.

Treatment Plot No. Sample	Days After Treatment																													
	–55	–46	–42	–41	–28	–13	–8	0	1	3	5	8	9	14	15	16	20	21	22	27	34	48	50	55	57	63	64	65	68	70	77
DMA 2,4-D Plot 6																															
Water				ND			ND		5.5			2.3		0.3			0.8							ND							
Sediment	0.11			0.43			ND		ND			ND		ND			ND							ND							
Plant							ND		0.37			0.03		ND			ND														
DMA 2,4-D Plot 10																															
Water					ND						ND	6.6						2.3		0.6	0.3								ND		
Sediment					0.33						ND	ND						ND		ND	ND								ND		
Plant											ND	0.01						0.13		TR	0.03										
BEE 2,4-D Plot 3																															
Water					ND						1.1			7.1			1.3			0.8	0.6								ND		
Sediment			0.06		0.38						43.80			0.60			1.44			ND	ND								ND		
Plant											2.60			0.70				0.08		ND	ND										
BEE 2,4-D Plot 9																															
Water				ND			ND		4.6			3.7		2.1				0.4						ND							
Sediment				0.29			ND		1.13			8.13		TR				1.65						ND							
Plant							ND		4.81			0.26		0.04				0.01													
Diquat Plot 2																															
Water					ND						ND			45.3			4.8			0.6	0.5								ND		
Sediment			0.05		0.47						0.27			0.09					ND	ND	ND								ND		
Plant					TR						TR			0.21			TR			ND	0.07										
Diquat Plot 4																															
Water			ND				1.8							1.6			0.3		ND					ND							
Sediment	0.05		0.48				ND							ND			0.07		ND					ND							
Plant							0.04							0.05			TR														
Diquat Plot 8																															
Water		ND				ND				2.1			0.8			0.2							ND								
Sediment		0.37				0.20				ND			ND			ND							ND								
Plant						ND				ND			ND			TR															
Control Plot 5																															
Water															ND							ND			TR	1.7	2.1		0.3	0.1	ND
Sediment						TR									0.56							ND			ND	ND	ND		ND	ND	ND
Plant																						0.03			0.13	0.02	TR		TR	TR	
Control Plot 7																															
Water															ND							ND			6.2				0.2	0.1	ND
Sediment						TR									0.51							ND			ND				ND	ND	ND
Plant																						ND			0.03				ND	TR	
Control Plot 1																															
Water							ND								ND							ND			73.5			1.7	0.5	0.7	ND
Sediment							1.13								0.45							0.24			0.57	ND			TR	ND	ND
Plant															TR							ND			0.11			0.30	ND	0.10	

six to 14 days after treatment. Peaks in all control plots were detected 57 days (0.13 mg/L and 0.03 mg/L) after the start of the study.

Water—1979

Three plots showed highest residue levels twenty-four hours after treatment (4.5 μg/L DMA 2,4-D, 91.8 μg/L DMA 2,4-D and 8.8 μg/L BEE 2,4-D). The other treated plot showed highest levels at day eight (20.6 μg/L BEE 2,4-D). Plots treated only with diquat showed 2,4-D peaks on day eight (4.5 μg/L) and day –6 (29.1 μg/L). Seven to 22 days later, the levels had dropped significantly.

One control plot showed highest levels 31 days after the start of the study (18.6 μg/L) with levels significantly lower about 16 days later. The other plot was sampled only once during the study.

Sediment—1979

Three plots showed highest residue levels one (5.9 mg/L BEE 2,4-D), eight (0.42 mg/L DMA 2,4-D) and 15 (25.3 mg/L BEE 2,4-D) days after treatment. Diquat treated plots showed highest 2,4-D residue levels 35 (0.51 mg/L) and 41 (0.63 mg/L) days after treatment. Secondary peaks were detected in all four of the 2,4-D treated plots (0.04 mg/L,

TABLE 5. RESIDUES OF 2,4-D IN WATER (µg/L), SEDIMENT (mg/L) AND PLANT (mg/L) SAMPLES IN BUCKHORN LAKE (1979). EACH VALUE IS MEAN OF FOUR SAMPLES COLLECTED FOR EACH DATE.

Treatment Plot No. Sample	Days After Treatment																											
	−20	−15	−13	−9	−6	0	1	8	12	15	17	21	22	24	26	31	35	38	41	45	47	49	55	58	61	72	78	84
DMA 2,4-D Plot 1																												
Water	0.2	0.5			2.0		4.5		1.9			1.1					0.2		ND		9.0							
Sediment	0.12	ND			0.03		ND	ND	ND			ND					0.01		0.04		ND							
Plant	TR	0.26			0.01		0.59	0.05	0.10			0.06					0.01		0.02		0.02							
DMA 2,4-D Plot 6																												
Water				TR	0.5		91.8	26.6		24.7			8.8		5.5		3.2					0.8	0.6		0.3			
Sediment				ND	TR		0.40	0.42		0.22			ND		ND		ND					0.07	0.95		ND			
Plant			ND		ND		3.02	0.58		0.46			0.22		0.33		0.05					0.03	TR		0.14			
Diquat Plot 2																												
Water					0.5		1.0	4.5		4.3			3.2		4.1		0.8					0.2	0.2		0.6			
Sediment					0.03		ND	0.02		ND			ND		ND		0.51					0.01	0.72		ND			
Plant			TR		TR		0.30	TR		0.19			0.02		0.01		TR					0.01	TR		0.08			
Diquat Plot 5																												
Water	ND	15.7			29.1		7.8	3.6	4.5			1.1					0.7		0.3		0.6							
Sediment	ND	0.15			ND		ND	TR	ND			TR					0.02		0.63		ND							
Plant	ND	0.31			0.09		0.17	0.04	0.04			0.02					ND		0.02		0.60							
BEE 2,4-D Plot 4																												
Water				1.5	0.2		6.8	20.6		9.8			10.5		6.5		2.7				1.1	0.3			1.8			
Sediment				ND	ND		1.78	4.14		25.30			5.79		45.00		12.10				1.91	5.21			0.32			
Plant			ND		TR		3.75	0.14		0.48			0.11		0.06		0.03				0.02	0.02			0.07			
BEE 2,4-D Plot 7																												
Water	0.2	65.3			13.0		8.8	8.2	1.9			4.2					0.2		0.3		0.8							
Sediment	TR	0.06			ND		5.90	1.35	ND			3.46					4.46		10.3		2.18							
Plant	ND	0.68			0.14		2.89	0.16	0.10			0.11					0.02		0.70		0.13							
Control Plot 3																												
Water						ND					TR			1.8		18.6		7.3		7.8		6.1		1.5		0.5	0.3	0.08
Sediment						ND					0.04			0.08		0.04		ND		ND		ND		0.05		ND	0.76	ND
Plant						ND					ND			0.13		0.02		1.56		TR		TR		TR		ND	ND	0.05
Control Plot 8																												
Water																										0.5	0.3	ND
Sediment																										ND	0.87	ND
Plant																										0.02	0.03	0.06

0.95 mg/L, 45.0 mg/L and 10.3 m/L) 41, 55, 26 and 41 days after treatment respectively. Significant declines in levels were detected six to 12 days after treatment. Control plots showed highest 2,4-D levels 78 days after the start of the program (0.76 mg/L and 0.87 mg/L).

Plant—1979

Four plots showed highest residue levels twenty-four hours after treatment (0.59 mg/L DMA 2,4-D, 3.02 mg/L DMA 2,4-D, 3.75 mg/L BEE 2,4-D and 2.89 mg/L BEE 2,4-D). Diquat treated plots showed peaks twenty-four hours (0.3 mg/L) and −15 days (0.31 mg/L) after 2,4-D application. Levels dropped significantly seven days after treatment. Control plots showed 2,4-D peaks 38 days (1.56 mg/L) and 84 days (0.06 mg/L) after the start of the study. The highest levels found in the control plots were found on day 16 (0.56 mg/L and 0.51 mg/L), day 63 (0.57 mg/L) and day 0 (1.13 mg/L). Fifty days later all levels had declined significantly.

Biomass

The effect of the 2,4-D application techniques on the various aquatic macrophytes, especially milfoil, was assessed visually and by biomass reduction determinations. Milfoil treated either with DMA 2,4-D or BEE 2,4-D showed signs of stress and degradation as early as eight days after treatment. Stems were twisted and exhibited rapid tip growth characteristics. Leaves at the stem tips were small and distorted. In some cases, the tips of the plants were completely devoid of leaves, with only bare stems remaining. Tables 6(A-C) summarize the biomass data for the study.

Mean biomass values (in grams, as fresh weight) and standard deviations were calculated for each control plot over the three year study period: 1977 (x 908 ± 102), 1978 (x 162 ± 89, x 172 ± 116, x 150 ± 60), and 1979 (x 479 ± 254 and x 499 ± 65). Dramatic differences in mean biomass values over the study period were detected.

TABLE 6(A). MEAN BIOMASS VALUES (gms/m²/FWT) OF AQUATIC MACROPHYTES IN TREATMENT PLOTS IN BUCKHORN LAKE, CANADA IN 1977.

	Days After Treatment																				
Plot No.	–8	–3	–1	0	16	19	21	24	28	31	35	36	39	42	46	56	60	63	67	74	77	88
1	595		392						227							271						
2		722			378							279								244		
3			547				492							315				498				
4				830		1129		786		842			890		827		900		949		834	1019
5			721				703							560				738				
6		525			550							142								235		
7			468								411							130				

TABLE 6(B). MEAN BIOMASS VALUES (gms/m²/FWT) OF AQUATIC MACROPHYTES IN TREATMENT PLOTS IN BUCKHORN LAKE, CANADA IN 1978.

	Days After Treatment																				
Plot No.	–24	–19	–15	–10	–6	–5	–4	–2	1	2	7	8	9	14	20	22	27	36	42	48	55
1																144		129	340	122	105
2					64							125		164	402		417				
3								221				179		102	115		235				
4			269			492			117		197			156							
5																40		240	356	167	61
6		49				195			97		198			303							
7																64		140	181	122	244
8	5			7			65			7			59								
9			118			59			64		84			183							
10					43							54		147	9		56				

TABLE 6(C). MEAN BIOMASS VALUES (gms/m²/FWT) OF AQUATIC MACROPHYTES IN TREATMENT PLOTS IN BUCKHORN LAKE, CANADA IN 1979.

	Days After Treatment																					
Plot No.	–20	–9	–6	–1	3	5	13	14	18	19	22	26	28	32	35	37	40	41	49	58	63	72
1	295	268		199		223		185	131			192			149				283			
2			86			171	112			69			59	20			89		63		144	
3					1125			515			581		296			494		389	366	184		362
4			215			346	185			146			132	82					141		363	
5	48	46		38		112		77	162						93				268			
6			79			221	315			310			464	390					716		521	
7	183	275		194		185		214	201						227				304			
8																			440	468		589

DISCUSSION

Test plots varied considerably over the three year period with respect to plant density and species composition. Consequently, it is difficult to determine if plant growth in each area was typical or not. Biomass results indicate marked differences between the three years of the study. In 1978, in particular, the milfoil population collapsed throughout part of the study area (replaced by *Sparganium* sp.) and rose dramatically in other areas. Early treatments (May) with DMA 2,4-D and BEE 2,4-D appeared to offer better, longer lasting control of milfoil than did later ones (June or July). In addition, DMA 2,4-D applied immediately after harvesting offered better control than the DMA 2,4-D applied one week after harvesting. The overall control achieved from DMA 2,4-D versus BEE 2,4-D, as early treatments, was essentially the same. Similarly, DMA 2,4-D and BEE 2,4-D applied at a later date did not produce substantially different results. DMA 2,4-D offered a quicker knockdown of milfoil but regrowth occurred, resulting in similar net control when compared to BEE 2,4-D plots. It is conceivable that dense vegetation at that time of the season inhibited BEE 2,4-D effectiveness in 1977. That year, the greatest plant biomass found during the study was noted, making it more difficult to distribute the granular 2,4-D than the liquid formulation. A similar pattern of residue peaks was noted in all three years. Generally, levels peaked after twenty-four or forty-eight hours following treatment at each site. Levels were non-detectable at all sites after 88 days. Artificial pond studies (Scott 1981 and Birmingham et. al. 1982) indicated that 2,4-D decreased to 1/2 of its maximum level 60 days after treatment and was essentially non-detectable after 147 and 178 days respectively. Bothwell and Daley's (1981) lake work showed non-detectable levels after 120 and 180 days.

Bothwell and Daley (1981) showed that persistence of 2,4-D was in part controlled by the organic content of the sediments, thus explaining the difference between the two rates in their study. After 88 days, 2,4-D was non-detectable in Buckhorn Lake, a much shorter period of time than that reported in the literature. It may be explained by the presence of high organic matter in the sediments. However, no documentation is available to support this contention. With a large body of water, such as Buckhorn Lake, considerable mixing may have lead to rapid dilution and dissipation of the 2,4-D. The residues found in the water, sediment and plant materials over the three year study period indicate that there was lateral movement of the 2,4-D from one plot to another. An analysis of Tables 3-5 shows residues both in treated and untreated plots, indicating that the chemical moved substantial distances over a period of time from one plot to another. Bothwell and Daley (1981) in their study of Wood and Kalamalka Lakes showed a spread of herbicide to untreated areas within twenty-four hours after application. Residues of 2,4-D were found in samples of water, sediment and plants prior to any application of chemical. The reasons for this are speculative, but may include non-regulated use of herbicides in the area, or run-off from adjacent agricultural and residential properties. Results show that by the end of each study year, residues of 2,4-D were non-detectable. It, therefore, seems unlikely that we are dealing with chemicals that have persisted in the environment from the previous season. Although some residues in the water exceeded the Ontario Ministry of the Environment's Drinking Water Objectives of 0.1 mg/L, these exceedances were strictly monitored. The restrictions as indicated on the product label have taken these objectives and guidelines into account. Under the provincial Pesticides Act and Regulations, permits are required in order to apply herbicides to water for aquatic weed control. These permits also require notification of adjacent property owners. Exceedances are strictly monitored and regulated through this permit system so that the exceedances occur only within the treatment area and not through the entire lake.

In all plots, residue levels in 1978 were lower than in the other two study years. This is probably related to plant biomass and species composition. The 1978 plant biomass was significantly lower than in the other years. This would have allowed quicker dispersion of the herbicides in the lake. Early in the season, the amount of plant material in the study area was extremely low. Later in the season, *Sparganium* sp. invaded the area. As it exhibits characteristics similar to *Vallisneria americana,* one would expect that it would not take up the 2,4-D effectively, thus allowing more time for the herbicides to dissipate.

The results of this study indicate that there is no real advantage to using DMA 2,4-D over BEE 2,4-D when efficacy and persistence are the only criteria examined. If applied early enough in the season, either chemical offers a similar degree of control. However, the liquid DMA 2,4-D may infiltrate more easily, particularly in dense vegetation situations.

There is definitely lateral movement of the herbicides through the water. This movement appears to be inversely related to the plant density in the area.

When DMA 2,4-D was applied immediately following harvesting (Table 3), better control was achieved than when the harvesting preceded the DMA 2,4-D application by one week. Table 6A shows the respective biomass reduction for the two plots in support of this statement.

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