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TITLE STUDIES ON CHEMICAL METHODS OF AQUATIC PLANT CONTROL IN FRESHWATER LAKES AND PONDS

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By

Norman O. Levardsen

A THESIS

Submitted to the School of Graduate Studies of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Department of Botany and Plant Pathology

1951

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STUDIES ON CHEMICAL METHODS OF AQUATIC PLANT

CONTROL IN FRESHWATER LAKES AND PONDS

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AN ABSTRACT

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Norman O. Levardsen

Aquatic plants, when they become so abundant that they interfere with the recreational use of lakes and ponds, are considered a nuisance. The present study on chemical methods of aquatic plant control has been made as a result of increased interest in water weed problems.

The control of submerged aquatic plants with nigrosine dye did not prove entirely successful. The purpose of putting nigrosine into the water was to so darken it that the plants would be unable to manufacture additional food because of a lack of light and would soon use up their reserves. In trials at a 17 acre lake and a .75 acre hatchery pond, the dye did not remain long in solution. It was determined by laboratory study that the disappearance of the dye could be attributed to salts in the water which caused the dye to be precipitated as an insoluble salt. At the hatchery pond a decrease in dissolved oxygen and a corresponding increase in carbon dioxide followed applications of the dye. Further work is required before definite conclusions can be made in regard to the value of nigrosine in aquatic weed control.

Trichlorbenzene and xylene both have herbicidal properties when sprayed beneath the surface but they require a large percentage of emulsifier to maintain the emulsion in contact with the plants for the desired period of time. When trichlorbenzene and xylene are mixed in the proportion of 1:3, this mixture is near the specific gravity of water. The method thus makes it possible to utilize these materials which, by themselves, would be either too heavy or too light but when balanced and emulsified remain in suspension for a longer period.

Pellets of either 2,4-D or 2,4,5-T did not control submerged weeds when distributed on the bottom of shallow water at concentrations considered to be practical. Pellets composed of 2,4-D and pentachlorophenol were effective and rapid in action.

The translocated herbicides were found to be superior to contact herbicides in the control of floating and emergent aquatic plants. Rootstock reserves were sufficiently high so that even when the exposed vegetative growth was killed with a contact spray, regrowth occurred. When translocated herbicides were utilized, best control was obtained when applications coincided with the first appearance of flowers. Some species required repeat applications when regrowth became established.

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INTRODUCTION

The present study was undertaken as the result of an increase in interest relating to the control of aquatic vegetation in recreational areas and because of the relative scarcity of information concerning weed control in aquatic habitats. The Fisheries Division of the Michigan Department of Conservation, as well as other state agencies, have been asked repeatedly to advise in these matters and have been unable to supply adequate information.

In view of recent developments in the use of herbicides for the control of terrestrial weeds, it was felt that an evaluation of these materials for the control of water weeds would represent a valuable addition to the available information.

In the fall of 1947 a cooperative agreement was made between Michigan State College and the Institute for Fisheries Research, whereby a fellowship in aquatic weed control was established. The study was to be made under the supervision of the Department of Botany and Plant Pathology, Michigan State College.

The material presented in this report represents a compilation of the results of that investigation. A rather broad study was undertaken with the view of evaluating the commercially available materials reported in the literature as being effective herbicides. The investigation of new materials and the development of new methods for the control of both submerged and emergent aquatic plants also have been undertaken.

The major portion of the study involved field work during the summer months. This was done, in the main, at the following stations: Hess Lake, Newaygo County; the State Fish Hatchery, Hastings, Barry County, and at Lake Lansing, Ingham County. Other areas were Loon Lake, Rifle River Area, Ogemaw County; Portage Creek Trout Pond, Jackson County, and East Mill Pond, near Romeo, Macomb County. Facilities at Michigan State College were utilized for greenhouse and laboratory phases of the study.

REVIEW OF LITERATURE

Aside from the use of sodium arsenite and copper sulfate, which are well documented in the literature and are outside the general scope of this paper, the literature (17), relative to the chemical control of submerged weeds, is less voluminous than that pertaining to emergent aquatics. The introduction of the use of chlorinated benzene (14) probably marks the beginning of the present era of control of entirely submerged weeds by chemical means. In the irrigation canals of the western United States, this material has been extensively utilized (10). It also has been used in lakes (23). A new development, the use of petroleum naphthas (12), marked another advance in aquatic weed control, at least in irrigation projects.

Good control of cattail, Typha latifolia, with one application of the butyl ester of 2,4-D, was reported by Bauman (4). When 2,4-D in tributylphosphate, with kerosene as carrier was used, favorable control was reported by Surber, et. al. (21) and by Cornell (6). Walker (22), as did Jackson (11), found it more economical to cut cattails under water than to spray with 2,4-D. Spraying the cattails when the average height of the new growth had reached 3½ to 4 feet gave good results (1). Handley (9) had best results from spraying in the spring with either the butyl or the isopropyl ester of 2,4-D when the blades were approximately 24 inches tall. Better results with repeat applications, than with single applications, were obtained by Snow (16) and by Wilson and Finney (24).

When ammonium sulfamate was used in controlling cattails, Bauman (5) did not achieve entirely satisfactory results. Ammonium sulfamate gave complete kill of cattails on dry land, but some root tips survived and grew when the sprayed cattails were standing in water (1). It was found most satisfactory to spray at the beginning of the flowering period.

Bauman (4) found that it did not seem to matter at what stage of growth arrowhead, Sagittaria latifolia, was sprayed, for it was still very susceptible to 2,4-D. Any 2,4-D preparation in a carrier of diesel fuel or water was effective, according to Snow (16). Surber (19) had good success with a one percent aqueous spray of 2,4-D. When arrowhead was sprayed early in the spring, as the plants made their first appearance. Handley (9) achieved effective control by using the butyl ester of 2,4-D.

When ammonium sulfamate was used, Bauman (5) did not obtain satisfactory control of arrowhead even by using a wetting agent.

Effective control of pickerelweed, Pontederia cordata, was obtained by Bauman (4) with the butyl ester of 2,4-D, applied while the plants were in full bloom.

Surber, et. al. (21) effected good control of white water lily, Nymphaea spp., when a pond was drained and the exposed leaves and petioles were sprayed with 2,4-D in tributylphosphate. Further study by Surber (19) indicated that Nymphaea could be killed with two percent 2,4-D in tributylphosphate with oil as carrier. Several applications of either the salt or ester of 2,4-D were necessary for control of this species as found by Snow (16). Handley (9) found Nymphaea odorata fairly resistant to 2,4-D and had best success when the leaves were sprayed early in the spring using either the butyl or isopropyl ester of 2,4-D.

More than a single application of 2,4-D was required to control soft-stem bulrush, Scirpus validus, as reported by Surber, et. al. (21). A 1 percent solution of 2,4-D in tributylphosphate was found by Surber (19) to be effective on soft-stem bulrush. Handley (9) had best results by spraying with the ester of 2,4-D early in the spring when the plants were approximately 12 inches tall.

The butyl ester of 2,4-D was found to be effective on spatterdock, Nuphar advena, by Bauman (4). Surface sprays with 2,4-D in tributylphosphate, as reported by Surber, et.al. (21), were ineffective. Handley (9) stated that Nuphar advena proved extremely resistant to 2,4-D and found even repeated treatments not completely successful. He had best results when treatments with 2,4-D were made at the time the leaves first appeared in the spring. Spatterdock, treated with 2,4-D in late May and with ammonium sulfamate in late June, was reported by Steenis (18) to have given over 96 percent control. Surber, et. al. (21) did not find ammonium sulfamate effective when used at the rate of 10 pounds per acre. Smith and Swingle (15) reported that sprays of creosote and fuel oil, sodium chlorate, and sodium arsenite killed only the leaves.

In the treatment of submerged aquatics with 2,4-D, Gerking (8) estimated that it would cost approximately $167 to treat a ½ acre pond having about 2½ acre feet of water.

Eicher (7) described field trials in which nigrosine dye was added to lake water in order to reduce the penetration of sunlight into the lake and thus inhibit the growth of aquatic vegetation by slow starvation of the plants. He stated that the water remained dark into the following season and greatest effect of the dye was then noticed because normal, semi-emergent aquatic plants failed to reach the surface. The biological effects of nigrosine dye, used for the control of weeds in hatchery ponds, was reported by Surber and Everhart (20). They stated that nigrosine dye had no harmful effects on sunfish or bass at concentrations required to control weeds.

MATERIALS AND METHODS

The aquatic plants used in this study include floating, submerged and emergent species. Some of the submerged were rooted in the bottom under several feet of water and never reached the surface. The emergent species were either on water-logged soil or standing in water. The names of the plants which were included in the experimental work, according to the classification of Muenscher (13), are as follows:

DIVISION CHLOROPHYTA

Characeae

Chara spp.

DIVISION SPERMATOPHYTA

Typhaceae

Typha angustifolia L.	Narrow-leaved cattail
Typha latifolia L.	Common cattail

DIVISION SPERMATOPHYTA (Continued)

Potamogetonaceae

Potamogeton amplifolius Tuckerm.	Broad-leaved pondweed
Potamogeton epihydrus Raf.	
Potamogeton natans L.	
Potamogeton pectinatus L.	Sago pondweed
Potamogeton richardsonii Rydb.	
Potamogeton robbinsii Oakes.	
Potamogeton zosteriformis Fernald	

Najadaceae

Najas spp.

Alismaceae

Sagittaria latifolia Willd.	Arrowhead, Duck potato

Hydrocharitaceae

Anacharis canadensis (Michx.) Planchon	Waterweed, Elodea
Vallisneria americana Michx.	Wild celery, "Eelgrass"

Cyperaceae

Scirpus validus Vahl.	Great bulrush, Soft-stem bulrush

Pontederiaceae

Heteranthera dubia (Jacq.) MacM.	
Pontederia cordata L.	Pickerelweed

DIVISION SPERMATOPHYTA (Continued)

Ceratophyllaceae

Ceratophyllum demersum L.

Nymphaeaceae

Brasenia schreberi Gmel.	Water shield
Nuphar advena Ait.	Yellow water lily, Spatterdock
Nymphaea odorata Ait.	White water lily

Ranunculaceae

Ranunculus flabellaris Raf.	Yellow water-crowfoot

Haloragidaceae

Myriophyllum verticillatum L.

Compositae

Bidens beckii Torr.	Water marigold

To study the effect of mixtures of xylene and trichlorbenzene on submerged species, it was necessary to secure suitable emulsifying agents. Various proprietary compounds were used and are shown, with the names of the manufacturer, in the following list.

EMULSIFIERS

Material	Manufacturer
Antarox A-400	General Aniline & Film Corp.
Dressinate 91	Hercules Powder Co.

EMULSIFIERS (Continued)

Material	Manufacturer
G-1255 and G-1283	Atlas Powder Co.
Glyceryl Laurate 3909	Glyco Products Co. Inc.
Glyceryl Laurate S	Glyco Products Co. Inc.
Intracol "M"	Synthetic Chemicals, Inc.
Mulsor	Synthetic Chemicals, Inc.
Mulsor V7	Synthetic Chemicals, Inc.
Neutronyx 834	Onyx Oil & Chemical Co.
Petromix 9	L. Sonneborn Sons, Inc.
Spans 40, 60, 65, 80, 85	Atlas Powder Co.
Sterox SK	Monsanto Chemical Co.
Sulfonated castor oil	
Tweens 40, 60, 65, 80, 85	Atlas Powder Co.

The number of chemical compounds available for weed control purposes is large. It was not possible to include all of these in this study. Among those used were nigrosine dye, various types of contact herbicides and some of the translocated growth regulating compounds. The materials used are as follows:

HERBICIDES AND OTHER COMPOUNDS

Material	Composition	Manufacturer
Ammate	ammonium sulfamate	The Dow Chemical Co.
Ammonium thiocyacate	ammonium thiocyanate	J.T.Baker Chem. Co.

HERBICIDES AND OTHER COMPOUNDS (Continued)

Material	Composition	Manufacturer
Amyl acetate	amyl acetate	
Benoclor 3	ortho- and trichloro- benzenes	Cloroben Corp.
Benoclor 3C	ortho-and trichloro- benzenes (added emulsifier)	Cloroben Corp.
Chlorosol A	alpha-hydroxy-beta- trichlorethyl sulfonic acid	Pitts. Agr. Chem. Co.
Dichloro Pentanes	dichloro pentanes	Sharples Chem's. Inc.
Dowcide G	sodium pentachloro- phenate	The Dow Chemical Co.
Dow Weed Killer (formula 40)	alkanolamine salts of 2,4-D	The Dow Chemical Co.
Esteron 44	isopropyl ester of 2,4-D	The Dow Chemical Co.
Esteron 2,4,5	butyl ester of 2,4,5-T	The Dow Chemical Co.
H-816	pentachlorophenol in oil	The Dow Chemical Co.
King-O-Cide	phenyl acetic acid and 2,4-D	J. T. Smith Chem. Co.
Nigrosine	(not known)	General Aniline & Film
Nigrosine	(not known)	Allied Chem.& Dye Corp.

HERBICIDES AND OTHER COMPOUNDS (Continued)

Material	Composition	Manufacturer
Orthodichlorbenzene	orthodichlorobenzene	The Dow Chemical Co.
Polybor	sodium pentaborate	Pacific Coast Borax Co.
Sodium 2,4-D (83%) Weed Killer	sodium salt of 2,4-D	E.I. du Pont de Nemours and Company
Sodium TCA (70%)	sodium trichloro-acetate	The Dow Chemical Co.
Trichlorbenzene	trichlorbenzene	The Dow Chemical Co.
Weed-No-More	butyl ester of 2,4-D	Sherwin Williams
Xylene	xylene	
#7898	petroleum distillates	The Standard Oil Co. of Indiana

When quantities of herbicides larger than a quart were to be applied to terrestrial weeds, a knapsack sprayer (Fig. 1) was utilized. This was of copper construction and of four-gallon capacity. The angle of spray could be adjusted by rotating the nozzle which was of the hollow cone type.

In order to include as many field trials as possible in the seasons' activities, small-scale applications of herbicides on submerged aquatic weeds were a necessity. Numbered stakes were placed at random through a fairly homogeneous bed of weeds and allowed to project above the surface. None were placed closer than six feet apart. A Sure Shot Sprayer of either five-ounce or one-quart capacity was used. It was soon discovered that when a sprayer was held in the orthodox position, with handle up and the nozzle pointing downward, the contents could not be completely emptied. The only practical way of eliminating this was to bend the nozzle extension to a vertical position (Fig. 2), so that the spray would be directed downwards while the sprayer was held in the customary manner.

The general proceedure was to pour the mixture, including ten percent of water to aid emulsification, into the sprayer, tighten the cap with a wrench and fill the remainder of the space with compressed air from a tank (Fig. 3). By holding on to the stake with one hand and holding the sprayer, with the nozzle extending below the surface, in the other, the contents could readily be emptied over a rather small area surrounding the stake. The appearance of the emulsion, just subsequent to spraying, is illustrated in Fig. 4.

For the treatment of large areas of submerged weeds, a Spartan Sprayer was utilized. This pump was of the two-cylinder type, capable of pressures up to 250 pounds per square inch. It was thus adequate for the proper emulsification of the balanced mixtures. The arrangement of the spray apparatus and solution tank is shown in Fig. 5. Fig. 6 shows the boom attachment to the stern of the boat. The sprayer was compact and, when placed in the stern of a boat, could be operated by one man (Fig.7).

For the more accurate laying out of plots, a nylon clothesline was used. This was equipped with fish net floats at eight foot intervals to keep the line at the surface. A wire core in the line eliminated much of the stretch of the nylon. Working from a boat, it was quite easy to lay out plots of fairly uniform size. Once the plots were laid out (Fig. 8) it was not difficult to scatter the pellets or to apply liquid herbicides quite uniformly within the plot confines.

Where small plots were used, 3 x 3 or 6 x 6 feet, frequently only one marker was used. Once the marker was in place, the required amount of pelleted material was distributed about the stake, covering an area approximately 3 x 3 or 6 x 6 feet. Occasionally four bamboo poles were ited together to form a 6 x 6 foot square and the pellets were distributed within this square.

In field trials with pelleted samples of 2,4-D, 2,4,5-T and 2,4-D-PCP at Hess Lake, Lake Lansing and at the Hastings Fish Hatchery, various methods of staking out and marking plots were used. One method, which worked well in some areas, consisted of the following: four-inch lengths of two by fours were cut, shellacked and then painted with two coats of a bright yellow, high gloss enamel. The letters "M.S.C." were then printed conspicuously on one side, together with an index number. On the other side was placed a staple to which was attached a length of copper fish line. Odds and ends of old pipe fittings were used as anchors. In setting out these markers, an effort was made to have the floats suspended at least twenty inches below the surface, so as to eliminate possible damage and movement due to ice.

When it was desired to obtain numerical data relative to the abundance of certain weeds, a counting frame was utilized. This was constructed of four pieces of lath, rivetted together to enclose an area of one square yard. If cattails were to be counted, one side of the frame was left open. In use, the two sides were held parallel and were pushed into a stand of cattails. A yardstick was utilized to see that the sides of the frame were parallel and that one square yard was enclosed.

During the course of the investigation, several experimental samples of variously compounded nigrosine dyes were secured and determinations made on the light occlusion properties of each dye. In the evaluation of these dyes, a modified Jackson Turbidimeter was used. This was constructed by inverting a 14 ounce fruit juice can over a 15 watt electric light bulb. The light from the bulb was allowed to pass through a hole in the bottom of the fruit juice can and up through a five-sixteenths inch circle painted on the bottom of a 200 ml. graduate. The graduate was enclosed by a cardboard tube, to exclude incident light, thus making possible a more accurate reading. The home-made turbidimeter is illustrated in Figures 9 and 10.

In the use of this instrument, the dye solution was poured slowly into the graduate until the light image just disappeared. Then, with a pipette, small quantities were withdrawn until the image reappeared. A few drops of the solution added was usually sufficient to cause extinction of the light and at this point no further dye solution was added. The cardboard tube was then removed and a reading of the level of the dye solution made directly from the scale on the graduate. This scale almost exactly corresponded to millimeters from the base of the water column, so that volume readings could be directly converted to millimeters. The margin of error was 3 mm. in 250 mm., 1.2 percent, which was not considered significant.

It is customary to refer to applications of phenoxyacetic acid compounds and Na TCA as being of so many pounds, acid equivalent, per acre. In this report, all references to dosage rates follow this custom.

RESULTS

Nigrosine

The lake chosen for the nigrosine experiment was Loon Lake in the Michigan Department of Conservation's Rifle River Area, Ogemaw County. The lake is mainly spring-fed and in normal years the evaporation and seepage equal the supply so that little water is lost through the outlet.

Although all the lakes in the area were open to fishing, Loon Lake was the least used because the nuisance of weeds interfered with rowing and fishing. Loon Lake is set fairly low, surrounded by hills so that it is not exposed to the wind action which is developed on larger, more open lakes. The turbidity was, in general, greater than that of the other lakes in the area. Practically all the plants in the lake were growing within the five foot contour. The methyl orange alkalinity was about 100 ppm. and the pH 8.0 indicating a fairly alkaline condition.

The water level was at least six inches below normal due to a very dry spring. Anacharis canadensis plants in several areas were so heavily coated with marl that they were bent over and did not interfere with rowing. A large patch of Anacharis canadensis, near the outlet, although discolored by marl, was just about to the surface and slowed up a boat drifting through it. Ekman dredge samples were taken in the deeper waters and it appeared that no rooted aquatic plants were growing in water over ten feet deep. The soft, pulpy peat on the bottom made it difficult to determine the exact depth of the water.

The main weed species were as follows:

Anacharis canadensis	Nuphar advena
Chara spp.	Potamogeton zosteriformis
Myriophyllum verticillatum	Vallisneria americana

Application of the dye to Loon Lake was made on July 17, 1948. In making the application, the dye was divided into three parts and distribution made by sprinkling the dry granules off the stern of a boat in three lanes which traversed the length of the lake. The water, in the wake of the boat, colored immediately and diffusion was fairly rapid. In the course of a few hours, the currents had so merged the color that the lanes were scarcely perceptible. Coverage was considered to be complete in 24 hours.

Before the application of the dye the Secchi disk had disappeared at five feet. Twenty-four hours later the reading was three feet in the open water. In the shallows, the marl-coated Anacharis canadensis plants were conspicuous against the blackness of the water.

The lake again was examined on August 13th, at which time the Secchi disk disappeared at 5 feet 6 inches. The caretaker at the area had periodically taken Secchi disk readings and these indicated a gradual increase in transparency over the intervening period. The marl-coated Anacharis canadensis plants did not appear to have been affected by the brief period of darkness as the leaves were of a normal, green color when the lime was removed. Eelgrass, Vallisneria americana, had become conspicuous in several areas and the terminal portions of Ceratophyllum demersum were within a few inches of the surface.

Due to the method of application, it was suspected that some of the crystals might have fallen into the layer of very light and fine, pulpy peat and become buried. To establish whether these crystals existed and had formed a heavy dye solution which would not diffuse through the pulpy peat, the following test was made on August 13th:

One of the lanes, made when the crystals were distributed, had begun within a cove and passed out of the mouth into the lake proper. A furrow, ten to fifteen inches deep, was dug in the pulpy peat of the soft bottom across the mouth of the bay; at right angles to the lane of crystals. The stirred peat settled rapidly so that by the time the furrow was finished, the water looked normal where first disturbed. This was in water about one and one-half feet deep. No blue coloration persisted in the water after the silt had settled.

On September 25th. the Secchi disk disappeared at seven feet. The water level was down about 10 inches due to the dry summer and several weed beds which previously had not come to the surface, had now contacted the surface. From a comparison of the growth of plants beyond stakes which had been put in to mark the extent of two beds of Chara and one of Anacharis canadensis, there was evidence from the spread of these beds thattheir growth had not been retarded by the application of the dye. The marl, by this time of year, had become so heavy on Anacharis canadensis especially, that the plant no longer interfered with rowing since it was lying almost prostrate on the bottom. When portions of the plants were shaken free of marl, the leaves were seen to be of a normal, green condition and when these examined plant fragments were returned to the water, they did not sink immediately, but remained seemingly suspended. This indicated that they were on the bottom because of the weight of the marl deposition. At this inspection samples of the water, the plants, and the pulpy peat were secured for later laboratory study in an attempt to determine the cause of the disappearance of the dye.

Following the failure of nigrosine to control, or kill the weeds in Loon Lake, experiments were made to determine the cause of the disappearance of the dye. In one of these a quantity of pulpy peat from the bottom of Loon Lake was allowed to drain and to dry very slowly. A two-inch layer of this dry peat was placed in each of three milk bottles. They were then filled with tap water which had been allowed to stand for some time to get rid of any residual chlorine. Equal sized crystals of nigrosine were dropped into each. The crystals fell through the water and sank into the pulpy peat of the bottom. One bottle was shaken vigorously so that the pulpy peat was completely suspended and the nigrosine was put into suspension. The other two bottles were allowed to stand. Two days later the milk bottle which had been shaken was still blue with dye and the pulpy peat had settled to the bottom. The bottles that had not been shaken were still clear. Eight days after setting up the experiment, the two undisturbed bottles had not colored. One of these was then shaken vigorously and after the peat had settled the water was bluer than that in the bottle which had been shaken at the start of the experiment. Subsequent shaking of the original and allowing it to stand did not regenerate the original intensity of color.

On August 15 six aquaria each 12 x 12 x 24 inches and holding 40 liters of tap water (which had been allowed to stand for several days) were set up as follows: each had two, flat, clay pans, ten inches in diameter in which was a layer of mud, taken from the bottom of Lake Lansing. In these pans were placed rooted portions of Vallisneria americana, Anacharis canadensis, Heteranthera dubia, Ceratophyllum demersum, Potamogeton amplifolius, P. richardsonii and Bidens beckii.

Two, new samples of nigrosine dyes were obtained, one was water soluble and the other insoluble in water. Stock solutions of the three dyes (including that used at Loon Lake) were made as follows:

a. .5 gm. of R-1156 in 50 ml. of 95% alc. and 250 ml. of water

b. .5 gm. of R-1155 in 300 ml. of water

c. .5 gm. of 128-B in 300 ml. of water

The aquaria containing the plants were treated with the stock solutions as follows:

Aquarium No.	Dilution	Ppm.
1.	200 ml. of "a"	8.23
2.	100 ml. of "a"	4.11
3.	200 ml. of "b"	8.23
4.	100 ml. of "b"	4.11
5.	200 ml. of "c"	8.23
6.	100 ml. of "c"	4.11

After these additions were made to the respective aquaria, they were carefully stirred, so that the mud would not leave the pans and cloud the water in the aquaria.

After a week aquaria Nos. 1 and 2 were fairly clear and most of the dye was floating on the surface, although some had precipitated or adhered to the glass walls. This was the water-insoluble dye. By the 7 of September, Heteranthera dubia was still living but the plants of Ceratophyllum demersum and Anacharis canadensis had disintegrated. The water surface of both tanks was covered by a froth and an odor of putrefaction came from both aquaria. The rest of the aquaria were still darkened from the dye but No. 5 and No. 6 appeared to have some of the dye on the surface film.

On September 16th. the contents of Nos. 1 and 2 were discarded. Putrefaction had occurred in both tanks and gas bubbles arose when the pans were lifted. The dye appeared to have settled on the bottom, as the white spot remaining where the pan had been was very distinct from the area outside. This dark area surrounding the white spots made by the pans, had a bluish cast but when alcohol was later poured over the bottom, the dye did not dissolve. This precipitated dye was removed only with difficulty when it was scoured with steel wool. The only plant left with signs of life was Heteranthera dubia.

On October 3rd. aquarium No. 5 had a surface film more intensely black than that of No. 6 but was not considered to be as clear as No. 6. In tank No. 5 Bidens beckii was the only plant living. Almost all the plants in tank No. 6 were in a healthy condition. The old plants of Potamogeton amplifolius were somewhat retarded but the young plants of Ranunculus flabellaris, Anacharis canadensis, Vallisneria americana and Heteranthera dubia had made some growth.

Aquarium No. 3 was just about as dark as No. 5, but lacked the surface film. Bidens beckii was in a healthy condition but Heteranthera dubia was retarded, and Vallisneria americana, Potamogeton pectinatus and P. amplifolius were dead. Aquarium No. 4 was almost clear. The young plants of Heteranthera dubia, Bidens beckii, Potamogeton amplifolius, P. pectinatus, and P. richardsonii had made some growth. Vallisneria _americana_ had not put out any new growth. Plants in control aquaria all had made considerable growth by the time of discarding the contents of the treated aquaria.

To determine whether the presence of mud would cause or be a factor in the clearing of dye solutions, a series of jar tests were begun. The first was set up January 18th. as follows:

Four one-gallon wide-mouthed jars were set up, each with 3500 ml. of tap water which had been allowed to stand. To each, respectively, the following materials were added:

Jar No.	Amount of dry peat	Weight of No. 128-B dye	Ppm.
1.	10 grams	.02 grams	5.7
2.	25 grams	.02 grams	5.7
3.	25 grams	.07 grams	20.0
4.	50 grams	.07 grams	20.0

The concentration of dye in the first two was so low that it was impossible to obtain a reading in the modified turbidimeter. A reading of the latter two was 275 mm. After the jars were set up they were each stirred vigorously, daily.

By January 31st., 13 days after the jars had been set up, Jar No. 2 was clear except for the stain due to the peat. No. 1 was stained likewise but in addition still had a slight bluish hue. No. 4 was cleared to the extent that no reading was possible.

A week later Nos. 1 and 2 were unchanged. No. 3 was stained but had a slightly perceptible blue color. No. 4 was clear of dye but was stained.

In another three weeks algae had increased to the extent of interfering with the experiments and thus the contents of the jars were discarded. No. 1 still showed a slight bluish hue.

In the comparison of the ability of different dyes to maintain solution, a series of nine one-gallon, wide-mouthed jars were used, each containing 3500 ml. of water. Into each of these jars was placed a measured quantity of dye from different experimental samples. The jars were placed on a bench in a greenhouse and periodically the dyed water in each jar was tested with the turbidimeter, twice. One reading was made of the water which was decanted off, the other after stirring. The results are given in Table I.

The dyes were compounded differently and, due to their inherent properties, they differed in ability to produce color; that is one-half gram of each of two dyes would not necessarily give equal color to equal volumes of water. The concentrations used were those which would make it possible to obtain a reading of the degree of light penetration by use of the turbidimeter. Any smaller amount of dye would have made such a dilute concentration that it would have been impossible to obtain a reading in the modified turbidimeter. A high reading indicates a less deeply colored dye solution than a low reading.

Another series of jar tests was made to more accurately determine the effect of mud and plants on the clearing of dye solutions. Wide-mouthed, one-gallon jars, each containing 3500 ml. of lake water, were used. Into these were placed, except in the control jars where no additions were made, either a layer of mud, a handful of Anacharis canadensis or a combination of these. Dye was placed in all the jars at known concentrations. These jars, with a cover of glass, were placed in the greenhouse and examined

TABLE I

CLEARING OF DYE SOLUTIONS DETERMINED
BY TURBIDIMETER READINGS

Dye	Concentration (in ppm.)	Turbidimeter Reading (length of liquid column in mm.)						
		1/14/50	2/6/50		3/8/50		4/7/50	
		Stirred	Unstirred	Stirred	Unstirred	Stirred	Unstirred	Stirred
1	285.7	120	130	120	150	140	120	110
4	71.	250	300	310+ *	310+	310+	310	
5	71.	180	245	221	310+	260	290	233
6	86.	217	255	225	305	240	310	250
7	57.	219	307	264	310+	310+	310+	310+
8	14.	265	277	260	307	305	310	305
ESB	14.	278	302	300	310+	310+	310+	310
R-1155	14.	278	280	280	310+	310	310	310
128-B	14.	276.5	285	285	310+	310+	310	310

(*) The maximum possible reading was 310 so that readings of 310+ do not indicate equal absolute turbidities periodically (Fig. 11). In Table II the results are tabulated as to the number of days required for clearing of the dye solution. In every case where the dye cleared, evidence of nigrosine was to be found in one or all of three places: clumps of dye could be plainly seen on the leaf surfaces of the plants, entrapped or chemically associated with the precipitate of lime on the sides of the jars, on the bottom of the jar in clumps or associated with lime deposits.

In an effort to see whether the type of water was a factor in the clearing of a dye solution, 3500 ml. of water were placed in each of nine jars together with .02 gms. of the dye used at Loon Lake and were set up as follows:

Tap water	1. dye only 2. dye and Apacharis canadensis 3. dye and 10 grams muck
Distilled water	1. dye only 2. dye and Anacharis canadensis 3. dye and 10 grams muck
Lake water	1. dye only 2. dye and Apacharis canadensis 3. dye and 10 grams muck

The jars were set up on March 31, 1950, and were allowed to remain in the greenhouse. A glass plate was set over each jar top to reduce evaporation.

On April 22nd. in the No. 1 series, the distilled water jar was quite blue with the tap water just slightly clearer. The lake water jar was the darkest and had a precipitate on the bottom. The tap water jar had a slight precipitate but none was evident in distilled water.

In the No. 2 series the tap water was slightly bluer than the other two. The plants in tap water appeared normal, with the older leaves and

TABLE II

RESULTS OF JAR TESTS WITH NIGROSINE DYE SAMPLES

Dye	Dye Concentration (ppm.)				Rate of Clearing								
		Additions			Elodea alone		Elodea and mud		Mud alone			Water	
	Initial	1st.	2nd.	Total	Days	Degree	Days	Degree	Grams	Days	Degree	Days	Degree
128-B	2.8			2.8	5	++	5	++		5	+	43	++
		5.7		8.4	43	+	12	+++		43	-		
			5.7	14.1			43	++					
	5.7			5.7	31	+	31	++	10	41	++	31	-
	5.7			5.7					25	13	+++		
	20.			20.					25	41	+++		
	20.			20.					50	20	+++		
1	71.4			71.4	46	+++							
	142.8			142.8	59	+++							
2	7.1			7.1	28	+++						53	+++
		5.7		12.8	53	+++							

TABLE II (Continued)

Dye	Dye Concentration (ppm)				Rate of Clearing								
	Initial	Additions		Total	Elodea alone		Elodea and mud		Mud alone			Water	
		1st.	2nd.		Days	Degree	Days	Degree	Grams	Days	Degree	Days	Degree
3	2.8			2.8	11	+++	11	+++	10	11	+++	11	+
		5.7		8.5	25	+++	18	+++	10	24	++	18	+++
	34.2			34.2					12	24	-		
	34.2			34.2					25	24	-		
4	42.75			42.75	21	+++						88	+
		42.75		85.50	38	+++							
5	28.5			28.5	21	+++						52	+
		28.5		57.0	28	+++							
			28.5	85.5	38	+++							
6	28.5			28.5	7	+++	7	+++	10	7	+	45	-
		28.5		57.0	27	+++	27	++	10	14	-		
			28.5	85.5	45	+++	45	+	10	45	-		

TABLE II (Continued)

Dye	Dye Concentration (ppm)				Rate of Clearing								
		Additions			Elodea alone		Elodea and mud		Mud alone			Water	
	Initial	1st.	2nd.	Total	Days	Degree	Days	Degree	Grams	Days	Degree	Days	Degree
7	28.5			28.5	21	+++						38	++
		28.5		57.0	28	+++							
			28.5	85.5	38	++							
8	2.8			2.8	2	+++	2	+++	10	2	+++	2	+++
		5.6		8.4	14	++	14	++	10	35	+++	45	+
			5.6	14.0	35	+++	35	+++	10	45	+++		
R-1155	5.7			5.7	13	+++			10	30	+	30	+
	5.7			5.7					25	30	-		
	11.4			11.4	30	++							
Fluorescein	11.4			11.4	45	+++						45	+++
	28.4			28.4	45	+++						45	+++

Key

- dark
+ slight lightening
++ faintly colored
+++ clear

axils containing dye deposits on them but none appeared on the new, green leaves. The plants in distilled water appeared normal except for two short sprigs which were bleached. On the upper surface of the older leaves, lime deposits and spots of dye were visible. The plants in distilled and lake water had grown satisfactorily.

In the No. 3 series the dye concentration appeared to be just about the same in all jars. The jar containing tap water had a greater growth of algae on the surface than did the others.

On June 1st. the jar with the tap water in the No. 1 series was very much lighter in color than was the distilled water jar. The lake water was intermediate in color but appeared to have a reddish cast rather than the blue of the distilled water.

In the No. 2 series the jar with the lake water was absolutely clear. A slight growth of a filamentous algae was present on the bottom. Anacharis canadensis was still green and was giving off oxygen bubbles near the top. The distilled water jar was almost as clear as the lake water jar but the Anacharis canadensis was not growing satisfactorily because filamentous algae had developed in the jar. The tap water jar was not colored from the dye but contained colonial algae and invertebrate life. Some of the Anacharis canadensis plants appeared normal.

In the No. 3 series the tap water was almost clear, just slightly stained. An algal growth was developing on the surface. The distilled water was still dark from dye but had a green surface scum of algae. The lake water was clear but had numerous algal filaments.

The solutions and plants were discarded after this examination because of algae growths. Plants in control jars had grown well throughout the experiment.

To determine what effect solutions of nigrosine at different pH levels might have on the clearing of the dyed water, the following experiments were conducted:

One-gallon jars with buffered solutions of tap water in the following pH ranges were set up according to tables by Clark and Lubbs:

pH	6.0	6.5	7.0	7.5	8.0	8.5

At once it was apparent that aluminum or other salts were forming an unstable suspension, especially in the alkaline range. Within 24 hours, the four highest buffered solutions (from pH 7.0 to 8.5) contained a white precipitate. On the 15th. of March, two days after the solutions were made, the clear water above the cloudy layer was siphoned off and enough tap water (which usually amounted to 100 ml.) was added to bring the quantity up to 3500 ml.

The jars were then placed in the greenhouse. In each was placed sufficient nigrosine dye No. 3 to give a concentration of 5.7 ppm. After assuring complete solution of the dye a generous amount of Anacharis canadensis was placed in each jar. The jars were then covered with glass plates to reduce evaporation.

On March 22nd. they were examined and the results were found to be as follows: the plants appeared to be growing best at a pH of 6.0 Here the concentration of dye appeared to be the least of any of the jars. At a pH of 6.5 most of the terminal growths of Anacharis canadensis plants were flaccid. At pH of 7.0 and above all the plant parts were flaccid and the jars smelled of putrefaction, especially those in the higher pH range. Jars containing water of pH of 6.5 and 7.0 were darkest and did not appear to have had as much dye taken out of solution as did the jars above this range which were lighter in color.

At the time of the last inspection, before the contents of the jars were discarded, it was noted that only at pH of 6.0 was there any evidence of plant life. The other jars did not contain any living plants and the solution of none of them was as clear as that at pH 6.0 It was noticed in cleaning the jars that the jar at pH 6.5 seemed to have had the greatest deposition of lime on the sides and bottom of the jar.

At the Hastings Fish Hatchery, Pond No. 8 has produced annually a very luxuriant crop of weeds, chiefly Anacharis canadensis and Ranunculus flabellaris. This pond had received artificial fertilization during the growing season in the experimental rearing of bait minnows. It was .75 acres in area and sloped in to a depth of about 6 feet in the center and near the drain basin.

On June 21, 1950, sixteen pounds of National Nigrosine 128-B were put in the pond. This was at the rate of 21.3 pounds per acre. The method of distribution was as follows: the dye was divided into three portions. These, one at a time, were placed in the bottom of a pail and the pail filled with water. When water was added, the dye seemed to coagulate forming large, hard lumps that slowly dissolved. The 16 pounds were distributed by walking around the edge of the pond in the shallow water and periodically allowing the pail to fill with water, subsequently pouring out the dye solution. Following this method of introduction and to aid dispersion, the concentrated dye solution near the shore was pushed out toward the center of the pond by means of boards. By the next day the dye had colored the open water in the center and was considered to be of uniform distribution after two days.

The Secchi disk reading, just previous to applying the dye, was one foot. This and subsequent readings were taken from a box which enclosed the outletat the deepest part of the pond. On June 26th., five days after putting in the dye, the Secchi disk reading was 1½ feet. This, therefore, indicated that the decreased penetration of light following application of the dye was only temporary.

A week after application of the dye, the shallow water appeared to be clearing and this fact was confirmed by Secchi disk readings. When fragments of the plants were examined, they showed black deposits on the leaves, especially on the upper surface of the _Anacharis canadensis_ leaves.

Fertilizer was added on June 29th.

On July 1st., three weeks after the initial application, another treatment of 15 pounds of dye was made. This was placed in the bottom of a 10 gallon milk can, after which the can was filled with water. By means of a portable power sprayer, the supernatant liquid was sprayed over the surface of the pond. As the level of the dye solution in the can fell, it was replaced by water taken from the pond until there were no more lumps in the bottom of the can. A week later the Secchi disk reading was 1½ feet, and on July 10th. it was 2 feet.

On the 18th. of July determinations of the oxygen and carbon dioxide concentrations of the water were made. At this time the oxygen level was 1.1 ppm. and the carbon dioxide at 39.0 ppm. The Secchi disk disappeared at 3 feet. With such a low oxygen content it was feared for the safety of the red-eared sunfish which were in the pond for other experimental purposes. The water, which had been shut off to prevent dilution of the dye, was then allowed to run into the pond. Shortly after this two days of heavy rain occurred so that on July 21st. the oxygen content was up to 4.2 ppm. and the carbon dioxide was down to 0.0 ppm.

In order to prove more definitely that the addition of the dye and subsequent coloring of the water can cause a depletion in the oxygen content of the subsurface water, another 15 pounds of dye were put in on August 4th. At this time the water to the pond was turned off and the dye distributed by means of a burlap sack of the crystals dragged behind the boat. The oxygen content at this time was 11.4 ppm. with 0.0 ppm. carbon dioxide.

Three days later the Secchi disk reading was one foot, the oxygen was down to 1.98 ppm. and the carbon dioxide concentration was up to 11.0 ppm. On the 11th. of August the light penetration was two feet, the oxygen content at 2.6 ppm. and the carbon dioxide at 11.0 ppm. At this time another 15 pounds of dye were introduced by means of a cotton bag filled with crystals and towed behind a boat. When plants were pulled from the deeper water (the tops were in the photosynthetic zone) for examination, it was noticed that the lower stems of *Anacharis canadensis* were bare of leaves. These stems, however, were green, turgid and not brittle. An odor of putrefaction was noticeable around the pond. Bullheads were noticed in distress and seemingly gulping for air at the surface on August 14th. A week after adding the dye the oxygen content was 2.3 ppm. and the carbon dioxide was 14.0 ppm.

Additional applications probably would have caused further reduction in oxygen concentration and this might have affected the fish adversely, therefore dye applications were stopped. There was apparently little or no effects upon the weeds (other than the bare stems) as they remained in a normal condition throughout the remainder of the summer. Results of the analyses of water samples and Secchi disk readings obtained during the course of dye treatments are shown in Table III.

TABLE III

EFFECT OF APPLICATIONS OF NIGROSINE DYE ON OXYGEN, CARBON DIOXIDE, PHENOLPHTHALEIN ALKALINITY, METHYL ORANGE ALKALINITY AND DEPTH OF PENETRATION OF LIGHT

Date	June		July					August				
	21st.	26th.	1st.	7th.	10th.	18th.	21st.	4th.	7th.	11th.	18th.	25th.
Dye added (in pounds)	16		15					15		15		
Oxygen (in ppm.)						1.1	4.2	11.4	1.98	2.6	2.3	
Carbon dioxide (in ppm.)						39.	0.0	0.0	11.	11.	14.	
Phenolphthalein alkalinity (in ppm.)						0.0	4.0	13.	0.0	0.0	0.0	
Methyl orange alkalinity (in ppm.)						24.0	132.0	144.	142.	167.	178.	
Secchi disk (in feet)	1	1.5		1.5	2.	3.		1.	1.	2.		2.
Remarks	water turned off					water turned on		water turned off				water turned on

CHLORINATED BENZENES AND XYLENE

In the beginning of the research on this problem, information relative to the effective chemical control of submerged aquatic plants was limited to the following materials:

1. Sodium arsenite
2. Copper sulfate
3. Benoclor
4. Orthodichlorobenzene
5. Petroleum naphthas

The first is well documented in the literature. The second is known to be effective on <u>Chara</u> but, in concentrations required for control, is highly toxic to animal life. Benoclor is also known to be very toxic to animal life. The last two, orthodichlorobenzene (one of the ingredients of Benoclor) and the petroleum naphthas are worthy of attention because of their cheapness, when compared to Benoclor, their availability, and their effectiveness even though it was known that fish life would not survive in treated waters.

Field trials during the first summer of experimental work included applications of Benoclor, orthodichlorobenzene, xylene and toluene. These will be discussed beginning with the experiments at East Mill Pond.

An emulsifiable mixture of orthodichlorobenzene and trichlorobenzene (No. 3) has had, during the past 15 years, a considerable use as an aquatic herbicide. Recently a material (No. 3C) containing a greater amount of emulsifying agent has been available. This was designed primarily for aquatic weed control in the flowing waters of irrigation canals of western United States but is useful also in shallow, standing waters of lakes.

One drum of each of the materials was applied at East Mill Pond, near Romeo, Michigan, during the latter part of July 1947. When the material (No. 3C) containing most emulsifier was sprayed beneath the surface of the water, a cloudy emulsion was formed. This emulsion, as it slowly settled to the bottom, came in contact with the submerged weeds. The other material (No. 3) containing a smaller quantity of emulsifier, did not form as good an emulsion as the material containing the greater amount of emulsifier. No. 3C was applied in the shallow water wheras the No. 3 material was applied in the deeper water because the emulsion of the latter tends to sink quite rapidly. Results of these applications were not considered satisfactory as the weeds were only temporarily retarded and a considerable number of fish were killed.

Two additional drums of material were obtained for experimental use during the 1948 season. A more complete check on the vegetation was to be made at this time with close attention to be paid to calculation of dosages. An outline of the areas treated is given in Fig. 13 and the treatments are given in Table IV. From the latter it will be seen that the rates varied from 26 to 64 gallons per acre during the 1948 season.

A description of the areas and treatments follows:

Area "A" was covered by means of the lane method, applying No. 3C next to shore and No. 3 in the deeper water. The aquatic plants in this area were mainly <u>Chara</u>, <u>Potamogeton epihydrus</u>, <u>Nuphar advena</u>. <u>Ceratophyllum demersum</u> and <u>anacharis canadensis</u> were present in the deeper water 25 feet from shore.

TABLE IIII

APPLICATIONS OF CHLORINATED BENZENES
AT EAST MILL POND, 1947-1948

Area		Date	Material	Rate per Acre (in gallons)
A	1	7/21/47	Bc. #3C	20
	2	7/21/47	Bc. #3	10
	1	5/29/48	Bc. #3C	18
	2	5/29/48	Bc. #3	16
B	1	7/21/47	Bc. #3C	10
	2	7/21/47	Bc. #3	15
C	1	7/21/47	Bc. #3C	5
	2	7/21/47	Bc. #3	5
	1	5/29/48	Bc. #3C	8
	2	5/29/48	Bc. #3	18
D	1	7/29/47	Bc. #3C	25
	2	7/29/47	Bc. #3	25
	1 & 2	5/29/48	Bc. #3C	40
E	1	5/29/48	Bc. #3C	16
	2	5/29/48	Bc. #3	32
F		5/29/48	Bc. #3C	64

In area "C" *Chara* and *Ranunculus flabellaris* practically surrounded the island. The former was mostly confined to the shallow part and merged in with the *Ranunculus flabellaris* which lay in the deeper water. In addition to these, *Anacharis canadensis* was common on the north and south sides of the island. On the south side a floating-leaved pondweed, *Potamogeton epihydrus*, formed an upper-story over the *Anacharis canadensis* and *Ceratophyllum demersum* on the bottom. Scattered about, especially on the eastern and southern sides, were the floating leaves of *Potamogeton natans*, *Nymphaea odorata* and *Potamogeton zosteriformis*.

Growth of *Potamogeton pectinatus* came to the surface in area "D", was very dense and uniformly distributed. Scattered throughout were the floating leaves of *Potamogeton natans*. In this plot only No. 3C was used.

In area "E" *Anacharis canadensis* was the most conspicuous weed, especially in the eastern and northeastern portions. The remainder of the plot consisted, for the most part, of *Nuphar advena* and *Ranunculus flabellaris*. Sixteen gallons of No. 3 were put in the deeper water while eight gallons of No. 3C was applied in the shallow water next to shore.

The shoreward half and the east end of plot "F" consisted of a practically pure stand of *Chara*. In the remainder of the plot, the surface was well covered with the floating leaves of *Potamogeton natans* and algae. Beneath this mat were scattered plants of *Ranunculus flabellaris* and *Ceratophyllum demersum*. Scattered lily pads, *Nymphaea odorata*, floated near the shore.

The results of the treatments of these areas were as follows:

Two weeks after treatment, the Potamogeton pectinatus in area "D" was still up to the surface and was in fruit. Fourteen weeks after treatment, the species was falling apart on the bottom and was partially covered with a layer of algae. By late June of the year following, it was obvious, by the stand of P. pectinatus that was developing, that the tubers had not been affected. Two sprayings of 40 and 50 gallons per acre did not give sufficient evidence of control to warrant further treatment.

For a time, during June and early July, it appeared as though the treatment of area "A" had been effective. Two weeks after treatment, Ceratophyllum demersum and some Anacharis canadensis appeared dead and on the bottom. The water was turbid, perhaps as a result of decay and putrefaction of plant parts. Samples taken with an Ekman dredge from the bottom of the deeper part of the area, failed to bring up any portions of live plants. In the shallows, the water was clear, with some debris on the bottom. A few scattered leaves of Potamogeton epihydrus were present just under the surface. Two months after treatment, regrowth was appearing all over the area. Bottom samples indicated that the Ceratophyllum demersum was making regrowth. In the shallows, scattered plants of Anacharis canadensis and Ceratophyllum demersum were appearing, but it was not until late the following summer that the area developed the density of weed growth that had been apparent just previous to spraying.

In area "C", two weeks after treatment, new vegetative growth of Ranunculus flabellaris was just beginning to appear from the sheaths at the base of injured leaves. These new leaves continued developing until two months after spraying, at which time the plants began to settle and fall apart, apparently from natural causes so that by early September all that remained was debris on the bottom. Submerged leaves of Potamogeton natans and P. epihydrus were apparently killed but the floating leaves did not appear to be affected by the underwater sprayings. Chara was not seriously harmed by the application but showed regrowth by the end of the summer.

In the shoreward part of area "E" Ranunculus flabellaris, two weeks after spraying, was apparently dead and on the bottom. At the end of the summer there was only debris left on the bottom underneath the leaves of Nuphar advena. By midsummer of the following year, little Ranunculus flabellaris came to the surface and Anacharis canadensis appeared to be as dense as Ranunculus flabellaris had been.

Although Chara was completely destroyed in area "F", it was noted that plants adjoining the treated area, soon crowded into the cleared water. The treatment was very effective on Ceratophyllum demersum and Anacharis canadensis under the Potamogeton natans. Less effective control was obtained near the southern margin which adjoined untreated water and where some dilution probably occurred. The filamentous algae scum, which just about completely covered the surface of the water, did not appear to be related to the results of the treatment (the death and decay of the Chara) since the water outside the treated area also had a heavy algae scum. The presence of small colonies of Anacharis canadensis and Ceratophyllum demersum near the shore can perhaps be attributed to the action of the algae mat which moved with changes in wind direction and thus was an agent in distributing weed fragments.

At Hastings, treatments were made using orthodichlorbenzene at rates ranging from 40 to 80 gallons per acre with no emulsifier. Aside from the fish kill, which accompanied every treatment, several other observations were made from these applications.

Even at 40 gallons per acre, growth of Anacharis canadensis was reduced over much of the plot area and in a month's time an estimated 30 percent of the bottom was clear. At higher concentrations, a considerably greater portion was clear. In every case there was extensive putrefaction which became evident when an oar was thrust into the bottom. This was especially noticeable where 80 gallons per acre had been applied. A month after such a treatment, Anacharis canadensis plants appeared to have separated at the soil level and it was possible to obtain an oarful of the loose weeds, wheras in untreated areas they were firmly attached to the substratum. This effect was also observed, but to a lesser extent, in plots where lower rates had been applied. By early September, approximately two months after treatment, in every plot there were some normal plants, apparently rooted on the bottom, while other areas in the plots had no living plants.

At Hess Lake, applications were made on August 21 as follows:

Plot No.	Rate per acre	Ppm.	Material
1.	58.0 gallons	400	orthodichlorbenzene
2.	69.6 gallons	533	xylene
3.	72.0 gallons	555	toluene

These materials contained sulfonated castor oil at approximately three percent by volume and had a small amount of water added just before spraying. By means of a sprayer, powered by a gasoline engine, the materials were sprayed beneath the surface at 200 pounds pressure.

When the area was next examined, effects of the treatments were noticeable in all plots. The predominate weeds in plot No. 1 were Myriophyllum verticillatum and Chara. In the shoreward part of the plot Nuphar advena was present. The leaves of Myriophyllum verticillatum appeared to have fallen and the bare stems were all that remained. However, new shoots could be observed at the basal regions and these continued growth until cold weather. Much of the Chara on the bottom was disintegrating. Nuphar advena was unaffected.

In Nos. 2 and 3 the effects of the materials were less noticeable than in plot No. 1. Some of the leaves of Myriophyllum verticillatum were brown but others were not. No effects of the treatments could be observed on Chara.

To further test the effectiveness of xylene, four applications were made at Hastings, September 7 as follows:

Plot No.	Rate per acre	Ppm.	Emulsifier
1.	160 gallons	2,450	10 percent
2.	160 gallons	2,450	10 percent
3.	320 gallons	4,900	5 percent
4.	160 gallons	2,450	10 percent

At the time of the next examination, three weeks later, the terminal portions of Chara were found to be whitened in plot No. 1. Under this thin layer, the rest of the Chara appeared normal.

Plot No. 2 contained principally Anacharis canadensis and Najas spp. The latter species appeared to have been more severely affected by the treatment than did A. canadensis. Much of the Najas became flaccid and was on the bottom undergoing decay. This growth of Najas had been near the surface at the time of application and therefore had been exposed to the emulsion for a longer period of time than the Anacharis canadensis which was at a slightly greater depth. New rhizoidal roots were seen on fragments of Anacharis canadensis.

The application of xylene at the rate of 320 gallons per acre appeared to have been effective in controlling Potamogeton pectinatus and Najas spp. as these species were apparently dead and disintegrating on the bottom. The treatment, however, did not prevent a clump of Polygonum in the center of the plot from flowering.

In No. 4 only in scattered areas was Najas controlled. Elsewhere it persisted together with Potamogeton pectinatus as isolated colonies which were in a healthy condition. Small tubers were being formed in the case of P. pectinatus.

In the use of these materials, the cost of emulsifier constitutes a significant portion of the expense. Sulfonated castor oil and mahogany soap were recommended by Balcom (2) for use with the petroleum naphthas. In the flowing waters of irrigation ditches of the western United States, where these compounds find widespread usage, it has been determined that the temperature of the water will affect the amount of emulsifier required for satisfactory emulsification (2).

The material applied at Hess Lake did not emulsify as well as might have been desired. The September applications at Hastings where 5 and 10 percent of emulsifier was used, were superior in this respect.

On the basis of observations made on spray applications it appeared that insufficient information was available relative to the influence of the type of emulsifier on the quality of the emulsion and that a study should be made with the view of finding those emulsifiers most effective with the materials used in Michigan waters.

The heavy and light materials varied considerably from the specific gravity of water. For example, the specific gravity of xylene is about .860 and for orthodichlorobenzene 1.30. In the case of the light materials, it was desired to maintain them in suspension for at least an hour before they came to the surface. For the heavy materials it was desired to maintain them in a suspended form for at least an hour before they sank to the bottom. This hour of contact was selected as a standard because such a time interval would allow for sufficient contact between weed plants and herbicidal suspensions to bring about a kill of the plants.

Since cost is an important factor in weed control practices, efforts were directed toward the use of as small an amount of emulsifier as possible and still achieve the desired result.

The procedure in evaluating emulsifiers consisted essentially of adding emulsifiers to 10 ml. of orthodichlorobenzene, trichlorbenzene, xylene, etc. and, after thorough aggitation, shaking this mixture with 90 ml. of water in a tall, 100 ml. graduate and observing the rate of settling. The quantity of emulsifier added was calculated on a volume basis.

In general, when 5 or 10 percent of certain emulsifiers were used, there was little settling within an hour's time. However, 5 percent was considered to be too costly when used on a field scale. Efforts were then directed toward reducing this amount and still achieving the desired hour of suspension.

The best method found to achieve this goal was to mix light and heavy materials. They were mutually miscible and the addition of one to another in any proportion caused the specific gravity to be closer to that of water, than was either separately.

The first attempt at mixing was that of combining 5 ml. of orthodichlorobenzene (heavy) with 5 ml. of xylene (light) and a very small quantity of Tween 40. When this mixture was shaken and poured into a graduate containing 90 ml. of water, a fairly good emulsion formed immediately. Upon shaking the graduate vigorously, a uniform cloudy emulsion resulted, which showed no separation after an hour's time. Subsequently a layer began to form on the bottom.

Other trials with different proportions and different emulsifiers were made. Seven ml. of xylene and 3 ml. of orthodichlorobenzene, plus a little sulfonated castor oil formed a good emulsion when shaken with water. Eighteen hours later the top 10 ml. in the graduate (here was the mixture) was clear and there was no settling on the bottom.

It was soon found that by eliminating the emulsifier from the mixture, one or two drops of the mixture, falling through a water column, would reveal whether the mixture was properly balanced. If the drops came immediately to the surface, the mixture was obviously too light. If a drop fell rapidly through the 90 ml. column of water, that indicated the mixture to be too heavy and would require the addition of the lighter component. By such a series of trials it was possible to arrive at the particular combinations desired which were near the specific gravity of water or slightly heavier.

With some of the materials the balanced mixtures appeared to be as follows:

orthodichlorobenzene-xylene as 1:2

trichlorbenzene-xylene as 1:3

The desired balance was that the mixture be slightly heavier than water as most emulsifiers are light and the addition of them would lower the specific gravity of the mixture.

By early summer of 1949 sufficient information had been gathered so that field applications were warranted. Three quarter-acre plots were staked out at Hess Lake in Newaygo Co. The weeds present were Chara, Potamogeton amplifolius, Nymphaea odorata, and Najas spp. The plots were laid out more or less paralleling the shore so that the same depth of water (approximately 2½ to 3½ feet) would be encountered in each plot and so that the weed growths would be more or less similar. The materials used were as follows:

Mixture	Ratio
trichlorbenzene-xylene	1:3
orthodichlorobenzene-7898	2:3
orthodichlorobenzene-xylene	1:2

Ten gallons of each of the above balanced mixtures were used making the applications at the rate of 40 gallons per acre. Adding water to the mixture at the time of spraying seemed to aid the formation of the emulsion when the material was sprayed beneath the surface. Amount of emulsifier added was calculated at 2 percent of the balanced mixture.

By means of a John Bean Spartan Sprayer with a 15 gallon tank, delivering about 3 gallons per minute at 200 pounds pressure, it was possible to spray the 10 gallons fairly uniformly over the quarter-acre plots by criss-crossing with a rowboat. The spray boom consisted of four No. 650067 Tee-Jet nozzles on 18 inch extensions, extending below the surface of the water and at 18 inch intervals. The date of application was June 21st.

The emulsion of the orthodichlorbenzene-xylene mixture did not stay up very well and separated quite rapidly. This rapid breaking was not desired as it prevented materials from remaining in contact with the plants for the desired period of time. Subsequent examinations failed to show any effects in plots other than that sprayed with the trichlorbenzene mixture. In this plot the Chara, a week later, was down on the bottom and covered with a filamentous algae. Apparently anaerobic decomposition was taking place for when an oar was stuck in to mounds of the debris, bubbles of ill-smelling gas came to the surface.

On this same date, June 29th., ten gallons of the trichlorbenzene-xylene (1:3) mixture plus 2 percent emulsifier was applied to a quarter-acre plot near shore. Chara was predominant here with scattered plants of *Myriophullum verticillatum*, *Potamogeton vaginatus* and *Najas* spp. The coverage was good and the material stayed up satisfactorily. Two weeks later the Chara no longer remained upright but was prostrate and fragmented. Chara, in falling to the bottom, appeared to take with it other species of plants and leave the plot relatively clear. During the rest of the season, the bottom of this area remained virtually free from plant growth. A year later there was still a great difference between the treated and untreated plots but individual plants of Myriophyllum verticillatum and Potamogeton vaginatus were present.

Other applications, later in the season, were made with this mixture and with the orthodichlorbenzene-xylene mixture. Applications on species other than Chara did not produce as good results.

On July 11 a plot, about one-sixteenth of an acre, was sprayed at the rate of 160 gallons per acre with the trichlorbenzene-xylene mixture plus two percent sulfonated castor oil as emulsifier. The bottom was covered with Chara and occasional plants of Potamogeton amplifolius. The applications was made with the power sprayer and No. 650067 nozzles. During the treatment numerous small fish, three-quarters to one inch in length, were seen in distress.

The next day the Chara had whitened and looked dead, just as it would look after being exposed to the air for a short period of time. Potamogeton amplifolius did not appear to be affected. The small fish had drifted to shore and it was estimated that there were from three to four quarts of them.

Three weeks after treatment, there still was no effect on the Potamogeton amplifolius. Chara, although it was bleached, was beginning to put put new shoots in the axils. At this time another ten gallons of the mixture was applied. Chara, two weeks after this second treatment, was apparently dead and disintegrating. The Potamogeton amplifolius remained unaffected.

Examination of the plot on June 14th. of the year following, revealed the complete absence of Chara. Even areas just outside the plot where some drifting of the mixture had occurred, showed a Chara-less bottom. With a plant hook, it was impossible to find any fragments of Chara. No noticeable difference was to be observed in the growth of Potamogeton amplifolius. It and a narrow-leaved form of Potamogeton were growing normally and already had their flowering spikes to the surface.

On August 18, 1949, five gallons of the trichlorbenzene-xylene mixture (1:3) was sprayed over the surface of a plot (50 by 40 feet) with an average depth of about two feet. This was in the northeast corner of pond No. 11 at the Hastings Fish Hatchery and was at the rate of 108 gallons per acre. The area was almost completely filled with Anacharis canadensis and some Heteranthera dubia.

A week later the white, soft, decayed, terminal portions of Anacharis canadensis were very conspicuous against the dark background. An oar, dipped into the water and weed mass, brought up a load of dead, brittle A. canadensis tops. The lower portions, however, were green and showed new shoots one inch long. The same type of regrowth was noted in the case of Heteranthera dubia, which appeared dead, but new shoots were developing from the bases. On the surface, bits of floating, decaying, filamentous algae supported leech carcasses and several dead bluegills. Other bluegills were seen in distress. A few were found resting on semi-submerged pond scum and when disturbed with a paddle, swam blindly into suspended mats of algae. Rowing a boat in the area seemed to bring more fish into difficulty. The chemicals were probably brought into suspension again by the agitation caused by rowing the boat. No visible drops of oil came to the surface.

Subsequent examinations during the summer indicated continued regrowth of both species. A surface spraying of the mixture is apparently not as successful as a subsurface one.

On August 29th. at Lake Lansing, five gallons of the trichlorbenzene-xylene (1:3) mixture was applied beneath the surface in an area 50 by 50 feet. This was at the rate of 87 gallons per acre. The plants were Vallisneria americana, Potamogeton amplifolius, P. zosteriformis, P. richardsonii and Heteranthera dubia. The mixture was applied at 200 pounds pressure using No. 650067 Tee-Jet nozzles. Even during and after treatment, it was noticed that the suspension tended to drift shoreward so that along the outer edge of the plot, the material did not remain long in contact with the weeds. Quite a few small, one-inch fish were seen in distress. A six and one-half inch pickerel was picked up and revived by being placed in clean water.

Five days later the results were very noticeable. Over most of the treated area, and that for ten or twelve feet shoreward, the Vallisneria americana leaves, which were about one and one-half feet long, were on the bottom. They were bleached white and transparent as were those of Potamogeton zosteriformis. Basal portions of both appeared normal. P. amplifolius was affected least of all. The leaves were perhaps a little off color but the basal portions were green and the rootstocks were normal. Heteranthera dubia stems were still slightly green in color at the internodes but the leaves were bleached.

Two weeks later one or two new, green leaves of Potamogeton amplifolius stood out in sharp contrast to the rest of the bottom with its pulpy peat and browned leaves of other plants. There was no regrowth of Vallisneria americana.

The following summer P. amplifolius came to the surface in parts of the plot and thus indicated that it had not been affected very seriously by the treatment. Vallisneria americana and Chara were rare in the plot.

The last field application with the mixture for the season, was on September 6, 1949. At the time of spraying, two gallons were added to the mixture which consisted of one gallon of orthodichlorbenzene, two gallons of xylene and 250 ml. of sulfonated castor oil. This was sprayed beneath the surface at high pressure, 250 pounds per square inch, over an area approximately 50 by 40 feet at the rate of 65 gallons per acre. The surface was well covered with the leaves of Brasenia schreberi. Underneath the surface, Vallisneria americana, Heteranthera dubia and Potamogeton zosteriformis were common.

A week later it was estimated that 90 percent of the Brasenia schreberi leaves were under the surface and turning brown. Heteranthera dubia appeared severely injured and the blackened, decaying plants and rootstocks could be pulled from the bottom, easily. Vallisneria americana leaves were dead and on the bottom. Ceratophyllum demersum leaves were brown and the stems were brittle. The following year it was obvious that Brasenia schreberi in the plot was distinctly thinner than in areas outside the plot. There was still evidence of Ceratophyllum demersum. This may have drifted in as apparently did some Anacharis canadensis. Vallisneria americana was still present and was apparently not permanently retarded by the treatments.

It had been observed that differences exist between surface and subsurface water temperatures. No information was available as to the effect of different temperatures on the rate of settling of different mixtures. A series of experiments directed at this particular problem, that is the effect of temperature on the settling of emulsions, was made. Table V indicates the results of these experiments and represents the average of four and in some cases six trials. Amount of emulsifier was calculated at approximately two percent.

Field trials indicated that insufficient information had been acquired relative to emulsifiers when used with balanced mixtures. Some emulsifiers which seemed to form a satisfactory emulsion with one balanced mixture were not satisfactory with another. A comparison in the amount of settling of trichlorbenzene, xylene and a balanced mixture of the two, as effected by various amounts of emulsifier, is shown in Table VI. The method of evaluation was similar to that described earlier. The amount of settling represents the average of four trials and was recorded one hour after the materials had been shaken with lake water in tall, 100 ml. graduates. Drops of emulsifier were those which fell from the end of a three mm. stirring rod. The mixtures had a specific gravity of 1.013

An evaluation of emulsifiers for use with balanced mixtures is given in Table VII. Lake Lansing water was utilized and emulsifiers at approximately two percent by volume. It is likely that some of the emulsifiers indicated as not being very satisfactory could be made so by altering the ratio slightly. The effects of different emulsifiers on balanced mixtures of xylene-trichlorbenzene is shown in Fig. 12.

TABLE V

A COMPARISON IN THE RATE OF SETTLING OF DIFFERENT TRICHLORBENZENE-XYLENE MIXTURES AT DIFFERENT TEMPERATURES USING TWEEN 60 AS EMULSIFIER AND 10 ML. OF THE MIXTURE

Trichlor-benzene-Xylene Ratio	15° C.			25° C.		
	½ hr.	1 hr.	1½ hr.	½ hr.	1 hr.	1½ hr.
1:2	5. ml.	7.4 ml.	10.0 ml.	4.4 ml.	8.4 ml.	10.6 ml.
1:2.5	3. ml.	4.5 ml.	6.7 ml.	2.0 ml.	4.2 ml.	6.2 ml.
1:3	0. ml.	2.0 ml.	3.25ml.	0.0 ml.	0.0 ml.	2.2 ml.

TABLE VI

A COMPARISON IN THE AMOUNT OF SETTLING OF TRI-CHLORBENZENE, XYLENE AND A BALANCED MIXTURE OF THE TWO AS AFFECTED BY DIFFERENT AMOUNTS OF EMULSIFIER

Amount of Emulsifier (Tween 40)	Trichlorbenzene	Trichlor-benzene-Xylene (1:3)	Xylene
2 drops	13.5 ml.	3.0 ml.	14.0 ml.
4 drops	13.0 ml.	0.0 ml.	8.0 ml.
6.drops	13.0 ml.	0.0 ml.	5.0 ml.
8 drops	13.0 ml.	0.0 ml.	6.0 ml.

TABLE VI

RATE OF SETTLING OF 10 ML. OF THE BALANCED

Balanced Mixture	Ratio	Sulfonated castor oil	Intracol [illegible]	Antarox A400	Neutronyx 834
Xylene-Trichlorbenzene	3:1	+++	+++	++++	+++
Xylene-Orthodichlorbenzene	2:1	+++	-	++++	+

Balanced Mixture	Ratio	Glycerol Laurate	Petronix	Span 40	Tween 40
Xylene-Trichlorbenzene	3:1	+++	+	-	++++
Xylene-Orthodichlorbenzene	2:1	+	++	-	+++

Balanced Mixture	Ratio	3 pts. Span 85 1 pt. Tween 85	1 pt. Span 85 3 pts. Tween 85	1 pt. Span 85 1 pt. Tween 85	3 pts. Span 60 1 pt. Tween 60	1 [illegible] 3 [illegible]
Xylene-Trichlorbenzene	3:1	++	+++	++	++	
Xylene-Orthodichlorbenzene	2:1	++	+++	++	++	

- Settling of 10 ml. i
+ Settling of 10 ml. i
++ Settling of 5 ml. i
+++ Settling of 5 ml. i
++++ Settling of 0 ml. i

IXTURES WITH VARIOUS EMULSIFIERS

Emulsifiers

ulsor	Mulsor V7	Storox SK	G-1283	G-1255	Dresinate 91
++	++++	+++	+++	+++	++
++	+++	+++	++	++	-

pan 60	Tween 60	Span 65	Span 80	Span 85	Tween 85
+	++++	-	++++	++	++++
++	++++	-	+++	++	+++

t.Span 60 ts.Tween60	1 pt.Span 60 1 pt.Tween60	3 pts.Span40 1 pt.Tween40	1 pt. Span 40 1 pt.Tween 40	1 pt. Span 40 3 pts.Tween 40
+++	+++	+++	++	+
++	++	++	+++	+++

15 minutes
30 minutes
30 minutes
60 minutes
60 minutes

It was apparent from some of the experimental work done in the laboratory that the type of water was a factor in the stability of emulsions. Tap water, distilled water and lake water did not react uniformly as shown by early tests. Table VIII indicates the results of experimental work using both a balanced and a slightly heavier than balanced mixture of xylene-trichlorbenzene with Tween 60 as emulsifier. Six drops of emulsifier were used per 30 ml. of mixture. Here again, 10 ml. of the mixture was shaken with 90 ml. of water and the amount of settling was observed hourly. The readings represent the average of six trials at room temperature.

It will be seen from Table VIII that differences appear to be greatest between the tap and lake water series when balanced mixtures were used. In view of these differences, only lake water (from Lake Lansing) was utilized in subsequent laboratory investigations of balanced mixtures, except where otherwise noted.

A field trial, June 18 was designed to compare the effects of a balanced mixture of orthodichlorbenzene-xylene (1:2) and one of trichlorbenzene-xylene (1:3). At this time of year Chara at Lake Lansing was about one and one-half to two feet in height. The applications were made by means of the power sprayer and were at the rate of 135 gallons per acre using two percent sulfonated castor oil as emulsifier. In order to obtain some idea of the density of the stand of Chara, the procedure as outlined by Ball (2) was followed. The average weight of Chara with six casts of the hook was 13.7 ounces with a range of 12 to 17.

At the time of the next examination, eight days after treatment,

TABLE VIII

EFFECT OF TYPE OF WATER ON STABILITY OF EMULSIONS USING TWEEN 60 AS EMULSIFIER

Type of Water	Trichlorbenzene-Xylene Ratio	Amount of Settling (in ml.)			
		1 hour	2 hours	3 hours	4 hours
Tap	1:2.5	4.6	10.3	10.9	13.8
	1:3	3.3	8.5	9.2	11.2
Distilled	1:2.5	3.9	7.9	9.1	10.8
	1:3	2.1	4.1	4.9	6.6
Lake	1:2.5	4.5	8.0	10.0	13.5
	1:3	2.3	4.3	5.2	6.6

there were indications that the applications had been fairly successful. Where there were no other weeds, Chara was down and on the bottom and it was very easy to obtain an oarful of the brittle and bleached plants. Where several plants of Potamogeton amplifolius were growing, the Chara appeared to drape over them.

Periodic observations were made the rest of the summer on these plots and nowhere did the Chara make regrowth. A few plants of Potamogeton amplifolius persisted throughout the summer. Likewise a few plants of Myriophyllum verticillatum continued growth, although it may have been that these drifted in following the decline of the Chara.

Toward the end of the season , several Ekman dredge samples were taken and in them were recognizable Chara fragments. No evidence of regrowth of the algae was to be found.

The Chara mat in pond No. 10 at the Hastings Fish Hatchery was about 18 inches thick and extended to within 6 inches of the surface. The uniformity of this stand , by June 21, 1950, made it ideal as a testing ground. The materials and rates of application are given as follows:

Mixture	Ratio	Gallons per acre	Emulsifier
Amyl acetate-dichlorpentanes	2:4	255.7	Mulsor V7
Xylene-ortho-dichlorbenzene	2:1	255.7	Tween 60
Xylene-tri-chlorbenzene	3:1	255.7	Tween 60

The emulsified material in the amyl acetate-dichloropentane and xylene-orthodichlorobenzene plots stayed up exceptionally well. Five or six hours later a whitened patch was evident about each stake.

In every plot, ten days later, the upper 5 to 6 inches of Chara were bleached and disintegrating (Fig. 14) but the lower 12 inches were normal (Fig. 15). The emulsion caused the killing of Chara for a depth to 6 inches and did not penetrate further.

One month after treatment, the plots still stood out in sharp contrast to the surrounding area. The upper layer of Chara was well disintegrated and fell apart when touched with an oar. In some plots the green Chara underneath was beginning to push up through the debris.

From the results of this series of applications it was apparent that when the Chara was dense, the emulsion of a balanced mixture would not penetrate more than the top few inches. Here the emulsion remained and effected a good kill.

The next proceedure was to so weight the mixtures that they might penetrate further into the Chara and affect a greater extent of kill. In an effort to secure penetration, a number of mixtures having different specific gravities were made and applied. The mixtures and ratios used were as follows:

Mixture	Ratio
Trichlorbenzene-xylene	1:2
Trichlorbenzene-xylene	1:2.5
Trichlorbenzene-xylene	1:3
Orthodichlorbenzene-xylene	1:1
Orthodichlorbenzene-xylene	1:1.5
Orthodichlorbenzene-xylene	1:2

The emulsifier used was Tween 60 and the applications were made at the rate of 255.7 gallons per acre on July 21. In the trichlorbenzene-xylene series, the ratio 1:3 represents a balanced mixture, wheras the 1:2 is heaviest and the 1:2.5 intermediate.

Two weeks after treatment, all the plots appeared to be about the same, that is the top few inches consisted of bleached and brittle Chara, while beneath this the plants were normal. There appeared to be no difference in the depth of penetration between any mixtures as evidenced by measurements of the top and bottom portions. No further efforts to weight the mixtures were made as the purpose of balancing is thus defeated and the emulsion does not long persist.

At Portage Creek Trout Pond, three applications were made with the trichlorbenzene-xylene mixture. The first was made July 8, 1950, over area "1-8" (Fig. 16) and at the rate of 120 gallons per acre using the 1:2 ratio and sulfonated castor oil to the extent of two percent. The area consisted entirely of Chara which had not been affected by treatments of dry herbicides made when the pond had been drained the previous winter.

Three weeks after treatment, it appeared that the control of Chara, especially in the shallow water, had been very good. In this area the plants were on the bottom and disintegrating. Results were not as satisfactory in water more than two feet deep. Here, only in certain areas, were the weeds down while in other areas normal plants seemed to support a layer of dead Chara. This condition existed for the remainder of the season, the shallow areas remained clear and the deeper areas were spotty.

Treatments of the remaining two plots were made July 31 using 1:3 ratios of the trichlorbenzene-xylene mixture at rates of 122.4 and 145.2 gallons per acre. Chara predominated in both plots with plants of Potamogeton natans and Ceratophyllum demersum less abundant. Location of these treated areas is given in Fig. 16 where area "9" was treated at the low concentration and area "12" at the high.

These plots were next examined three weeks later. Even at the low concentration, very good control of Chara was obtained. The plants were on the bottom and were disintegrating. Potamogeton natans appeared to have been injured, as shown by the fact that most of the floating leaves were dead and of a light-brown color. Each plant, however, was observed to have at least one or two green leaves. The presence of these leaves indicated unsatisfactory control of this species.

The effects in the plot which had received the greater concentration were similar to those of the lower. Ceratophyllum demersum and Chara were disintegrating on the bottom, three weeks after treatment. The treatment appeared most successful in water one and one-half feet deep, although satisfactory control was obtained in water up to two and one-half feet deep. Potamogeton natans responded in much the same way as it had at the lower concentration.

Although an earlier trial at Lake Lansing had failed to reveal any difference in effectiveness between xylene-trichlorbenzene and xylene-orthodichlorbenzene, another set of applications were made July 14, at the rate of 85.6 gallons per acre to see if lower dosages would show a difference. These applications were made at Hastings, pond No. 10, where a heavy stand of Chara was very uniform over the two plots.

A week following the application it was observed that the tops of the *Chara* plants were killed in both areas while underneath the plants were still green. Three weeks later the areas in the shallow water of both plots seemed to show the best control. Here portions of both plots were clear, *Chara* having fallen to the bottom and only stubs and debris were left. A visual examination indicated a greater degree of control in the trichlorbenzene-xylene plot than in the other.

Chara, nine weeks after treatment, in areas where just the upper portions had been killed, had resumed growth but did not make a reappearance in the shallow areas where it had been effectively controlled earlier in the summer.

On the 24th. of June a balanced mixture of orthodichlorbenzene-xylene, with Tween 60 as an emulsifier, was applied at the rate of 200 gallons per acre on *Heteranthera dubia* and *Myriophyllum verticillatum*. This application killed the weeds to the roots so that nothing remained on the bottom but pieces of dead stems.

Another application made a week later on the same species, but at a concentration of 67 gallons per acre, did not give a satisfactory control. Neither did an application at the rate of 127 gallons per acre made July 6th. give more than just temporary control.

Other applications made on *Chara* with the balanced mixture of trichlorbenzene-xylene, in mid-July and early August, at rates of 70 to 127 gallons per acre, did not give as satisfactory control as did early season applications.

In an effort to effect a kill of the lower portions of a dense patch of *Heteranthera dubia* by making the mixtures heavier than a balanced one, a series of three treatments were made August 4th. using trichlorbenzene-xylene at ratios of 1:2, 1:2.5 and 1:3 at concentrations of 127 gallons per acre with Tween 60 as the emulsifier. There did not appear to be a better kill of the upper portions of Heteranthera dubia than the lower when the 1:3 ratio was used nor a better kill of the lower portions than the upper portions when the 1:2 ratio was used. Other applications on Heteranthera dubia were made at concentrations ranging from 75 to 172 gallons per acre. At the higher concentration, regrowth from injured plants was retarded for a longer period of time than at the lower, but satisfactory control was not obtained.

Two applications of the balanced mixture were made on Vallisneria americana in mid- and late-August. These were at rates of 127 gallons per acre using Tween 60 and Antarax A-400, respectively, as emulsifiers. In both cases control was complete and in two weeks time only a very small amount of debris remained to indicate the presence of the weed species.

Two experimental sprayings were made September 24th. on a dense stand of Elodea which came almost to the surface in 36 inches of water. Trichlorbenzene-xylene mixtures were again used at the rate of 128 gallons per acre. These mixtures instead of being in the ratio of 1:3 were combined so as to be heavier than balanced mixtures and to have specific gravities of 1.05 and 1.1

Although the mixtures did not emulsify very well, this poor emulsification apparently had little effect on the results since three weeks later, the treatments were very effective, even over a larger area than where the mixtures had been applied. The bottom in both plots was clear of live Anacharis canadensis and only debris remained.

2,4-D PELLETS

In September of 1949 experimental samples of 2,4-D pellets were obtained. Their composition was as follows:

Code number	Ingredients and concentration per 100 lb.
H-9123	9.1 pounds 2,4-D and 72.8 pounds NaPCP
H-9125	4. pounds 2,4-D
H-9126	4. pounds 2,4,5-T

It was intended that these pellets would be broadcasted over the surface of the water, sink and settle into the bottom. They were so compounded as to go slowly into solution. Once on the bottom they would slowly liberate the active ingredients which, it was hoped, would be absorbed by the roots and thus exert a toxic influence on the plants.

It was proposed that the three samples of pellets be put out in the fall in order that they should slowly dissolve during the winter and the active ingredients be absorbed or otherwise contact the resting portions of the weed plants.

One of the first indications of the effectiveness of at least one of these compounds appeared after the 2,4-D-PCP pellets had been applied at the rate of 426 pounds per acre. This was scattered over a plot of soft-stem bulrush, Scirpus validus, which was growing in shallow (4 inch) water on sandy bottom. The date of application was September 2nd. A week after application, the bulrush leaves had turned a light tan to a whitish yellow color and were beginning to lodge. Two weeks after application, the boundary of the plot was clearly defined as the green, normal leaves outside the area stood out in sharp contrast to the burned, lodged leaves within the plot. During the remainder of the season, further disintegration and decay were observed. Underground rootstocks did not have the normal appearance nor turgidity that those had outside the area.

The south end of pond No. 10 at the Hastings Fish Hatchery was laid out in square-rod plots. By putting in stakes and making a grid pattern, plots were laid out in the fall of 1949 and treated (Table IX). A fairly uniform depth of water, about two and three quarters to three feet, was obtained by keeping away from the edges of the pond. The weeds were not at their stage of most vigorous growth. The main species were Chara, Anacharis canadensis and Ranunculus flabellaris. No further attention was given these plots following application of the pellets until the following March.

On March 15, 1950, holes were chopped through the ice in the center of each plot which had been treated as follows:

Pounds per acre	Material	Plant species
6.4	2,4-D	Ranunculus flabellaris
19.2	2,4-D	Chara, Potamogeton filiformis
19.2	2,4,5-T	Anacharis canadensis
3.2	2,4-D-PCP	Anacharis canadensis
320.0	PCP	Anacharis canadensis
800.0	Sodium borate	Anacharis canadensis
1600.0	Sodium borate	Anacharis canadensis

TABLE IX

RESULTS OF SPRING EXAMINATIONS OF FALL TREATED PLOTS

Material	Rate per acre (in pounds)	Results
2,4-D-PCP	.63	Sago pondweed almost to surface
	1.27	Elodea growing well
	1.9	Water-crowfoot dense and growing well
	3.18	Mud plantain growing up well
	3.2	Water milfoil to surface over whole plot
	19.4	Soft-stem bulrush retarded
2,4-D	3.1	Evidence of new Elodea growth
	6.4	Water-crowfoot dense and growing well
	12.8	Scattered Chara plants
	19.2	Sago pondweed dense and almost to surface
2,4,5-T	3.1	Water-crowfoot growing up to surface
	4.8	Chara a solid mat
	19.2	Sago pondweed dense and almost to surface
Sodium borate	800.	Evidence of new Elodea growth
	1600.	Water-crowfoot almost to surface
PCP	160.	Scattered Elodea and Chara
Check		Elodea at least a foot high with lime precipitated on the leaves

A rake was lowered through the hole and several samples of the bottom material were brought up and onto the surface of the ice. At this examination, some apparent differences were noted between plots.

In the plots where 2,4-D, 2,4,5-T and sodium borate, at the rate of 800 pounds per acre had been applied, the weeds appeared to be sparse. It was not uncommon to bring up a rakeful of mud alone without any weeds or there would be included pieces of dead plant debris. Green sprigs were not common. Those sprigs that were collected, were placed in jars and, after several days in the laboratory, showed signs of renewed growth.

On the bottom of the plot which had received 2,4-D-PCP, the debris of <u>Chara</u> could easily be seen extending upward several inches from the bottom. With a rake it was possible to obtain a rakeful of the debris. Some of this was obviously dead but a considerable portion of it looked as though it might grow (growth of portions brought back to the laboratory, verified the observation). Included in the rakefulls of <u>Chara</u> debris were green sprigs of <u>Anacharis canadensis</u>.

In the plot which had been treated with PCP, approximately the same condition existed as that in the area treated with 2,4-D-PCP.

<u>Anacharis canadensis</u> in the plot treated with 1600 pounds of sodium borate, was conspicuous and a rakeful could be gathered with little difficulty. Approximately one-fourth of the plants in a rakeful appeared to be in a normal condition and able to resume growth when conditions were again favorable.

In every plot there were plants in various stages of greenness. The plots were again examined on May 13 and on May 29. Results of these observations are presented in Table IX and indicate regrowth in every plot.

On September 23, 1949, a square-rod plot was staked out in shallow water in which Typha latifolia and a sedge were present. This was on mucky bottom at the south end of pond No. 12 at Hastings. Treatment consisted of 2,4-D-PCP pellets at the rate of 3.18 pounds 2,4-D per acre. This treatment apparently had no effect during the winter for the following spring the cattails again came in to re-populate the plot.

On October 2 and 12 seven applications were made in water about three feet deep at Lake Lansing. The weeds consisted of a well mixed stand of Chara, Potamogeton amplifolius, P. zosteriformis and Vallisneria americana. The materials used and the rates of application were as follows:

Material	Rate per acre (in pounds)
2,4-D	4.3
2,4-D	8.6
2,4-D	12.5
2,4-D	17.4
2,4,5-T	8.6
2,4,5-T	12.5

When the plots were next examined, June 1?, 1950, no noticeable difference could be observed between treated and untreated plots. During the remainder of the summer, growth of all species continued and no evidence of control developed.

At Hastings, in the north end of pond No. 11, an area was located which contained Anacharis canadensis and Heteranthera dubia. An application of 2,4-D pellets was made September 30th. at the rate of four pounds per acre. Examination the following year failed to reveal any signs that control had been effected.

At Hess Lake two large plots were located in the shallow water. They contained mainly Chara, Vallisneria americana and Potamogeton amplifolius. On October 1, 1949, 2,4-D pellets were distributed over one plot at the rate of 4.8 pounds per acre and 2,4,5-T at the same rate over the other plot. In late April of 1950, the time of the next examination, it appeared as though Potamogeton amplifolius had been affected by the treatments as in both of the plots there was debris of this species present but no living portions. Chara appeared unaffected and continued to grow throughout the ensuing summer. Vallisneria americana and Potamogeton amplifolius later appeared and their growth continued during the summer. No difference could be observed between the treated plots or between them and adjoining, untreated plots.

About 75 yards offshore was a very uniform stand of Potamogeton amplifolius and Chara, the latter almost completely covering the bottom with the former too numerous to run through with an outboard. In this area one-quarter acreplots were staked out. Treatments of these two plots were made on the same date as the above two applications but with half the concentrations. Eight months later, an examination failed to reveal any signs of control. Chara was still quite uniform on the bottom. Potamogeton amplifolius had come to the surface and was in flower. During the remainder of the summer there appeared to be no decrease in the plant population of these two plots.

In the winter of 1950 an opportunity was found to apply treatments of dry herbicides on the bottom of a drained pond. The treatments were made on March 14 over an area where *Chara* became abundant and objectionable during the growing season. The general location of the plots was in area "1-8", Fig. 16. The materials and concentrations used were as follows:

Herbicide	Rate per acre (in pounds)
Na TCA	216
2,4-D	6.4
2,4-D-PCP	14.4 (2,4-D) and 116.5 (PCP)
Na PCP	120.0
2,4-D-PCP	28.8 (2,4-D) and 233.0 (PCP)
Alpha hydroxy beta trichlorethyl sulfonic acid	128.
Sodium borate	480.
Copper sulfate	638.

The dry materials were distributed over the frozen pond bottom by hand. A month later water was let in and covered the treated plots. Stakes put in to limit the plot boundaries, remained conspicuous although those in the deeper water were submerged. Three months after treatment, living plants were found in all the experimental plots. A garden rake and Ekman dredge were used to bring up plants and debris for examination. Approximately four months after treatment no difference could be seen between the treated plots. *Chara* formed a practically uniform mat over the bottom of the area.

Since a preliminary field trial had indicated a possible difference in effectiveness between the samples of pellets, laboratory work was designed to determine if these differences existed. Some indication of the rapidity of toxic action that might be expected from future field trials and an idea of concentrations that might be required were also desired.

In comparing these compounds, wide-mouthed one-gallon jars were used. Cuttings of plants were potted and allowed to remain in aquaria in the greenhouse until they were rooted and showed evidence of the formation of new leaf tissue. These potted plants were then used in the jar tests, results of which are given in Table X.

In the late spring of 1950 additional samples of the three kinds of pellets were secured. These had much of the fine material removed so that they were not as dusty nor as disagreeable to handle as the previous samples. Nevertheless the 2,4-D-PCP pellets, when handled, would usually initiate a cough.

At Hess Lake thirteen treatments were made on June 14. Seven were made on practically pure Chara which, at this time of year, was up about six inches. The treatments were as follows:

Materials	Rate per acre (in pounds)
2,4-D	32
2,4-D	64
2,4,5-T	32
2,4,5-T	64

TABLE X

RESULTS OF JAR TESTS WITH EXPERIMENTAL PELLETS

Material	Parts per million	Potamogeton amplifolius		Anacharis canadensis	
		Days	Effect	Days	Effect
H-9125	.2	10	-	17	++
	.2	9	-		
	.25	28	+++	28	++
	.25	28	-	28	+
	.25	18	-	18	-
	.5	9	-	10	++
	.5	28	-	28	-
	.5	25	+	25	+
H-9123	.02	17	+++	17	+++
	.05	18	-	18	-
	.1	18	-	18	-
	.2	25	-	25	-

	.2	6	-	6	-
	.25	18	-	18	-
	.25	18	-	18	-
	.5	6	-	6	+
H-9126	.2	10	+	10	++
	.2	17	++	17	+++
	.25	28	-	28	++
	.5	6	+	6	++
	.5	28	-	28	+
Dowcide G	.1	18	-	18	+
	.1	18	-	18	-
	.2	17	++	9	-
	.2	9	-	9	-
	.25	18	-	18	-

Key

- dead ++ slight growth
+ still green +++ no control

(Continued)

Materials	Rate per acre (in pounds)
2,4,5-T	128
2,4-D-PCP	72 (2,4-D) and 576 (PCP)
2,4-D-PCP	144 (2,4-D) and 1152 (PCP)

None of these treatments were effective on either *Chara* of *Potamogeton amplifolius* since these species continued normal growth throughout the summer.

The remaining six plots were in shallow water from one and one-half to two and one-half feet deep. The bottom was sand and the weeds were small plants of *Vallisneria americana* and *Potamogeton amplifolius*. Just outside the edges of the three innermost plots, two square-yard areas were laid out by means of yardsticks and stakes. All the plants in these two areas were harvested and allowed to drain for two minutes on hardware cloth after the loose sand, adhering to the roots, was shaken off. The average weight of the plants in these two areas was 15 grams. It was intended that later in the summer plants in square-yard sample areas within the treated plots would be removed and weighed. An estimation of the effectiveness of the treatment could then be made. The treatments were as follows:

Material	Rate per acre (in pounds)
2,4-D	256
2,4,5-T	128
2,4-D-PCP	58 (2,4-D) and 498 (PCP)
2,4-D-PCP	174 (2,4-D) and 1398(PCP)

(Continued)

Material	Rate per acre (in pounds)
2,4-D-PCP	291 (2,4-D) and 2329 (PCP)
2,4-D-PCP	582 (2,4-D) and 4658 (PCP)

The pellets were distributed as evenly as possible within the confines of the plots which were approximately 8 x 8 feet. Twenty minutes after applying 2,4-D-PCP at the rate of 291 pounds per acre, there was noted a reddish color in the water. A somewhat less intense color was to be seen in the plots treated with the same material at a lower concentration.

Two weeks later, it was very difficult to see any difference between the plots. However, eight and one-half weeks after treatment, it was observed that the weeds were not as conspicuous in the areas treated with 2,4-D-PCP at 174 and 291 pounds than they were where treated with 58.0 pounds per acre. The plants had apparently fragmented as a result of these high concentrations but an occasional green plant portion was found.

Twelve weeks after treatment, there was nothing to weigh in the area which had received the greatest concentration of 2,4-D-PCP. The few weeds left in the two plots which had received less than this amount, were too thin to count or weigh. Two square-yard samples were taken in the plot treated with the least amount of 2,4-D-PCP and the average of these was 12 ounces. Sample weights were not taken in the areas treated with 2,4-D and 2,4,5-T primarily due to the depth of the water and because it was so obvious that they supported more plants than did the sampled plot. 2,4-D-PCP gave complete control at 582 pounds per acre. The line separating the 2,4-D from the 2,4-D-PCP plot was very distinct.

On June 17 three adjoining plots, each about one-fourth square rod in area, were laid out on cattails and the following treatments were made:

Material	2,4-D per acre (in pounds)	Phenol per acre (in pounds)
2,4-D-PCP	174.72	1397.76
2,4-D-PCP	291.20	2329.60
2,4-D-PCP	582.40	4659.20

Shortly after the applications it was apparent that the treatments were having some effect. The sedges and cattails were browned as if scorched. Pellets, which had accidentally fallen along the margin of the areas, left distinct brown spots in the sod. Five weeks after treatment there were only nine cattail plants alive in the area which had received the greatest amount of pellets. In the other two plots it was estimated that there was less than ten percent regrowth. This regrowth continued to grow during the remainder of the season.

On July 22, 2,4-D-PCP pellets were distributed at the rate of 128 pounds per acre in water less than two feet deep where Heteranthera dubia and Myriophyllum verticillatum were growing on the sandy bottom. When the plot was next examined, three weeks later, the treatment appeared to have been effective. The weeds were down on the bottom and no live roots or stems could be seen. Plants were slightly slippery and flaccid. The few Anacharis canadensis and Ceratophyllum demersum plants that were in the plot were leafless. Portions of the bottom were clear of plant material. Four weeks after treatment, further disintegration of Heteranthera dubia was noted in the shallow water.

Another area was treated at the rate of 291.2 pounds 2,4-D and 2329 pounds of phenol per acre. This was on a mucky bottom where Potamogeton perfoliatus, Heteranthera dubia and Anacharis canadensis were growing. Some of the pellets, although in an advanced stage of solution, were still recognizable four weeks after treatment. The weeds were flaccid, covered with marl and appeared dead. There was an occasional green shoot on the bottom in water less than a foot deep. Nine weeks after treatment, the bottom was open, debris of Heteranthera dubia was conspicuous but no new shoots were to be found. The area affected by the treatment seemed to be slightly larger than the area over which the pellets were applied.

An area of about a square rod of soft-stem bulrush, Scirpus validus, growing in the shallow water of pond No. 1 at Hastings, was divided into two parts and one of these was treated July 22 with the 2,4-D-PCP pellets at the rate of 145 pounds 2,4-D and 2328 pounds phenol per acre. Six days after treatment, the leaves leaned over as if hit by a heavy rain. Thirteen days later they leaned further and were bleached to a light yellow color. There was an odor of PCP in the vicinity and an evidence of the former existence of the pellets could be seen on the bottom. Two months after treatment, there were only a few stubs of leaves sticking up to indicate where the plot had been (Fig. 17 and 18). The matted roots in the treated area did not appear normal as did those of the untreated area.

Two adjoining plots were staked out over bulrush on July 22. One plot was treated with 2,4-D-PCP at the rate of 129.2 pounds 2,4-D per acre, the other at twice this rate. In the matter of a few days, all the leaves in both plots were bleached and leaning. Six weeks later there was no sign of regrowth in the plot which had received the pellets at the high rate of application. The bases of some of the bleached leaves in the other plot were still green and there were four new leaves that were just breaking above the surface in the square-rod plot.

On June 17 three one-half square-rod plots were cut out of a uniform stand of narrow-leaved cattails. The soil was water-logged but no standing water was present. Treatments were made with the 2,4-D pellets at rates of 28, 48 and 96 pounds 2,4-D per acre. These treatments were not effective.

A series of three one-half square-rod plots of cattails were cut out of a uniform stand with a passage way between each plot to facilitate distribution of pellets and subsequent examination. The applications were made June 17 at rates of 38.4, 64.0 and 128.0 pounds 2,4,5-T per acre. Five weeks later, no difference could be seen between the treated plots and the untreated. An examination later in the season failed to reveal any evidence of herbicidal action. The basal portions were turgid and the rhizomes appeared normal.

Translocated Herbicides

Typha

Applications of less than two pounds per acre of the isopropyl ester of 2,4-D as an aqueous spray, produced a mottling of the leaves of cattail, Typha latifolia, and a browning of the tips. The lower portions remained green and the centers continued growth. During June and July of the first season of experimental work, applications of two pounds and at rates up to 4.5 pounds per acre, did not give satisfactory control. An application made late in the summer, August 5 as an oil spray at the rate of 2.75 pounds per acre, showed an apparently better control than did any previous treatment. Therefore, many subsequent applications of the ester form of 2,4-D were applied as oil sprays.

Only a few applications were made during the 1949 and 1950 seasons. During the 1949 season, best results were obtained when two successive applications were made at a six week interval. One plot was re-sprayed June 20 when the regrowth was well established. As a consequence of the second spraying regrowth, from the meristematic region, did not begin to appear until late August. Evidently the little regrowth made subsequent to that time, enabled the plant to store up enough food so that the following season some plants did reappear in the plot although there were fewer than in adjoining, untreated plots.

The butyl ester formulation did not show any apparent superiority over the isopropyl ester for controlling cattail even when used at the rate of 6.5 pounds 2,4-D per acre.

Rates as high as five and six pounds per acre of the isopropyl ester of 2,4,5-T did not prevent regrowth. Several applications of less than these amounts were made but they only succeeded in slightly rusting the foliage. This species appears to be quite tolerant to both 2,4-D and 2,4,5-T.

In order to obtain some idea of the comparative effectiveness of the free acid and two 2,4-D formulations (ester and amine), three adjoining plots were staked out. Square-yard sample counts of plants were taken to obtain an estimate of the density of the cattails. The treatments were applied June 17, 1950, at the rate of 3 pounds 2,4-D per acre. The free acid was dissolved in tributylphosphate and all three spray solutions were applied as oil sprays.

In every plot, six days after the applications, effects of the treatments were noticeable. Eleven days after treatment, the upper third of the leaves of plants, where the acid had been used, became browned and were so dry that they had fallen over. The plants in the other plots were considerably browned and showed some lodging. This browned appearance, upon closer examination, was seen to be due to numerous spots, closely arranged upon the leaves so that from a distance, the entire upper portions of the leaves appeared brown. The lower portions of most leaves were still green and apparently had not been contacted by the spray. The bases of other plants were not turgid and when these plants were pulled or separated at the growing point, there was a smell of oil and a slippery feel to the meristematic tissues. Apparently the oil had moved down the leaves to this growing point.

The plants in the acid-treated plot, three and one-half weeks after treatment, appeared to be slightly more affected than the others in that more of the plants were prostrate. Regrowth was observed in all plots.

All three were again sprayed on July 11 at the same concentration. Ten days after re-treatment, there was still considerable green showing in the amine-treated plot. More of the plants in the ester-treated plot appeared to be down than in the other plots, but all showed new growth four weeks after re-treatment. At this time sample areas were again counted. The treatments, together with before and after counts, are given in Table XI.

TABLE XI

COMPARISON OF THE EFFECTIVENESS OF ACID, ISOPROPYL ESTER AND AMINE SALT OF 2,4-D ON CATTAIL, *TYPHA LATIFOLIA*, SHOWING THE AVERAGE NUMBER OF PLANTS PER SQUARE YARD AND THE PERCENT REDUCTION

Material	Before Treatment	Percent Reduction	Regrowth
acid	18	72.	1.7
isopropyl ester	17	76.	1.0
amine salt	11	55.	2.7
control	15	0.	.3

Sagittaria

On July 20, 1948, the isopropyl ester of 2,4-D was applied to a plot of arrowhead, *Sagittaria latifolia*, and cattail, *Typha latifolia*, at the rate of 2.78 pounds 2,4-D per acre. Six days later the cattails showed little injury but at least 60 percent of the arrowhead leaves were twisted and browned. Eleven days after spraying, all that remained of the arrowhead plants were brown, crisp leaves. Three weeks after treatment, the control appeared to have been very good as there was less than ten per-cent regrowth. The year following, however, both species resumed growth.

An arrowhead plot, which had been sprayed the year previously with TCA and was regrown, was sprayed July 12, 1949, with 2,4-D at the rate of 2.78 pounds per acre. Four weeks later the application appeared to have been successful as there were no living arrowhead leaves in the plot and some of the rootstocks were decaying.

On August 8, 1949, two square-rod plots of arrowhead were sprayed with the isopropyl ester of 2,4-D at the rate of 2.78 pounds 2,4-D per acre. One application was made as an oil spray wheras an aqueous spray was used in the other.

Six days later plants, in the plot which had been treated with the aqueous spray of 2,4-D, were down and showed typical twisting of petioles. Two weeks after treatment, the old leaves were dead and decaying but new leaves were conspicuous. The bases of the old leaves were dead but the rootstocks were alive and remained so for the rest of the season. The area never took on the appearance of untreated, adjoining areas (Fig. 19), although 4 or 5 new shoots per square yard made good growth.

The effects on the plants in the plot where 2,4-D in oil had been used followed rather closely those where an aqueous 2,4-D spray was used. It would be expected that the addition of the oil would accelerate the effects of the 2,4-D treatment. In this case the reverse appeared to occur as the weeds in the plot which had been treated with an aqueous spray, were prostrate before those in the oil-treated plot. In both cases, however, a satisfactory control was obtained.

With the advent of the 1950 season, it appeared that a radical change had taken place over the area covered by the plots. Water hemlock had invaded this area and only a few arrowhead plants were left to indicate the previous existence of this species. This growth of water hemlock was sprayed at the approximate rate of three pounds 2,4-D per acre on August 21. Three and one-half weeks later, hardly a trace of the plants remained. Water hemlock is very susceptible to 2,4-D.

The only effect of the treatment of arrowhead with applications of the isopropyl ester of 2,4,5-T at rates of one and two pounds per acre, made July 20, was a slight crinkling of the leaves. A few leaves did dry up but the majority, although distorted, maintained their positions in the plot. Later there were signs of regrowth.

An application of three pounds per acre was made on August 9. Nine days later some leaves were brown, some yellow and others were inverted. Although there was considerable evidence of injury, new growth began to appear through the dried leaves by August 25.

When 2,4-D and 2,4,5-T were compared for their effectiveness on arrowhead, 2,4-D appeared to be superior.

Pontederia

At the beginning of this investigation pickerelweed, Pontederia cordata, was sprayed with light applications of the isopropyl ester of 2,4-D. On July 22, 1948, an application was made at the rate of 2.09 pounds 2,4-D per acre. A week later, the leaves were twisted as is typical of 2,4-D injury to broadleaved plants. Other leaves and their petioles were on the surface of the water and some were leaning on one another and looked as though they had been hit by a heavy rain. Within thirty days, new leaves were appearing at the surface throughout the sprayed area.

At Lake Lansing an isolated patch of pickerelweed, approximately one square-rod in area, was sprayed on July 26, 1948, at the rate of 2.78 pounds 2,4-D per acre. Five days later about five percent of the leaves and petioles had pulled loose and were floating on the surface. The remaining leaves pulled easily. A slight tug caused the petiole to separate from the rhizome. Pulling on the petioles of untreated plants generally caused the petioles to break at some distance above the point of attachment to the rhizome. The leaves in the entire plot were pulled by hand at this time. This was done in order to test the theory that the scars made by the separated petioles, would become a focus of bacterial infection which might lead to decay of the rhizome. At the time of the next examination, nine days after pulling, the bottom of this area was conspicuous with dead petioles and no new leaves were to be seen. Later, although parts of the rootstocks appeared to be in an advanced stage of decay, there were portions which were obviously not dead.

On July 1, 1949, the isopropyl ester of 2,4-D at the rate of three pounds per acre, was applied to a plot consisting mainly of pickerelweed. Ten days later, the leaves were brown, they were easy to pull, the bases were soft and they smelled of decay. None of the leaves had self-pruned, that is, none had separated from the rhizome. Sixteen days later, a few new pickerelweed leaves had appeared above the surface. The bases of the petioles of these were soft, smelled of decay and pulled very easily. Pickerelweed petioles, four weeks after treatment, still pulled easily and no regrowth was evident in the center of the square rod plot. By September 15, one and one-half months after treatment, the plot was bare when compared to untreated areas. Approximately twenty leaves of pickerelweed were all that showed above the surface. Petioles and leaves were decaying beneath the surface.

An emulsion consisting of the isopropyl ester of 2,4-D plus fuel oil, water and an emulsifying agent, was applied on July 11, 1949, at the rate of 2.5 pounds per acre. Five days after treatment, the leaves pulled very easily. A few new leaves were just appearing above the surface at this time. A month later, the leaves, which had been hit with the spray, were either lodged or had self-pruned and were floating on the surface. Regrowth was evident so that the treatment was not considered satisfactory. From these observations it appeared that regrowth would occur if pickerelweed was sprayed with concentrations less than 2.5 pounds 2,4-D per acre.

Another square-rod plot was sprayed on the same day, July 11, at the rate of four pounds 2,4-D per acre. Four days later there were a few new leaves which had appeared. However, some of these pulled easily. Six weeks after treatment, approximately twenty-five new leaves could be observed in the square-rod plot. The old leaves were dried and shrivelled but they remained upright. On September 15, more than two months after spraying, regrowth was very slight and the dry petioles were fallen over so that the plot had an open appearance in contrast to adjoining, untreated areas.

When oil was used as a carrier for 2,4-D instead of water, it appeared to do a better job of softening the lower end of the petiole. With low rates of applications, new leaves would frequently appear above the surface a month after treatment. By the end of the growing season, the plot would be just as dense as the adjoining, untreated plots.

Several sprayings were made during the summer of 1950 in order to secure numerical data with which to compare the effectiveness of various formulations. On June 26 the isopropyl ester of 2,4-D was applied on pickerelweed at the rate of 3.48 pounds per acre. Examination, twelve days later, showed that the treatment had not been very effective. Some leaves were darkened, blotched, and hung down but there were many new leaves pushing their way up through the surface of the water. In comparison, an average of 6.5 leaves per square foot were found within the plot, while untreated areas had an average of 19.6 leaves. By September 6 the plot was filling with the new leaves, although it was still considerably thinner than adjoining, untreated areas.

Another square-rod plot was sprayed at the rate of 3.48 pounds 2,4-D per acre on June 26. Four days later the leaves had lost their turgor. Twelve days after treatment, some bulrushes, which were in the plot, were bleached almost to the water surface. They pulled fairly easily but the meristematic zone did not show any obvious sign of decay. The pickerelweed leaves had become dark-streaked or blotched. Leaf counts were made on August 2. The treated area had an average of eight per square foot wheras the checks averaged fourteen. The new leaves, which were counted, were large and were in an upright position. In the bare patches old, dead leaves were entirely browned and leaned almost to the water surface. Although there was a layer of algae over the plot, the general impression was that control had not been too satisfactory. Seven weeks later, another application was made at the same rate. This application was very effective as shortly afterward, very few leaves appeared above the surface and the old, dry, dead ones leaned over and later decayed in the water. Four weeks after the re-treatment, the plot had an open appearance; algae covered the surface wheras in adjoining areas there was little or no algae among the petioles. Eight new leaves were trying to penetrate the algal mat at this time. The leaves hit by the last spraying were twisted and the petioles were beginning to lean. Here again, it appeared that one June spraying at three pounds 2,4-D per acre was less effective than two sprayings at intervals of about two months.

The butyl ester of 2,4-D appeared to be equally as effective on pickerelweed as the isopropyl ester formulation. Early in the investigation, both formulations were used but it soon became apparent that one was as effective as the other when used at similar concentrations.

A light application of the isopropyl ester of 2,4,5-T at the rate of 1.39 pounds per acre, was applied July 30 to a plot of pickerelweed. The immediate effect was to cause the leaves to become inverted and to lose their turgor. They looked as though a light rain had beat on them.

Four days after spraying the leaves were still green. In the course of the next week many petioles were seen to be leaning and approximately ten percent were down and horizontal with the surface. Eighty percent of the petioles were leaning or were prostrate, nineteen days after treatment. Most of the leaves in the plot were prostrate after five and one-half weeks but there were new leaves which were coming through the surface. These continued to appear throughout the rest of the season.

A somewhat heavier application, twice the above, was applied on July 26 to a plot of pickerelweed. Two weeks later the leaves were brownish-streaked and were drooping. All the leaves were browned with no new leaves evident, three weeks after treatment. A regrowth began to appear in September and developed to such an extent by the end of the season that the plot became almost as overgrown as adjoining areas.

The following July 1, 1949, the ester of 2,4,5-T was applied to a plot of pickerelweed, <u>Pontederia cordata</u>, at the rate of 2.78 pounds per acre. Ten days later, the leaves were black-streaked but could not easily be pulled. New leaves protruded above the surface. The bases of the injured leaves did not have an odor or other sign of decay. Fifteen days after treatment, the old leaves were dry and shrivelled. A new growth was developing at this time.

At the rate of 2.78 pounds 2,4,5-T per acre, another application in an oil emulsion was applied July 1 at Lake Lansing. The sprayed leaves and petioles were browned and shrivelled, eleven days later. New leaves had appeared above the surface and both these and the injured ones pulled easily. There did not appear to be any oil or oily residue at the bases of the pulled petioles. The injured leaves were browned to the water level and, within sixteen days, the petioles pulled easily. The bases appeared normal except that a few had worm-like markings. Four weeks after treatment, about fifty percent of the pickerelweed leaves in the plot were green, the rest were dry and shrivelled. Some of the regrowth pulled easily but the basal portions were not decayed nor stained. By the first week in August, five weeks after treatment, regrowth was more abundant than at a previous examination and by the end of August the patch was as green as the untreated area.

A heavier application at the rate of four pounds 2,4,5-T per acre applied in an oil emulsion, was made July 12. This application showed much the same sequence of events as lighter applications, except that regrowth did not develop as rapidly.

On June 26, previous to the flowering of pickerelweed, the phenyl acetic acid-2,4-D formulation was applied at the rate of 2.65 pounds 2,4-D per acre. This area also contained some bulrush, Scirpus validus and water shield, Brasenia schreberi. Water shield leaves, two weeks later, were less numerous than in adjoining, untreated areas and they had what appeared to be small, brown-edged holes. Some leaves had the characteristic brown or blackish blotches which are commonly observed on other species as a result of 2,4-D applications. The bulrush leaves were light brown down to the water level and pulled easily. The regrowth, especially of pickerelweed, was such as to cause the plot again to be sprayed (July 1) at the same concentration. Two weeks later almost all the leaves of bulrush and pickerelweed were brown. The bulrush leaves were browned all the way down to the root and pulled easily. The bases of some of the leaves smelled of decay. Pontederia cordata leaves were shrivelled, the petioles pulled easily and very few new leaves appeared above the surface. Petioles of water shield were coiled and few leaves appeared at the surface. Beneath the surface, leaves could be seen in various stages of decay. Quite a few of the pickerelweed leaves had separated from the basal meristem and were floating on the surface, three weeks after the re-treatment.

Four weeks later, August 8, by actual count of several square-yard areas taken at random, there were but a third as many new leaves per square yard as there were dead pickerelweed leaves protruding above the surface. This did not include the petioles of pickerelweed and the thin leaves of bulrush which had separated from the base and were floating on the surface.

A later application was made July 8 at the rate of 2.65 pounds 2,4-D per acre when an area of Pontederia cordata was in flower. Two weeks later it was noticed that the bases of the petioles were soft and were decaying. The leaves pulled very easily and practically all of the leaves had lost their turgor. Three and one-half weeks later an examination showed that a considerable number of the leaves and attached petioles had separated and were floating at the surface. The remainder were completely browned and separated with but a slight pull. In another week more leaves had separated from the rootstock and were floating at the surface. A considerable number were decaying underneath the surface and there were no normal leaves in the center of the plot. The comparison between treated and un-treated plots is shown in Fig. 21. There were fifteen new leaves which had appeared in the square-rod plot, six weeks after treatment. The old, browned petioles could be observed beneath the clear surface. Eight and one-half weeks after treatment the center of the plot was free of leaves. Around the edge new leaves were present due to the crowding in of growth from outside the treated area.

<u>Nymphaea</u>

Early in this investigation, fairly low concentrations of the isopropyl ester of 2,4-D were used on white water lily, <u>Nymphaea odorata</u>. On July 26, 1948, the ester form was applied at the rate of 1.39 pounds per acre. Regrowth occurred a short time after wards. On August 6 twice this amount was applied using fuel oil at the rate of 80 gallons per acre as carrier. This was sprayed on white water lily and yellow water lily, <u>Nuphar advena</u>. Three days later, the petioles of both species were coiled and the leaves, which had been hit by the spray, were undergoing decay. In spite of this there was evidence of new growth from the rootstock. Two weeks later, the coiled petioles were beneath the surface and the old leaves were floating, inverted on the surface of the water or they were submerged. Although new leaves were opening above the surface, three weeks after treatment, the plot did not contain as many leaves as adjoining, untreated areas.

To see whether a high dosage would have a more permanent effect, an application was made, July 11, at the rate of 5.5 pounds 2,4-D per acre. Observations made shortly after spraying showed responses similar to other early observations of 2,4-D injury. In 18 days, the old leaves were decaying at or just below the surface. The plot looked more open and new leaves were not as much in evidence as in a similarly treated plot of __Nuphar__ __odorata__. The greatest effect appeared to be in the center of the plot where several rhizomes came almost to the surface of the water. Prior to spraying, this fact was not noted as the petioles supported the leaves above the surface to form a uniform canopy. After the leaves had been knocked down by the treatment, the proximity of the rhizomes to the surface was apparent and it was in the region of these rhizomes that the least amount of regrowth occurred.

At this stage of the investigation it appeared that, although high initial rates might be desired, repeated treatments seemed likely to be required. With this in mind a treatment at the rate of 3.48 pounds per acre, using fuel oil as carrier, was made July 8 (Fig. 23). Two days later the typical responses were very much in evidence. The contacted leaves were inverted on coiled petioles and they were decaying. Shortly afterward there were a dozen new leaves opening at the surface. Fifteen days after treatment, there were more new leaves opening at the surface. The old leaves were decaying under the surface and the petioles were coiled and brittle (Fig. 24). An additional application was made on August 17 using fuel oil and the same 2,4-D concentration. This appeared to be very effective since only a few green leaves appeared at the surface. The lateness of the season may have had a bearing on the regrowth.

Single, heavy applications at the rate of ten pounds 2,4-D per acre, were tried on small scale plots during June and July but regrowth developed in every case.

No apparent difference in effectiveness could be observed between the butyl ester and the isopropyl ester of 2,4-D when applied to __Nymphaea__ odorata.

The first application using the phenyl acetic acid-2,4-D formulation on white water lily was made June 26, 1950. This treatment was at the rate of 2.65 pounds 2,4-D per acre. Twelve days later, the leaves that had been hit with a sufficient amount of the spray, were decaying but new leaves were unfolding at the surface. It was then decided to spray again at the same rate. Ten days after this re-treatment, the plot appeared open and a considerable amount of algae had come to the surface. The difference between this and adjoining, untreated plots was quite distinct. However, two weeks after the second spraying, there were a considerable number of new leaves in the center of the plot. The old leaves, which had been present at the second spraying, were dead, brown and disintegrating. Within four weeks following the second application, the surface was a solid mat of algae in which were floating small, new leaves of Nymphaea odorata. Other leaves were unfolding below the mat.

Another solid mat of white water lily leaves were sprayed June 26 at the rate of 2.65 pounds 2,4-D per acre (Fig. 25). Effects from this application (Fig. 26) were similar to those of the other treatment. The surface, a month after treatment, again was covered with new leaves (Fig. 27). At this time the plot was sprayed at the rate of 7.15 pounds 2,4-D per acre. Ten days later the surface was conspicuous with dead and decaying leaves. Algae now covered the decayed leaves and blanketted the plot. The surface of the water outside the plot still had white water lily leaves tightly packed together with little or no algae visible. Only four, small leaves appeared in the center of the square-rod plot. The leaves from outside the plot were crowding in around the edges, but the center was clear. At the time of the last inspection, twenty-five days after re-treatment, algae covered the surface and there were about thirty small, new leaves in the plot (Fig. 28).

In order to observe the effects of a heavier initial application, a treatment was made, July 10 using the phenyl acetic acid-2,4-D formulation at the rate of 7.15 pounds 2,4-D per acre. Two weeks later, the treatment appeared to have been very effective. The old leaves were decaying at the surface and several new leaves were observed (Fig. 22). Three weeks later there were very few new leaves opening above the surface. The treatment appeared to be almost as satisfactory as those in which two applications had been used.

A light, late-season application at the rate of 3.71 pounds 2,4-D per acre, had the immediate effect of twisting the petioles and browning the leaves. One month after treatment, new leaves were opening at the surface and they continued to appear during the remainder of the season. Bulrushes in the center of the plot were dead and no regrowth was observed.

Nuphar

The general sequence of events following the application of the isopropyl ester of 2,4-D on spatterdock, Nuphar advena, was much like the effect caused by using any of the other 2,4-D compounds. If the leaves, prior to treatment, extended above the surface, they would almost invariably be turned upside down by twisting and growth of the petiole which arched above the surface. The leaves that were hit by the spray would slowly decay and new leaves would come from the rhizomes to replace the older ones at the surface. It is probable, although it was not definitely determined, that these leaves came from the same rhizomes which supported the injured leaves. With the tremendous size of the rhizome and amount of food stored within, this may well be the case.

On July 22, 1948, spatterdock was sprayed with an aqueous spray of the isopropyl ester of 2,4-D at the rate of two and one-half pounds per acre. A week later, the leaves which, previous to the application, had been projected above, were now prostrate on the surface. Two weeks after treatment, portions of some leaves showed signs of decay. Others were of a yellow to greenish color. From an examination five weeks after treatment, it was obvious that the regrowth would soon re-populate the surface.

Another application was made August 6 at the rate of three pounds 2,4-D per acre in an oil spray. This did not prevent young leaves, previously visible beneath the surface, from growing and unfolding above the surface by the end of the month. These appeared amid the coiled petioles of the decaying leaves which had been contacted by the oil spray. Although the plot appeared thin by the end of the season the following year the surface again became covered with leaves.

An application at the rate of five pounds 2,4-D per acre was made July 11, 1949, but even this concentration did not prevent the surface from becoming covered with new leaves by August 5.

In general, it appeared that the isopropyl ester of 2,4,5-T caused a reaction by the leaves of spatterdock similar to that caused by 2,4-D compounds. On July 27, 1948, the ester form was applied at the rate of 1.39 pounds 2,4,5-T per acre. After a few days the leaves and petioles showed the typical twisting reaction to the 2,4-D compounds. Five days after treatment green, developing leaves could be seen coming from the rhizome, although the surface was a mass of twisted leaves and petioles. Subsequent natural lowering of the lake level caused the new leaves to be projected above the surface. The regrowth continued to grow the remainder of the season.

Another application of the isopropyl ester at the rate of two pounds 2,4,5-T per acre made July 22 did not prevent regrowth from becoming established within three weeks of spraying. Applications made in August at three and four pounds 2,4,5-T per acre produced the typical twisting and curling of the contacted leaves but did not prevent the development of new leaves from the extensive rhizome.

No applications were made in 1949 or 1950 since the isopropyl ester of 2,4,5-T did not appear to have any advantages not possessed by 2,4-D.

An application of the phenyl acetic acid-2,4-D formulation at the rate of 6.89 pounds 2,4-D per acre, was made July 23, 1950 on spatterdock when the leaves were extended above the surface (Fig. 29). Within two weeks the usual 2,4-D symptoms appeared (Fig. 30). Shortly afterward regrowth from the rhizome began to appear above the surface of the water.

Mid-August applications of the phenyl acetic acid-2,4-D formulation at the rate of 3.18 and 3.71 pounds 2,4-D per acre, did not give satisfactory control.

Contact herbicides

Typha

On July 7, 1949, one pound of sodium pentachlorophenate pellets were dissolved in a gallon of water. This was applied on cattail, *Typha latifolia*, at the rate of 148.4 pounds per acre actual Na PCP. The solution sprayed out well and adhered satisfactorily to the upright and wax-coated leaves of the cattails which, by this time of year, were quite tall and had formed brown seed stalks. A month later, the leaves were browned but did not tend to lodge. An examination, five and one-half weeks after treatment, showed that the meristematic zone had not been injured and was continuing growth, pushing up the old, browned growth to give a tiered effect.

Another spraying on August 9 was made at the rate of 148.4 pounds per acre. Although the leaves of the cattails were browned within a short time after the application, the basal meristem was unaffected and continued growth.

The addition of fuel oil and sulfonated castor oil to a solution of the pellets which had been dissolved in water, did not appreciably increase the effectiveness of the salt when applied at the rate of 148.4 pounds per acre. There was considerable lodging, two weeks after application, but new shoots appeared from the rootstocks and the meristem continued growth.

On July 13, 1948, one pound of TCA in a gallon of water plus a commercial sticker-spreader (Triton B-1956) was applied on a square rod plot of cattails, Typha latifolia, and arrowhead, Sagittaria latifolia. This was at the rate of 112 pounds per acre. A week after treatment the leaves of the arrowhead were very light brown and dry. The margins were a darker brown. The cattails and sedges in the plot were light brown in color and, on superficial examination, the plants looked dead. Eighteen days after the treatment, the dried and shrivelled arrowhead leaves were conspicuous. Nevertheless new leaves were developing from the crowns. At this time the treatment appeared to have been successful on the cattails as the burned leaves were lodged and were very brittle. The plants did not show the regrowth from the meristematic regions that is so characteristic a response of this species to 2,4-D applications. The next year this plot was again populated with arrowhead plants but no cattails appeared except along one edge of the plot which adjoined a particularly vigorous stand.

A Hastings a plot sprayed July 8 with 112 pounds TCA per acre had developed considerable regrowth by the end of the summer.

On August 12, 1948, a dense plot of cattails was sprayed with TCA at the rate of 168 pounds per acre. Where the spray had contacted the leaves they became brown, but other areas contained green plants which continued to grow. Complete coverage is essential for killing as TCA does not appear to be a translocated herbicide.

At the rate of 224 pounds per acre, TCA was applied to cattail on August 19. The spray solution contained a wetting agent and was applied as an aqueous spray. In a few days the cattail leaves were light brown and several days later they appeared dry and began to lodge or fall over. At the end of the season, this plot had little regrowth. In June of the following year, control was still apparent since less than a dozen new plants had regrown in the plot.

A late season application was applied on August 25, 1948, at the rate of 112 pounds TCA per acre plus 2,4,5-T at the rate of 103.56 pounds per acre. A month later, in addition to the usual browning, the centers of the clumps, where regrowth first appears, showed no green color. The following season, while it was apparent that there had been a reduction in the stand, quite a few plants resumed growth. Control had not been as effective as where twice as heavy an application of TCA had been used.

On August 9, 1949, square-rod plots of cattails were sprayed with TCA using sulfonated castor oil as emulsifier. The applications were as follows:

Rate per acre (in pounds)	Carrier
27.6	water
27.6	fuel oil
55.2	fuel oil

Five days later, the leaves which had been hit by the aqueous spray, were browned but the remainder still had green portions. A few of the bases were stained brown and, when pulled apart, revealed brown areas within the tissue wheras normal plants were white. Two weeks after treatment the injured leaves were dry and had begun to lodge but the seed stalks of fruiting plants had not fallen over.

A month after treatment, the bases of some of the plants, when cut through, were white and turgid: others, which probably had received a heavier spray dosage, had a white center approximately the diameter of a lead pencil. Outside this center, the bases of the leaves were brown and apparently dead. At this time there were seven new shoots, one and one-half to two and one-half feet in height, which had come from underground rootstocks in the treated plot.

Five days after treatment, the leaves of most of the plants which had been treated at the high concentration were brown. The addition of fuel oil appeared to facilitate coverage; the oil aids in penetration of the leaf tissue. Many of the bases appeared to be soft, due to a loss of turgor of the outer leaf tissues. Two weeks after treatment the leaves were dry and most of them were broken and leaning. A month after treatment, there were eight new shoots which could be seen to come from underground rhizomes.

In the remaining plot, as in the one where fuel oil had been used, the leaves quickly took on a browned appearance. Two weeks after treatment they were dry and lodged but a few had green centers. Three weeks after treatment, there did not appear to be as many soft bases as in the plot where the higher rate of TCA was used. Many bases were turgid and appeared normal when cut through.

An aqueous application of TCA applied July 11, 1950, on cattails at the rate of 144 pounds per acre, whitened the foliage in a short time, but a month later there was evidence of new growth.

The first spraying with ammonium sulfamate was on June 23, 1948, at which time four plots of cattails were treated. These treatments coincided with the time the pollen was being shed. One plot was sprayed at the rate of 160 pounds per acre while an adjoining plot received ammonium sulfamate at the rate of 320 pounds per acre. A commercial wetting agent was added to the spray solutions.

Two days later the leaves, which had been wet by the spray, were mottled a light brown. No significant difference could be seen between the plots at this time. Ten days later the leaves, especially in the plot which had received the higher concentration, were browned almost to the ground level. Two weeks after treatment, no green was visible on the plants. Apparently the only living plants were several along the margin of the plot. An inspection, four weeks after treatment, showed regrowth in the plot which had received the lower concentration and regrowth was observed in the other plot ten days later. The regrowth was in the form of new basal shoots and this continued through the remainder of the season. Apparently the tops had been completely killed with the 320 pound application but the rootstock reserves were sufficient to provide for further vegetative growth.

The other two plots were each sprayed at the rate of 160 pounds per acre using a wetting agent. Although the treatments caused considerable discoloration of the plants and severely affected the understory of sedges and willows six weeks later regrowth was beginning to appear and by eight weeks, complete recovery was apparent.

A later application on cattails, July 1, at the same rate did not show any better control than earlier sprayings.

On July 7, 1948, a plot of cattails was sprayed with PCP at the rate of 80 pounds of parent phenol per acre, using kerosene as carrier. All plants in the plot turned completely brown overnight and, during the succeeding days, the leaves began to fall over as though beaten by a heavy rain. The plot made a sharp contrast with adjoining areas but a small amount of new growth was evident in the central region of each plant base. Growth continued and within two weeks the new shoots stood up above the dead and almost prostrate leaves.

A spraying of cattails and milkweed July 8 at the rate of 80 pounds of phenol per acre, had the same effect as earlier treatments on cattails. The milkweed leaves dropped within a week. Two weeks later, however, regrowth appeared from the apical portions of the milkweed stems and from the basal, meristematic regions of the cattails.

An application made July 28 at the rate of 17 pounds of phenol per acre on cattails, followed much the same pattern as earlier treatments except for a somewhat slower response.

A late-season application was made on August 25 using 17 pounds of phenol per acre in oil. A month after treatment, regrowth of cattails was small but this may have been due to the cessation of growth from natural causes. In the spring of the following year, the growth of the treated plots showed no difference from the growth of the untreated plots.

Cattails were sprayed August 9 at the rate of 17 pounds of phenol per acre using fuel oil emulsified with water and sulfonated castor oil. Five days later the usual browning was evident. After another five days the cattail leaves had further dried, they were quite white and there was considerable lodging. Two weeks after spraying, it was noticed that the bases of some of these whitened plants were soft and that new shoots were coming from the underground rhizomes. Further lodging was to be seen a month after treatment as well as a few new shoots which came from the meristematic regions of the old plants (those which had been hit by the spray). Observations up until the end of the season revealed an increase in the number of new shoots and thus indicated that control had not been satisfactory.

Another application at the rate of 17 pounds of phenol per acre in fuel oil was applied on cattails, August 21, 1949. A month later some plants were well bleached and lodged with little sign of regrowth. At first it was thought that the soft bases of the plants were due to an effect of the chemical, but it later appeared to be a normal occurrence at that time of the year as many of the plants from untreated areas had the same characteristic soft base. The following spring the plants in this plot grew and showed little or no difference in abundance from adjoining, untreated areas.

In June 1950 three square-rod plots of cattails were laid out by means of paths cut between them at the limits of the quadrats. To determine the density of the stand of cattails in the plot, counts of plants were made in square-yard areas at the corners of each plot, thus giving four counts for each plot or a total of 12 for the three plots.

On the day of the application, June 30, there was a slight wind therefore the applications were not made under the most ideal conditions. The material was applied with a Sure Shot Sprayer at rates of 8, 16 and 24 pounds of phenol per acre. Five days later it was obvious that the coverage had not been good as many of the plants remained the same while others in each plot were brown and were partly fallen over, typical reactions to treatment with this material. A month later there still appeared to be a greater amount of lodging in the plot which had received the greatest concentration than in the others. All, however, were exhibiting regrowth.

Five weeks after treatment it was obvious that the regrowth was not going to be affected by the original treatments. Final counts were therefore made. The number of dead and living plants were noted. A new shoot, one and one-half feet in height, was observed next to practically every one of the dead plants. Results of these counts, as well as those made previous to treatment, are included in Table XII.

TABLE XII

EFFECT OF A PCP IN OIL APPLICATION ON REDUCING STANDS OF CATTAILS

Rate per acre (in pounds)	Original plant population	Dead plants after treatment	Percent reduction	Regrowth
8.	22.0	2.2	10.0	4.2
16	20.0	7.0	35.0	8.0
24	17.0	4.5	26.5	4.5

The first application of ammonium thiocyanate at the rate of forty pounds per acre was made on cattails, July 8, 1949, at the Hastings Fish Hatchery. Fuel oil, emulsified in water with sulfonated castor oil, was used. A week after the application, the leaves smelled of oil and they were slightly browned. A month later, regrowth was well advanced. The use of water alone as carrier in a subsequent spraying schedule, at the same concentration, achieved less control than the fuel oil application.

Two additional plots of cattails were sprayed July 8 at the rate of 120 pounds per acre: water was used as a carrier in one and fuel oil in the other. A week later, the leaves in both plots were browned but more so in the plot where the oil had been used. The plants in this plot had the characteristic oily smell and feel. When the bases of several of the plants in each plot were cut, the centers were greenish-white, indicating an incomplete kill. Regrowth subsequently appeared in both plots less, however, in the oil-treated one. There was enough difference between this oil-treated plot and adjacent, untreated areas to warrant further applications with increased concentrations.

The last spraying for the year was made on August 8, 1949, at which time two adjoining plots of the narrow-leaved cattail, Typha angustifolia, were treated. They each received ammonium thiocyanate at the rate of 320 pounds per acre. One was applied as an oil spray at the rate of approximately ten gallons per acre; the other as an aqueous spray. Coverage was good in spite of the height of the cattails. A week later the plants in both plots had become whitened. Some of the leaves had begun to lodge and within a month the contrast between treated and untreated was great (Fig. 31). There was no sign of any regrowth from the centers. There were no new shoots except near the periphery where invasion may have been responsible.

Early the following spring it was clear that control had not been as successful as had been thought in the late fall. By June the plants were back in full growth so that no difference could be seen between these treated plots and the adjoining, untreated areas.

On June 23, 1950, the same plots, which had been sprayed August 8 of the previous year, were again sprayed. One received ammonium thiocyanate at the rate of 160 pounds per acre as an oil spray and the other received twice this amount as an aqueous spray. Even at this date, the narrow-leaved cattails were up to six feet in height. The weather was windy and poor coverage was obtained. Five days after treatment, the cattails in both plots had the upper third of their leaves whitened. After two weeks, the dark "tails" stood out in sharp contrast to the whitened tips. The bases were still green in both plots. This contrast remained distinct for the remainder of the month. On August 8, six and one-half weeks after the treatments, the green bases were continuing growth and were pushing up the whitened tops. This indicated that no permanent control was accomplished when applications were made at the rate of 320 pounds per acre.

On October 7, 1949, four square-rod plots of narrow-leaved cattail were staked out. One plot received alpha-hydroxy-beta-trichlorethyl sulfonic acid at the rate of 200 pounds per acre and a second plot received sodium pentachlorophenate at the rate of 320 pounds per acre. The other two plots received soluble sodium borate at the rate of 320 pounds per acre and the sulfonic acid compound at the rate of 200 pounds. These dry materials were distributed by hand over their respective plots as evenly as possible.

In the late spring of the following year it was apparent that all the plots, except the sodium pentachlorophenate-treated plot, had been affected. Fig. 32 clearly shows the effects in the sulfonic acid-treated plot.

Two of the plots which were adjoining, showed a striking contrast. Not a live cattail could be found in the center of the sulfonic acid-treated plot more than ten months after application of the herbicide. It is true that there were several which had invaded the area, coming in from the perimeter. The dead stubs bore witness to last years growth. The adjoining plot, which contained plants that had been treated with sodium pentachlorophenate, showed no control and the plants looked as uniform and normal as those in untreated areas.

Applications of alpha-hydroxy-beta-trichloroethyl sulfonic acid at the rate of 49 and 98 pounds per acre, when dissolved in water or oil and used as a foliage application, did not appear to be as effective as the dry application. Examination of these plots a month after spraying, revealed some injury in the form of dead outer leaves but the central leaves were still green. Even though the outer leaves were browned and dead, they remained upright and did not show the lodging which frequently occurred with PCP and TCA treatments.

<u>Sagittaria</u>

During the 1948 season, two applications of ammonium sulfamate were made on arrowhead, <u>Sagittaria latifolia</u>. The first was on June 24 using 160 pounds per acre. Twenty-four hours later there were burned areas between the veins of the leaves. Nine days later the leaves of three-fourths of the plants were dry, shrivelled and barely recognizable. Two weeks after treatment there was evidence of new leaves protruding above the ground surface at the base of the old, dead leaves. A week later, three weeks after treatment, an estimate was made that only one-half of the old plants had made regrowth. At the time of the last examination, early in August, regrowth had not developed sufficiently to cover the area. However, the following year, the area again grew up to arrowhead.

An application on arrowhead made later in the season, July 1, at the rate of 160 pounds of ammonium sulfamate per acre, did not show any better control than did the earlier spraying. A few plants of Pontederia cordata were also in the plot and showed, one week after treatment, much the same reaction as did Sagittaria latifolia. The leaves were browned and curved back on themselves, some almost touching the ground. It may have been that the spraying was not too uniform since approximately fifty percent of the leaves of arrowhead were completely browned and the remainder showed various degrees of browning. Three weeks after treatment, regrowth was observed from Pontederia cordata and from a plant of Nuphar advena which grew in the plot. Regrowth from Sagittaria latifolia did not appear to come rapidly but by the end of the summer there was enough to assure perpetuation of the stand.

On August 8 a square-rod plot of arrowhead was sprayed with fuel oil at the rate of forty gallons per acre. This proved to be a very effective treatment (Fig. 20), following much the same sequence of events, except for the twisting, as in another plot treated with 2,4-D. The use of fuel oil alone appeared to be effective in the control of arrowhead as there was only a small amount of regrowth the following year.

Ammonium thiocyanate at the rate of 160 pounds per acre was applied, August 8 on an area of arrowhead. The response of the plants in this plot differed from those in plots treated with 2,4-D. Six days after treatment, the leaves were whitened and shrivelled, although they remained upright. Two and one-half weeks after treatment, regrowth was appearing from the bases of the injured leaves. A month after treatment, the plants appeared normal and were approaching the density of untreated areas.

Pontederia

An application of sodium pentachlorophenate pellets dissolved in water, was made on pickerelweed, *Pontederia cordata*, August 5 at the rate 148.4 pounds per acre actual Na PCP. Ten days later, the leaves were dark and appeared wilted. A few new leaves were projected above the surface. Two and one-half weeks later, many of the petioles had fallen and were prostrate on the surface of the water. An examination was made six weeks after treatment and this showed that an apparently satisfactory kill had been obtained. In the square-rod plot, only 18 new leaves extended above the surface. The following year, however, this plot produced abundant growth of pickerelweed and by mid-summer, no demarcation existed between treated and untreated areas.

When pickerelweed was sprayed with PCP in oil, it was usually only a matter of hours until the leaves would be browned to a chocolate color. Within a week after treatment, at rates of from 16 to 50 pounds of phenol per acre, regrowth would be evident and two weeks later regrowth would be well advanced.

A spraying of pickerelweed with ammonium thiocyanate at the rate of 160 pounds per acre, did not show any permanent control.

Nymphaea

On July 12, 1948, a square-rod patch of white water lily, *Nymphaea odorata*, was sprayed with PCP in oil at the rate of one-half pound phenol per acre. Twenty-four hours later, about 40 percent of the leaves had rolled margins. Two weeks after treatment, new leaves and flowers had appeared and were covering the browned and curled ones. These were sprayed with the isopropyl ester of 2,4-D at the rate of 1.39 pounds per acre, using the aqueous spray. These new leaves were rolled within a few hours. On July 31, five days after the plot was re-sprayed, the margins of the leaves were still rolled, the petioles were twisted and many leaves were beneath the surface and in the process of decay. None were floating in a normal position. A week after spraying with the translocated herbicide, the twisted petioles were very conspicuous against a background of decaying leaves. At this time several new leaves were protruding and opening above the surface, but those which had been hit by the spray were upside down, submerged and disintegrating.

On August 6, eleven days after re-spraying, the regrowth in the plot was sparse, about six new leaves were unfolded above the surface, the remainder were upside down and the petioles were coiled. Three weeks after re-spraying, algae covered most of the surface. The algae probably blanketted the water surface and so discouraged further regrowth. On September 8 the plot stood out in sharp contrast to adjacent, untreated areas which had no algae but were covered with the leaves of the white water lily.

An application at the rate of eight pounds of phenol per acre, applied July 10 did not seriously retard the growth of *Nymphaea odorata*.

Nuphar

During the summer of 1948 several sprayings of spatterdock, Nuphar advena, were made with ammonium sulfamate. In all cases the results were identical. The leaves, which protruded or floated on the surface, were killed when covered with the spray. This did not interfere with growth from the rootstock and eventual re-population of the surface.

On June 23 an application using 128 pounds per acre was applied to spatterdock. At this time most of the leaves were supported above the surface of the water. Twenty-four hours later, many of the leaves were curled to the midrib, as one would roll a scroll and some were mottled with brown spots. Forty-eight hours after treatment, some of the leaves were almost completely browned, others had just the centers green with a brown periphery. These latter leaves remained erect and protruding above the surface during the remainder of the summer. Those which were completely browned, probably half of the total, soon decayed at, or just below, the surface. Eighteen days after treatment regrowth was evident in the form of new leaves breaking through and opening above the surface film.

On June 25 a square-rod plot of Nuphar advena was sprayed at the rate of 128 pounds per acre. By July 3 fully half of the leaves were dead and submerged, the rest were partially browned with some portions dry and disintegrating. A few, approximately twelve, were large and green. These probably had received none of the spray since the plot was dense and complete coverage was not obtained. Eighteen days after treatment, the green centers of the leaves which had been slightly covered with spray solution, were still conspicuously protruding above the surface.

Four and one-half weeks after treatment regrowth had progressed to such an extent that it was decided to see what effect the application of a phenoxyacetic acid derivative would have on this new growth. Accordingly, this plot was sprayed with 2,4,5-T at the rate of 1.39 pounds per acre. Three days later, the petioles and leaves were twisted similar to that of Nymphaea odorata leaves which had been sprayed a day earlier with a similar amount of the isopropyl ester of 2,4-D. On August 2 new leaves were to be seen coming from the rootstocks, although at the surface there was still a mass of twisted leaves and petioles. The lake level was down at the time of the next examination and injured leaves were projected above the surface. Continued new growth was observed during August. The old leaves either were projected above the surface or were decaying beneath it. New leaves continued to appear during the remainder of the season.

Spatterdock, Nuphar advena, was not seriously affected by sprayings of PCP up to forty pounds of phenol per acre. Within a few hours of spraying, the leaves were browned to a chocolate color and regrowth appeared a short while afterward. Although the leaves were killed which were contacted by the spray, the application did not prevent new leaves from soon replacing the dead ones.

DISCUSSION

Nigrosine

As a result of laboratory work, it was determined that a chemical change was responsible for the disappearance of the dye in Loon Lake. The dye formed an insoluble compound with salts in the water and thus was precipitated. In the laboratory this precipitate could be observed on the leaves and on the sides or bottom of test jars. It was not found possible to put this precipitated dye back into solution.

Variously formulated dye samples were obtained. Some of these formed true solutions or colloidal suspensions while others were insoluble in water. Solutions or suspensions, however, of all of these were cleared in jar tests by Anacharis canadensis plants. Sometimes clearing took place in jars where there were no plants.

On the basis of observations at pond No. 8, Hastings Fish Hatchery, where nigrosine was used, it was shown that a decrease of oxygen and a corresponding increase of carbon dioxide followed applications of the dye. Neither Eicher (7) nor Surber and Everhart (20) included observations on the oxygen-carbon dioxide ratio following nigrosine treatments, although the odor of putrefaction, as indicated by Surber and Everhart, very likely denoted a low oxygen condition.

To be effective in controlling submerged plants it would appear that sufficient nigrosine dye must be added to the water to prevent light from reaching the plants. When the plants are almost to the surface, more dye will be required to exclude the light from them than if they were not so near the surface. It is not easy to maintain this high concentration in view of the field and laboratory experiences.

In the concentration of dye were maintained by repeated additions for a sufficiently long period of time, it is very likely that submerged plants would die. Decay of this plant material would lead to a low oxygen- high carbon dioxide condition in the water. If it persisted for any considerable period of time, it is quite likely that this condition would be detrimental to animal life.

CHLORINATED BENZENES AND XYLENE

When balanced mixtures of chlorinated benzenes and xylene were first used, the type of water appeared to be a factor in the stability of emulsions. When this was shown to be the case (Table VIII) only lake water was utilized in determining the choice of emulsifier. Table VII is an evaluation of a number of emulsifiers when tested with balanced mixtures using Lake Lansing water. Those indicated gave satisfactory results. Table V shows that when a non-ionic emulsifier is used, temperature of the water, is not an important factor in the settling out of balanced mixtures. The influence of the amount of emulsifier on settling is shown in Table VI. With balanced mixtures nothing is gained by adding more than just the minimum amount required since there is not the strong tendency of the mixture to either rise or fall, as is the case when the materials are utilized separately.

Several attempts to show differences in effectiveness between balanced mixtures of orthodichlorobenzene-xylene and trichlorobenzene-xylene did not give conclusive evidence of the superiority of one over the other.

Where weed beds were dense, it was soon apparent that the emulsions of balanced mixtures would not readily penetrate more than a few inches. Increasing the rate of application did not increase penetration. Mixtures which were made heavier than balanced mixtures for example by changing the ratio from 3:1 to 2:1, did not penetrate significantly further than did the balanced mixtures. The interference with the distribution of the sprayed mixture by weeds is apparent from an examination of the results with applications of balanced mixtures. This was especially noticeable when a somewhat open growth of Chara in shallow water was successfully controlled by spraying at low rates. Similar rates only killed the upper few inches of a dense Chara mat growing in deeper water. The inability of the emulsion to penetrate a mat of Chara, should not be attributed to a breaking of the emulsion due to temperature changes (Table V).

On species other than Chara, higher rates appeared to be a necessity. A tall but somewhat open (not dense) growth of Anacharis canadensis was successfully controlled by an application at the rate of 1?7 gallons per acre but with a mixture containing comparatively more trichlorbenzene to make the misture heavy. Potamogeton amplifolius was very resistant to treatment with the balanced mixtures and repeated trials with high concentrations did not give satisfactory control.

From the results, there is some indication that better control can be obtained when applications are made early in the season.

Control could be obtained early in the season with lower rates than were required for control later in the season.

It would be highly desirable to investigate other balanced mixtures than orthodichlorobenzene-xylene or trichlorbenzene-xylene as with this method it is possible to utilize materials which, because of of their weight, would be unsuitable if used alone or they would require too large an amount of emulsifier.

2,4-D PELLETS

Although a considerable number of treatments were made on aquatic plants with various phenoxyacetic acid derivatives as fall or winter applications and at rates considered to be reasonable, none could be considered as being effective. It can be seen from the results of jar tests (Table X) that in several instances, identical treatments did not give identical results. Differences in effectiveness between the materials are indicated. The sodium salt of PCP and a combination of this compound with 2,4-D are more effective herbicides than are 2,4-D or 2,4,5-T. Derivatives or 2,4-D and of 2,4,5-T, when they were effective, required a longer period of time than did the PCP compounds which have a more rapid, toxic action.

When the rates in field trials were increased, this difference in effectiveness was observed. It would appear, therefore, that the application of 2,4-D and 2,4,5-T pellets, as formulated, would not be an effective nor an economical means of controlling the weed species indicated. The use of PCP in various formulations, gives more promise of usefulness in this method of aquatic plant control than does any derivative of phenoxyacetic acid.

Translocated Herbicides

Typha

Although cattails are resistant to 2,4-D, some degree of control can be obtained by repeated foliage treatments. The results are better when these are made using oil sprays rather than aqueous sprays.

Single applications of 2,4-D at high concentrations, did not give the desired control. Treatments of five pounds 2,4-D per acre almost invariably caused the cattail leaves to become brown, to dry, to lodge and to create the impression of a favorable control. Although a number of the plants would be apparently dead as a result of the treatment, in practically all cases, by early fall there were signs of regrowth from the rootstocks. If no regrowth appeared by the end of the season without exception it did appear the following year.

Best results were obtained when an initial application of at least three pounds per acre was made in June, before the pollen was shed. The next application, at the same concentration, was made six weeks later when regrowth was established. In spite of these two applications totaling six or more pounds of 2,4-D per acre, there was evidence of regrowth from the rhizomes by the end of the season.

As a result of a comparison of the acid, the ester and the amine salt of 2,4-D, it does not appear that any of them is outstandingly superior over any of the others.

Sagittaria

Arrowhead, **Sagittaria latifolia**, appears to be more readily controlled with applications of the translocated herbicides than any other species tested. This does not mean, however, that all applications gave the desired control. Of the treatments made, best results were obtained with mid-July to early-August applications at the three pound rate. Complete control was not obtained in all cases but better results were obtained with 2,4-D than with 2,4,5-T.

Pontederia

Pickerelweed, Pontederia cordata, is not as sensitive to 2,4-D as is arrowhead, **Sagittaria latifolia**, but it does respond favorably to applications. Three pounds per acre of either the ester or the phenyl acetic acid formulation gave good results.

When light applications of 2,4-D were applied to pickerelweed, the bases of some of the petioles in the plot would soften and separate, causing the petioles to become detached and to float at the surface. A greater number would be caused to separate when spraying coincided with the beginning of the flowering period. July sprayings more nearly coincided with the flowering period at which time food reserves are low. Regrowth is more likely to occur following June sprayings because reserves are still relatively abundant in the root system.

Nymphaea

Nymphaea odorata has a large rootstock and is resistant to treatments with translocated herbicides. An application causing maximum shock, applied when reserves are lowest, would allow a minimum amount of regrowth.

Single applications with either the isopropyl ester at rates up to ten pounds per acre, or the phenyl acetic acid-2,4-D formulation at rates up to three pounds per acre, generally did not give satisfactory control. When the petioles were short and where the rhizome approached the surface, the isopropyl ester of 2,4-D was very effective at the rate of 5.5 pounds per acre. This would suggest the advisability of dropping the water level, if this were possible, and then spraying the exposed plants. A single spraying made July 10 with the phenyl acetic acid-2,4-D formulation at 7.15 pounds 2,4-D per acre, twice the recommended dosage, was very successful.

Two applications of the phenyl acetic acid-2,4-D formulation at 2.65 pounds per acre, were very effective on Nymphaea odorata when the first was applied in late June and the second in late July. A slightly greater control was obtained by using one application of 2.65 pounds and a second at 7.15 pounds per acre at an interval of a month. Two applications of the isopropyl ester of 2,4-D at rates of 3.48 pounds, applied July 8 and again on August 17 when regrowth became established, gave satisfactory control for the season.

Nymphar

No great success was achieved in the control of spatterdock, Nuphar advena, with any of the 2,4-D or 2,4,5-T formulations used. All plants that apparently had been severely affected, later developed regrowth.

Control by a single application seems unlikely to be secured with this species in view of the tremendous size of the rootstock and the food stored therein. When compared to the white water lily, spatterdock appears to be more resistant to 2,4-D.

The phenyl acetic acid-2,4-D formulation did not appear to be superior to the readily available commercial formulations of 2,4-D. Even at the rate of 6.89 pounds 2,4-D per acre, control was not obtained with the phenyl acetic acid-2,4-D compound.

Contact Herbicides

Typha

Contact herbicides, in general, did not prove effective on cattails. When rates of TCA, PCP, ammonium thiocyanate, or ammonium sulfamate were sufficiently high, the applications were very effective in killing the leaves. Occasionally more than just the leaves were affected but in practically every case, growth from the rhizome continued the following spring. The use of fuel oil as carrier for these compounds did facilitate coverage but did not materially affect the end result at the concentrations used. Addition of a small amount of spreader-sticker appeared beneficial in some applications. The cost of treatment with the contact herbicides is considerably greater than that with translocated herbicides.

When a treated area was surrounded with untreated plants, new shoots often developed in the treated area because of invasion. Complete coverage, therefore, is required in an attempt to control cattails.

The ease of application and apparent effectiveness of alpha-hydroxy-beta-trichloroethyl sulfonic acid warrants the further study of this material for the control of cattails. Soluble sodium borate may well also be included in further study.

Sagittaria

Apparent kill of sprayed leaves of arrowhead, Sagittaria latifolia, was achieved when ammonium sulfamate and ammonium thiocyanate were applied at the rate of 160 pounds per acre. Regrowth, however, occurred from the bases of the affected leaves. Higher rates did not give the desired control.

On the basis of the success obtained with one experimental spraying of arrowhead using fuel oil, further study of this material is warranted.

Pontederia

No applications of PCP or ammonium thiocyanate gave satisfactory control of pickerelweed. The leaves were seriously affected but the bases of the petioles did not soften or separate. Even at the time of maximum growth, there apparently is sufficient energy left to enable new leaves to reach the surface.

In view of the comparative economy and good results which were obtained by the use of translocated herbicides on this species, the use of contact sprays is not recommended.

Nymphaea

The control of white water lily, Nymphaea odorata, by contact herbicides does not appear to be as satisfactory as does control with translocated herbicides. An application of PCP followed, two weeks later, by an application of 2,4-D gave an appearance of good control.

Nuphar

The large and extensive root system makes it difficult to effect control of *Nuphar advena* with either contact or translocated herbicides. Ammonium sulfamate and PCP were effective in killing leaves contacted by the spray, but they were not effective in preventing regrowth in treated areas.

SUMMARY

1. The use of nigrosine dye for the control of submerged aquatic plants was not satisfactory. Apparently salts in the water react with the dye to form insoluble precipitates and thus the dye is removed from solution. In a hatchery pond of .75 acres, although the dye was not present in sufficient quantity to control weeds, the dissolved oxygen content of the water, two and one-half to three feet below the surface, dropped to a low level wheras the carbon dioxide content increased. This is not considered to be a healthy condition and thus the use of nigrosine dye is not recommended for the control of aquatic plants in hatchery ponds.

2. Balanced mixtures of orthodichlorobenzene-xylene and trichlorbenzene-xylene were found to be effective in the control of submerged weeds. The emulsified, balanced mixture remains longer in contact with the submerged plants than do either of the components.

Smaller quantities of the mixture are required for the control of Chara than for other weeds. Applications made early in the season give promise of better control than those made later. Potamogeton angulifolius appears to be particularly resistant to the balanced mixtures.

3. The use of 2,4-D and 2,4,5-T compounded into pellets, did not appear to be a satisfactory means of controlling submerged weeds. Quantities of 2,4-D-PCP pellets required to be effective were considered to be too high in cost from a practical point of view.

The application of dry herbicides on the bottom of a drained pond did not give satisfactory control.

Best results from the use of translocated herbicides occurred when applications coincided with the period of flowering. Applications at the rate of three pounds 2,4-D per acre at this time gave good control of pickerelweed, Pontederia cordata. White water lily, Nymphaea odorata, required an additional treatment a month later. Cattail, Typha latifolia, was not satisfactorily controlled by two spray applications. Arrowhead, Sagittaria latifolia, was the most sensitive to applications of the translocated herbicides.

5. The large quantity of food reserves in the rootstocks of aquatic plants makes them difficult to control by spray applications of contact herbicides. Even at flowering, reserves are sufficient to provide for regrowth when the tops are killed with contact herbicides.

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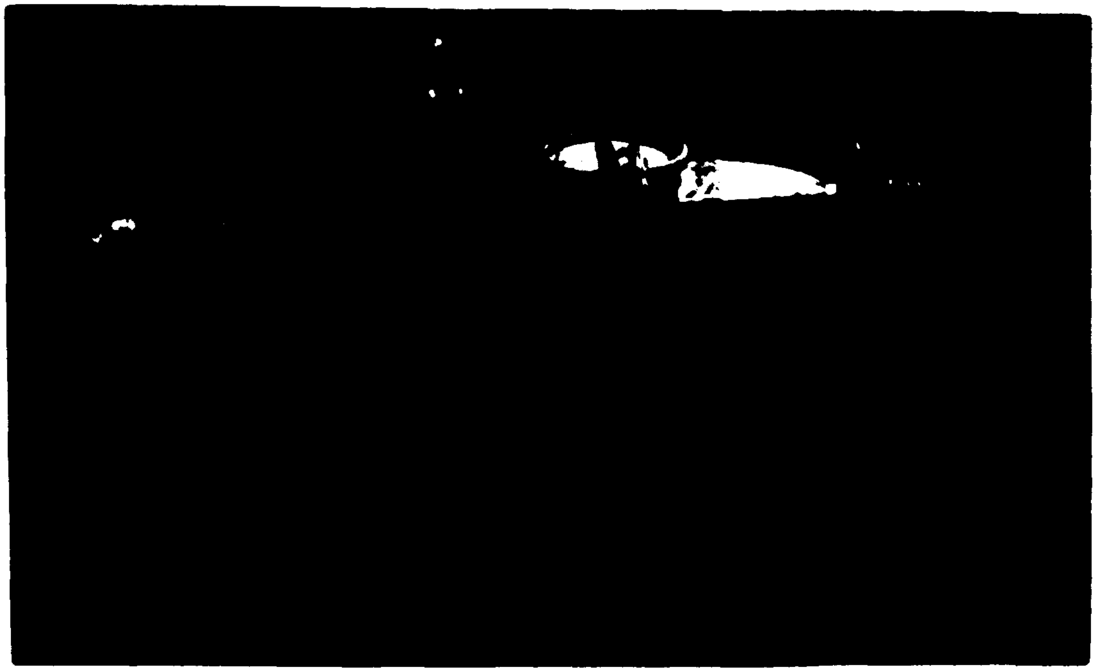


Fig. 1. Knapsack sprayer

Fig. 2. Sprayers before and after modification

Fig. 3. Equipment for spraying small experimental plots.

Fig. 4. Appearance of emulsion shortly after spraying.

Fig. 5. The arrangement of spray apparatus and solution tank

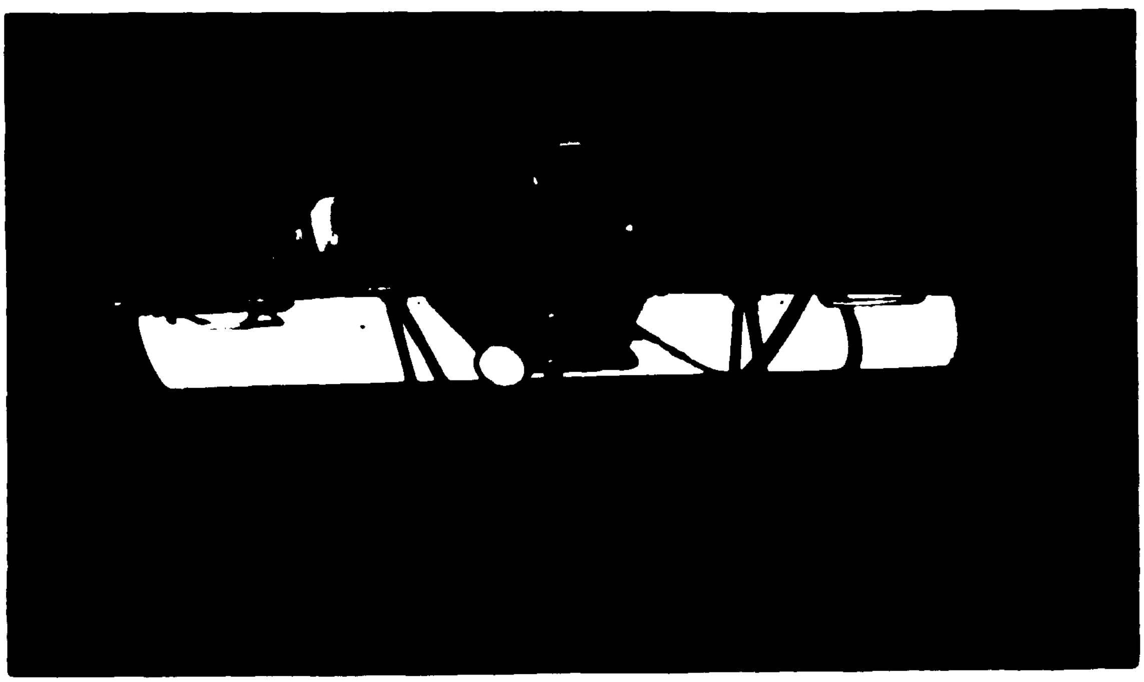


Fig. 6. Boom attachment to stern of boat

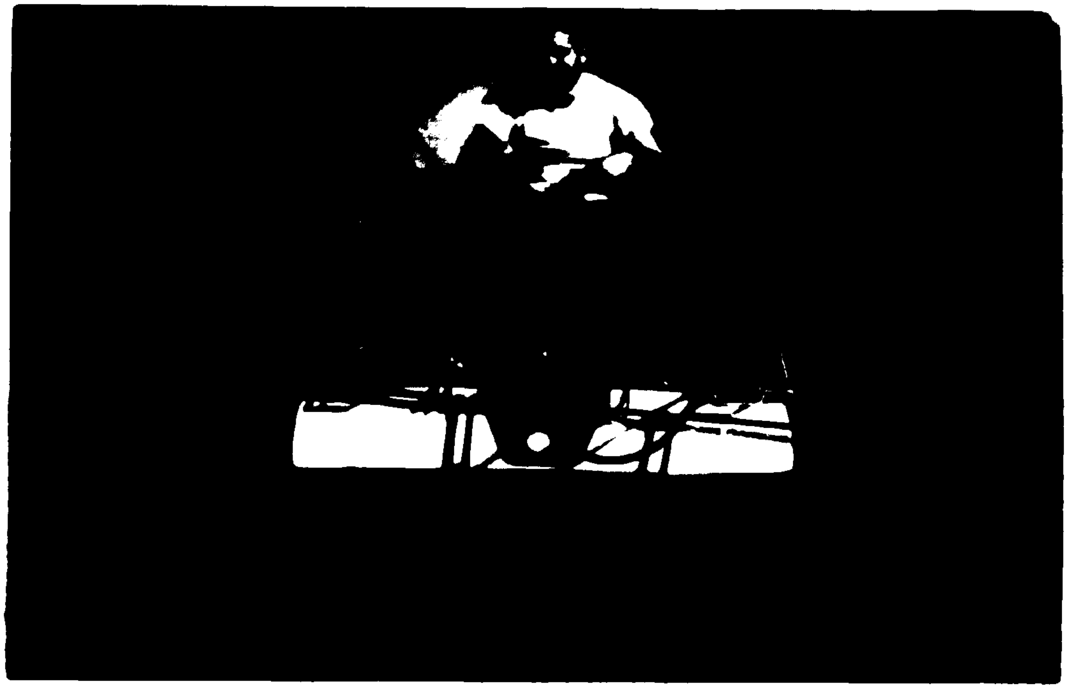


Fig. 7. One-man operation of spray rig

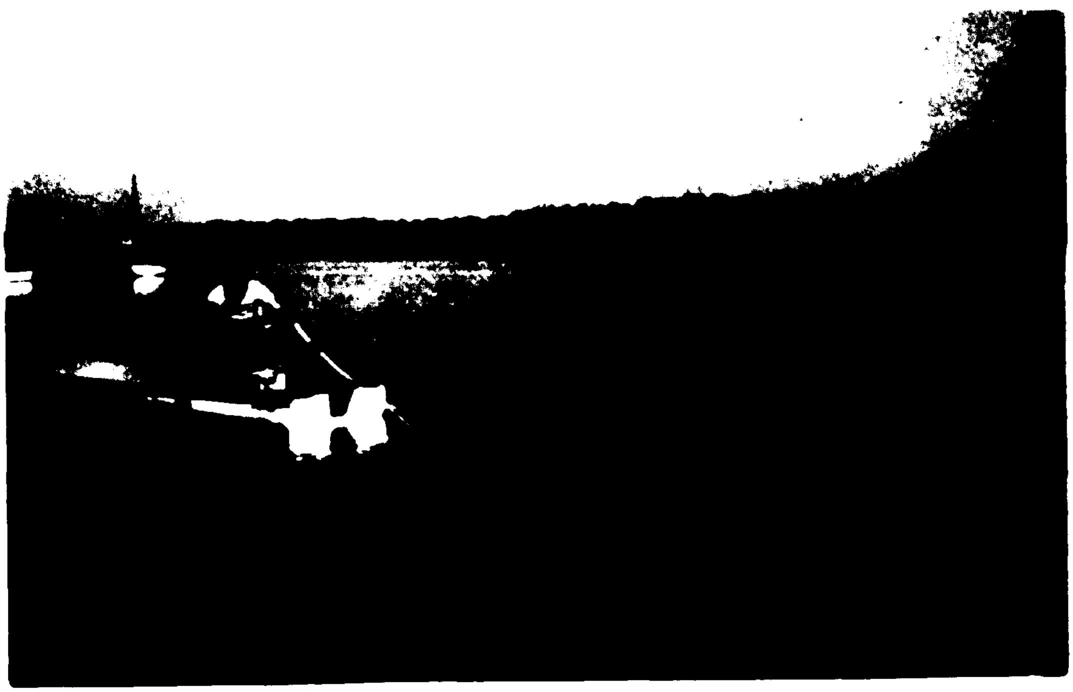


Fig. 8. Method of laying out plot boundaries

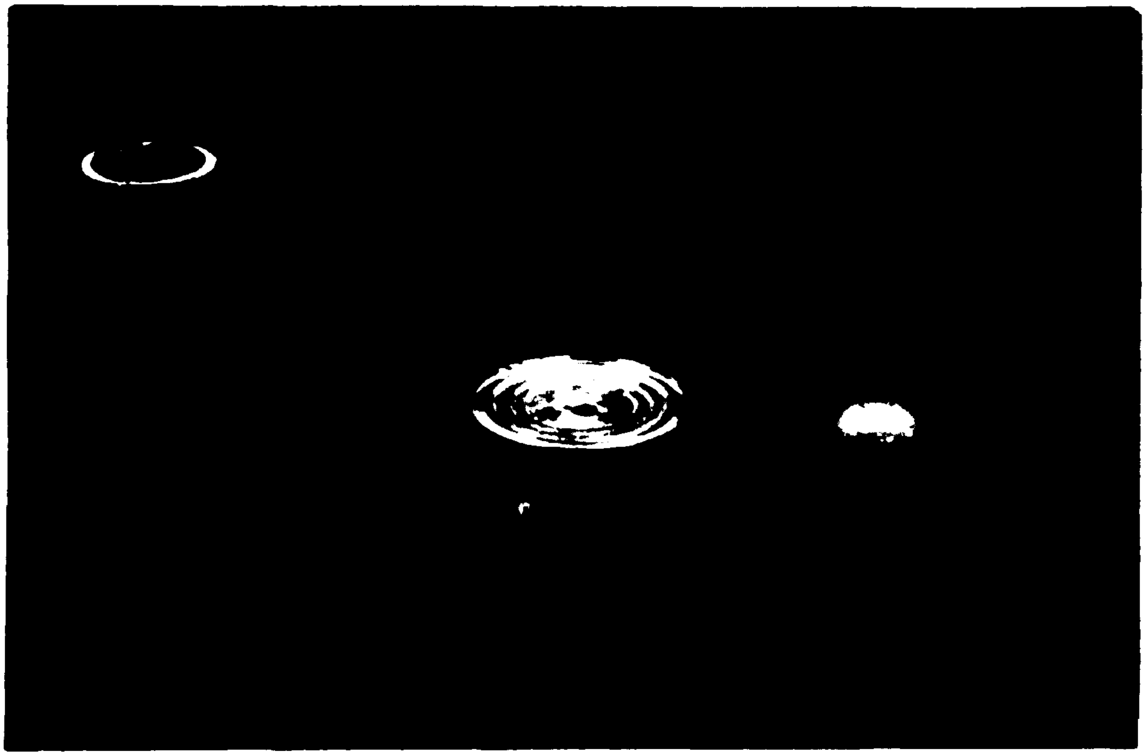


Fig. 9. Components of home-made turbidimeter

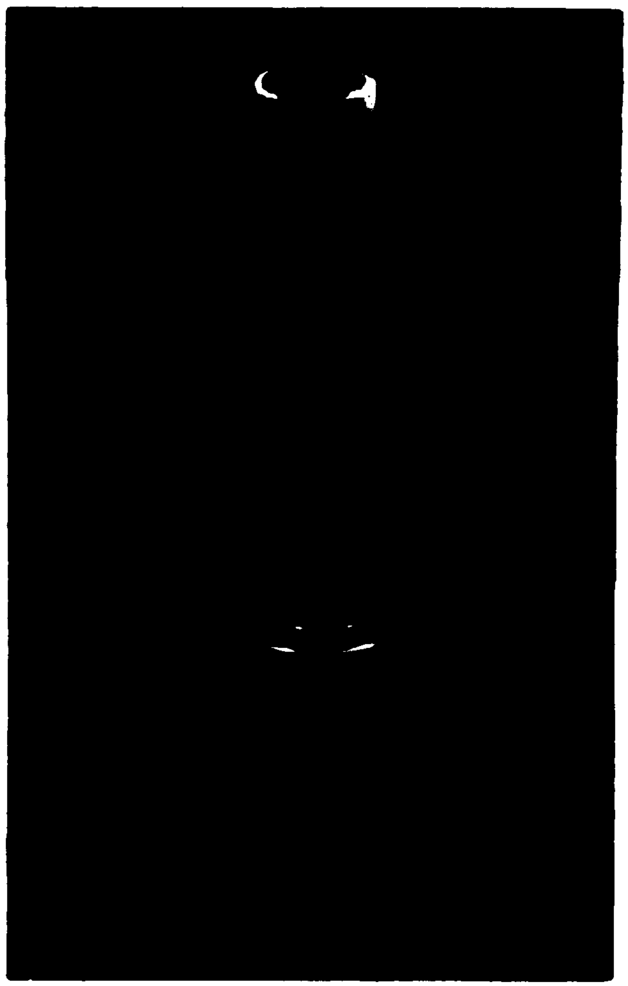


Fig. 10. Home-made turbidimeter (assembled)

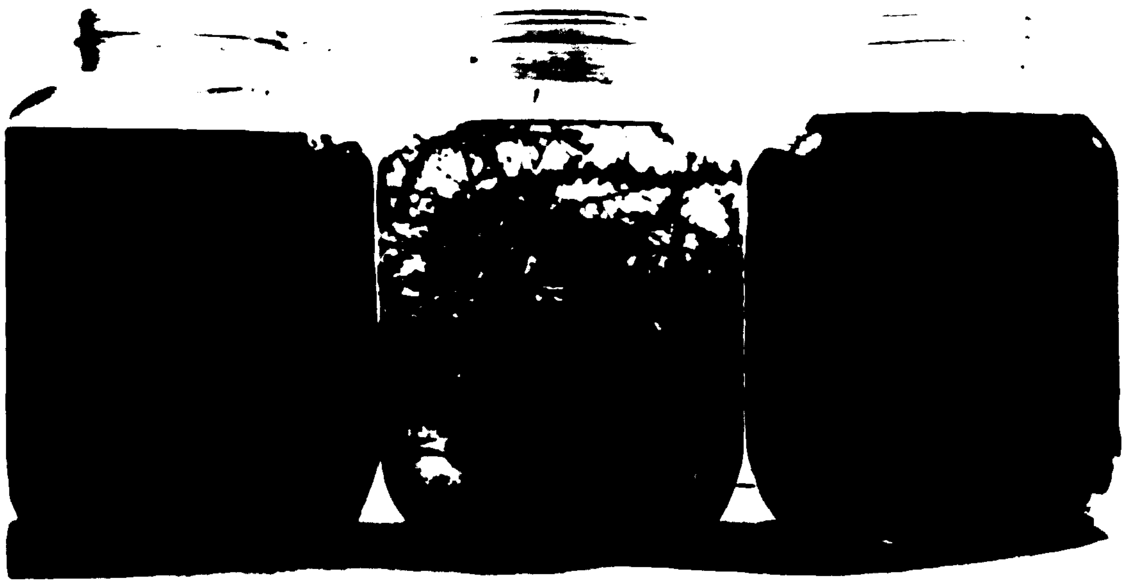


Fig. 11. Clearing of dye solution. All jars had originally the same concentration of dye but the two at the left were set up eight weeks before the one at the right. The jar at left showed practically no clearing when compared to the one at right which also did not contain plants and which was set up on the day the photograph was taken.

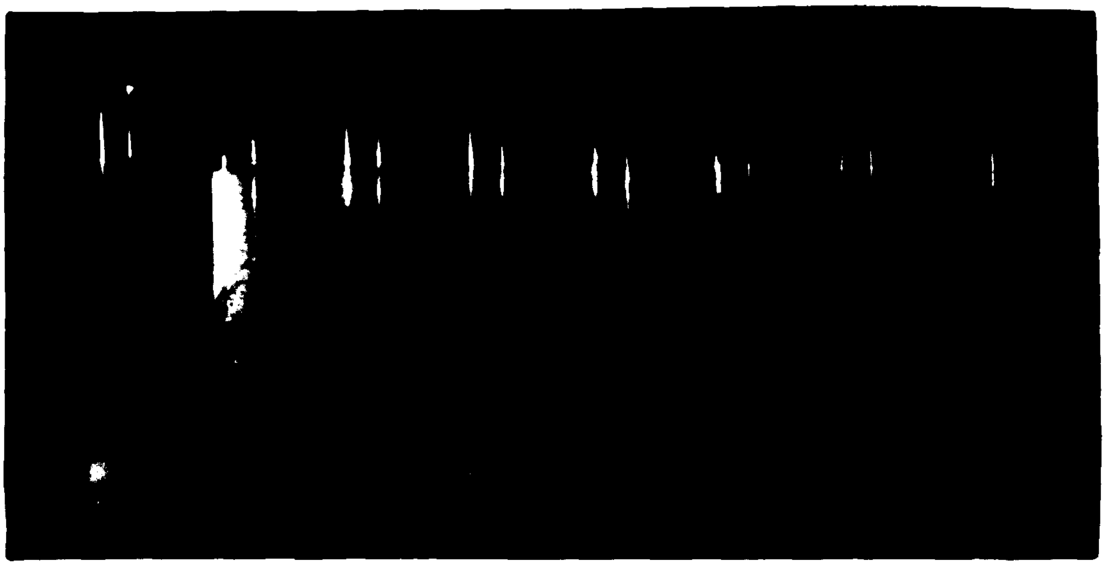


Fig. 12. The effects of different emulsifiers on balanced mixtures of xylene-trichlorbenzene.

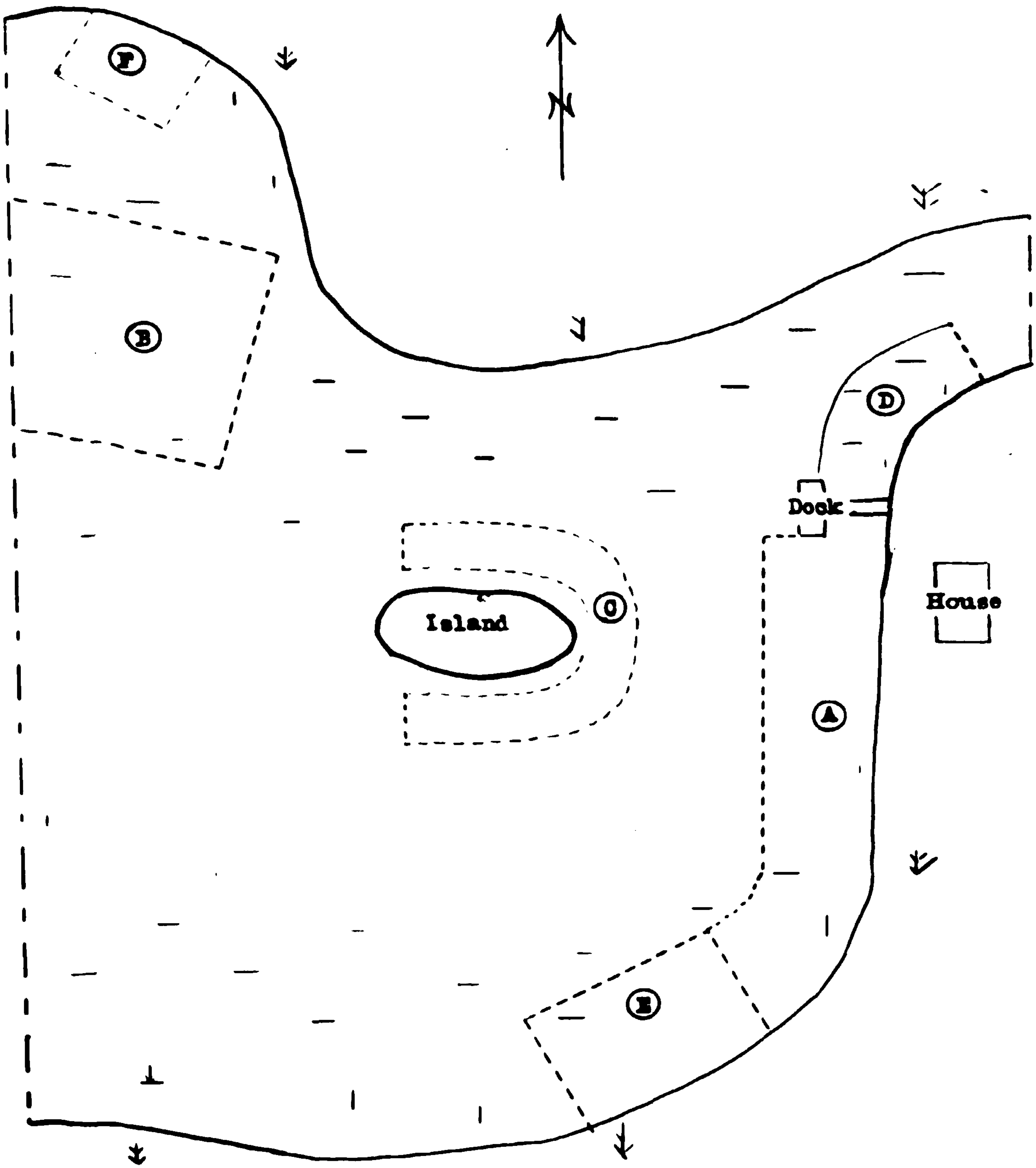
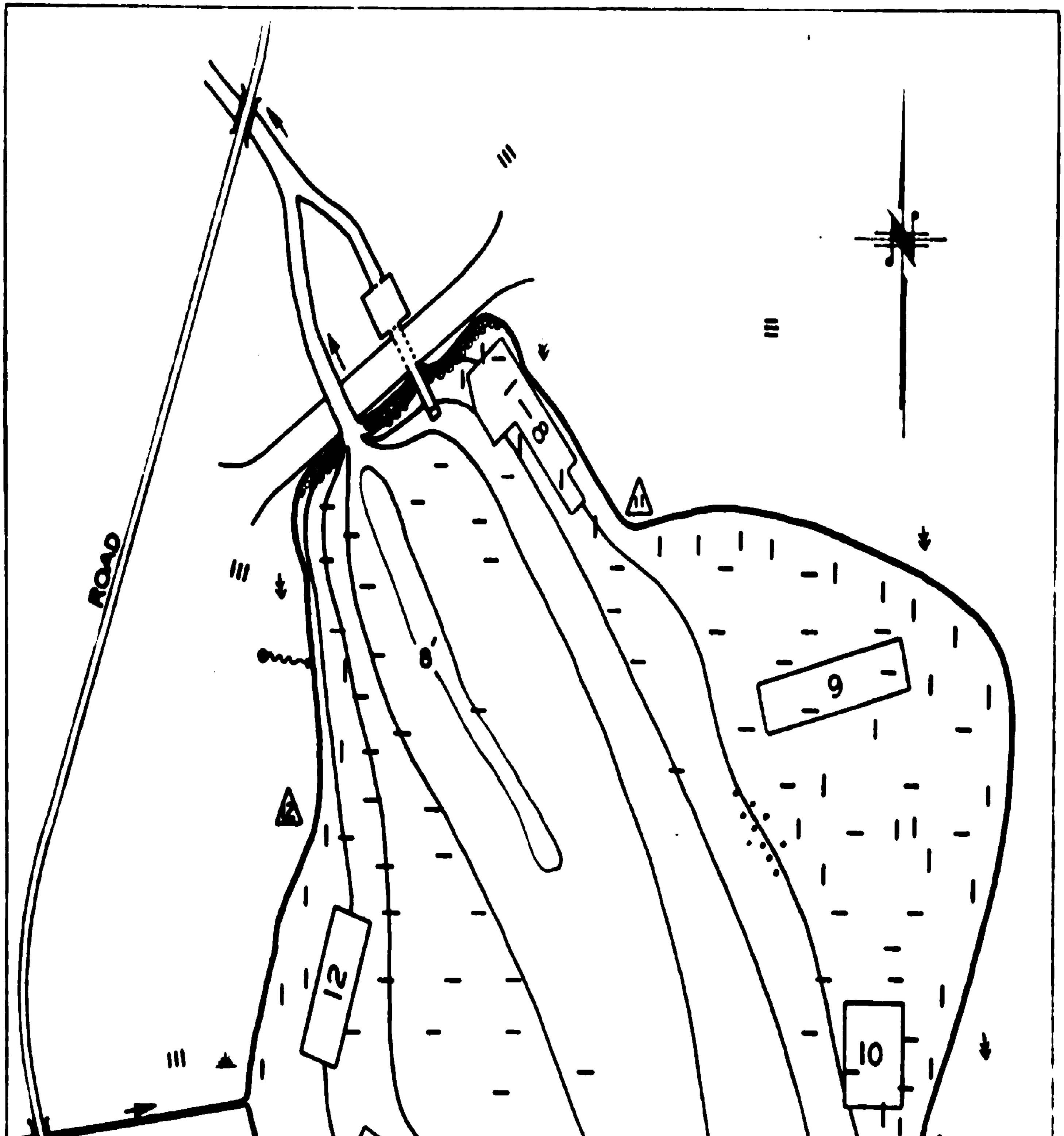


Fig. 13. Location of treatment areas at East Mill Pond

Fig. 14. Appearance of *Chara* shortly after spraying with balanced mixture of xylene-trichlorobenzene.

Fig. 15. Terminal six-inch portion of *Chara* killed by balanced mixture; basal portion not affected.



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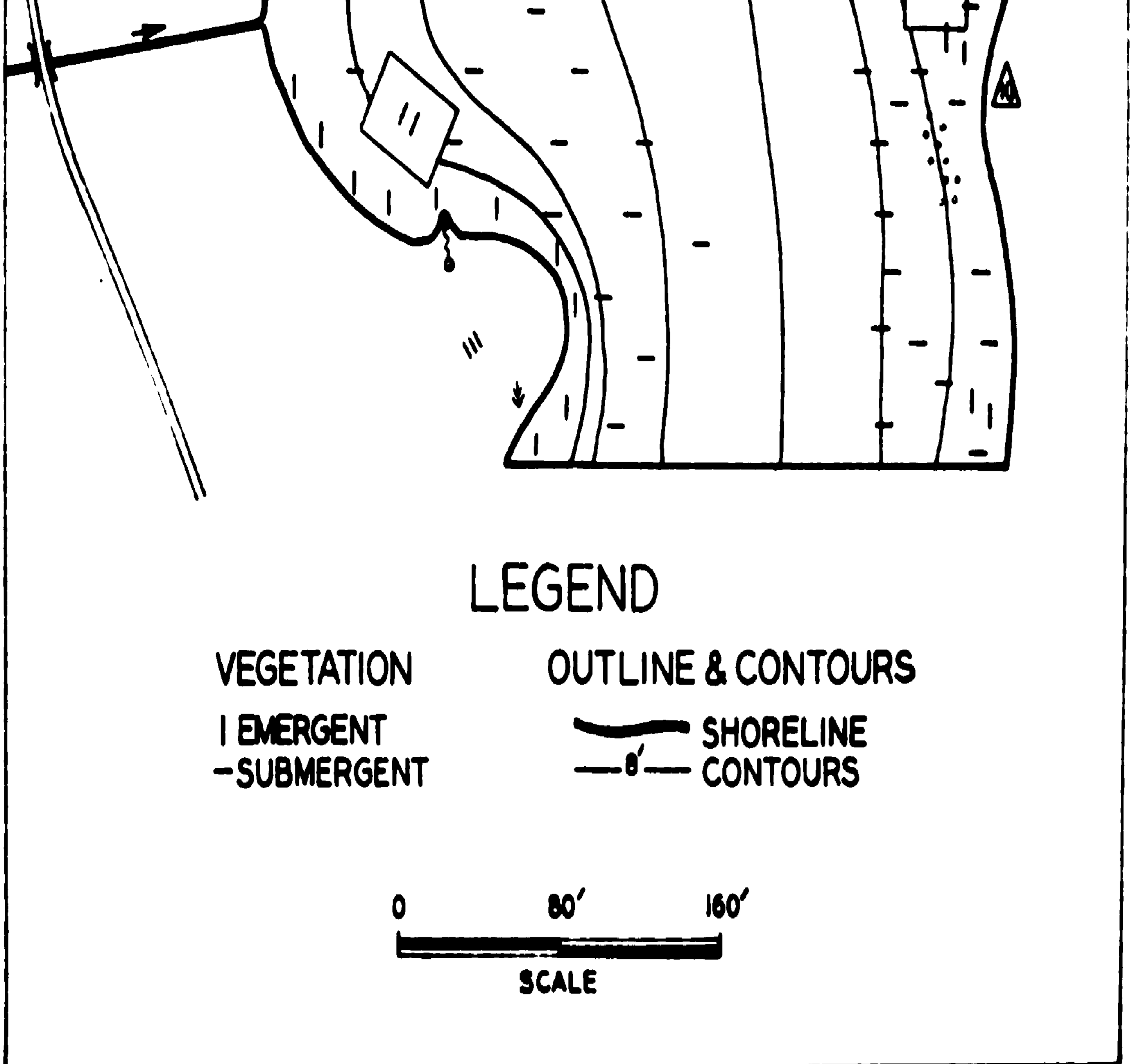

FIG. 16 LOCATION OF PLOTS IN PORTAGE CREEK POND
JACKSON COUNTY T.2S.,R.2E.,SEC.8

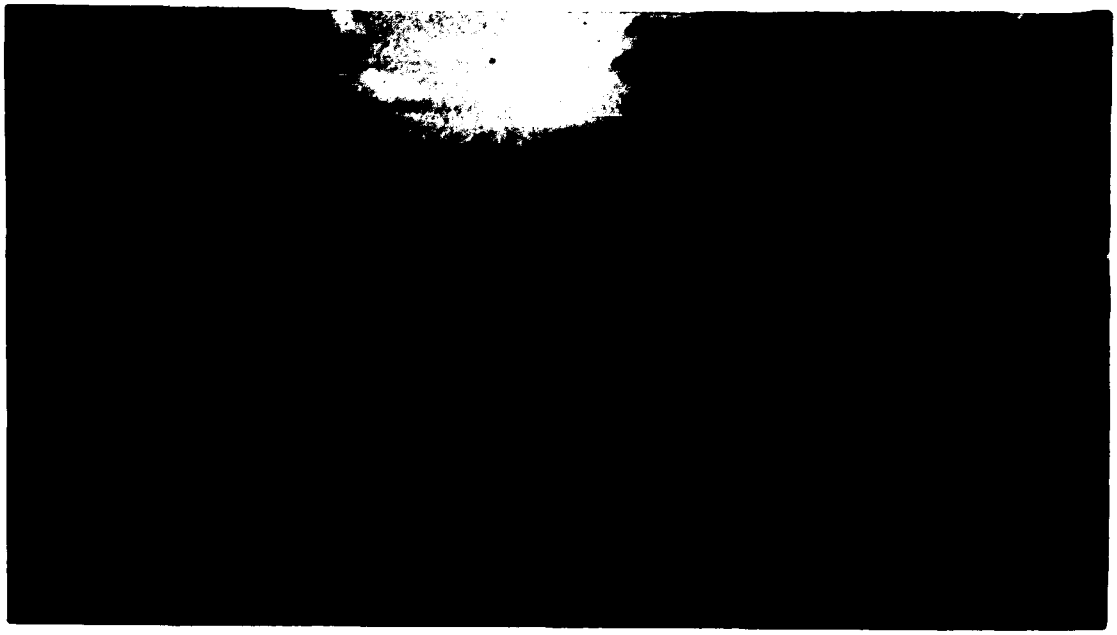

Fig. 17. Soft-stem bulrush, (*Scirpus validus*), six days after treatment with 2,4-D-PCP pellets. Photographed from waterside.

Fig. 18. Same plot as above, thirteen days after treatment. Photographed from landside.

Fig. 19. Duck potato, (*Sagittaria latifolia*), thirty days after treatment with an aqueous solution of the isopropyl ester of 2,4-D at the rate of 2.78 pounds 2,4-D per acre.

Fig. 20. Duck potato, (*Sagittaria latifolia*), thirty days after treatment with fuel oil at the rate of 40 gallons per acre.

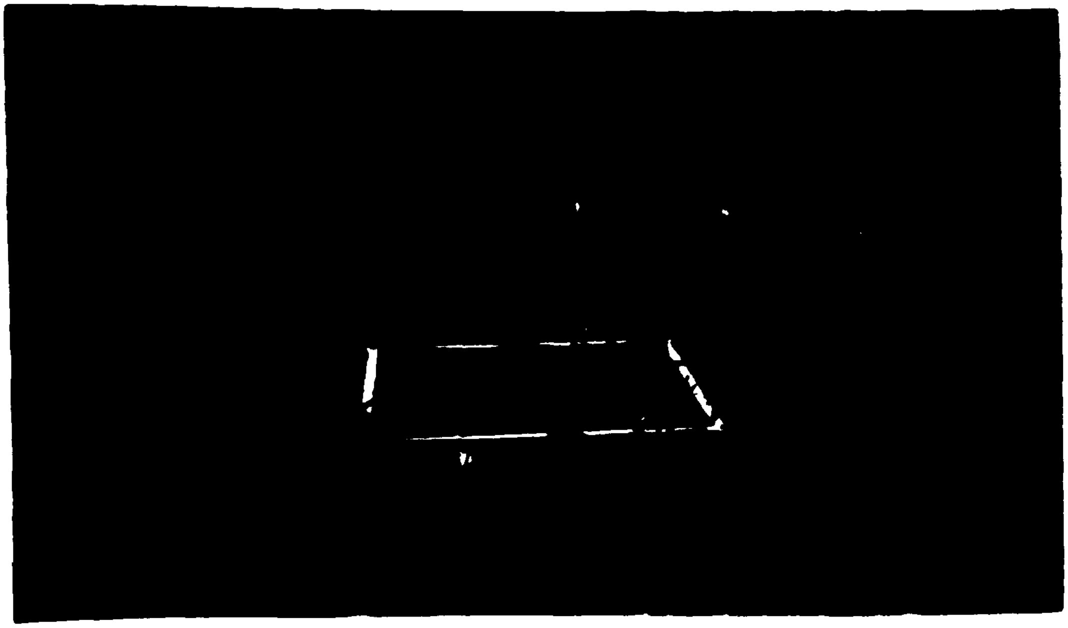

Fig. 21. Pickerelweed, (*Pontederia cordata*), thirty-one days after treatment with phenyl acetic acid-2,4-D at the rate of 2.65 pounds 2,4-D per acre.

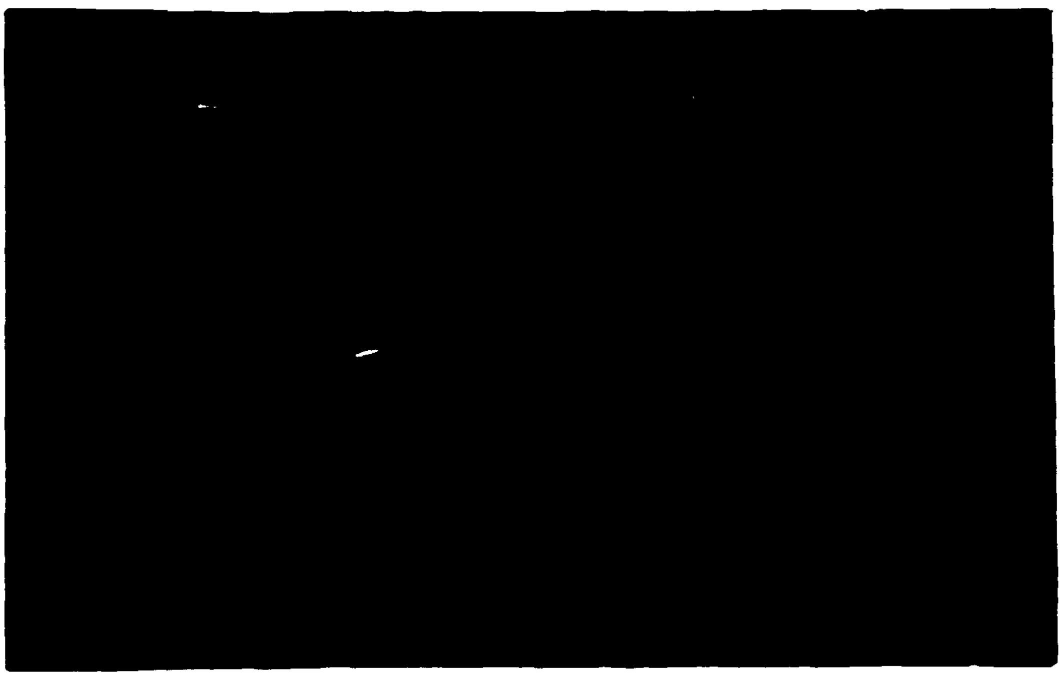

Fig. 22. White water lily, (*Nymphaea odorata*), thirteen days after treatment with phenyl acetic acid-2,4-D at the rate of 7.15 pounds 2,4-D per acre.

Fig. 23. White water lily, (*Nymphaea odorata*), before treatment.

Fig. 24. White water lily, (*Nymphaea odorata*), fifteen days after treatment with the isopropyl ester of 2,4-D in oil, at the rate of 3.48 pounds 2,4-D per acre.

Fig. 25. White water lily, (*Nymphaea odorata*), before treatment.

Fig. 26. White water lily, (*Nymphaea odorata*), twelve days after treatment with phenyl acetic acid-2,4-D at the rate of 2.65 pounds 2,4-D per acre.

Fig. 27. White water lily, (Nymphaea odorata). Twenty-seven days after treatment with phenyl acetic acid-2,4-D at the rate of 2.65 pounds 2,4-D per acre.

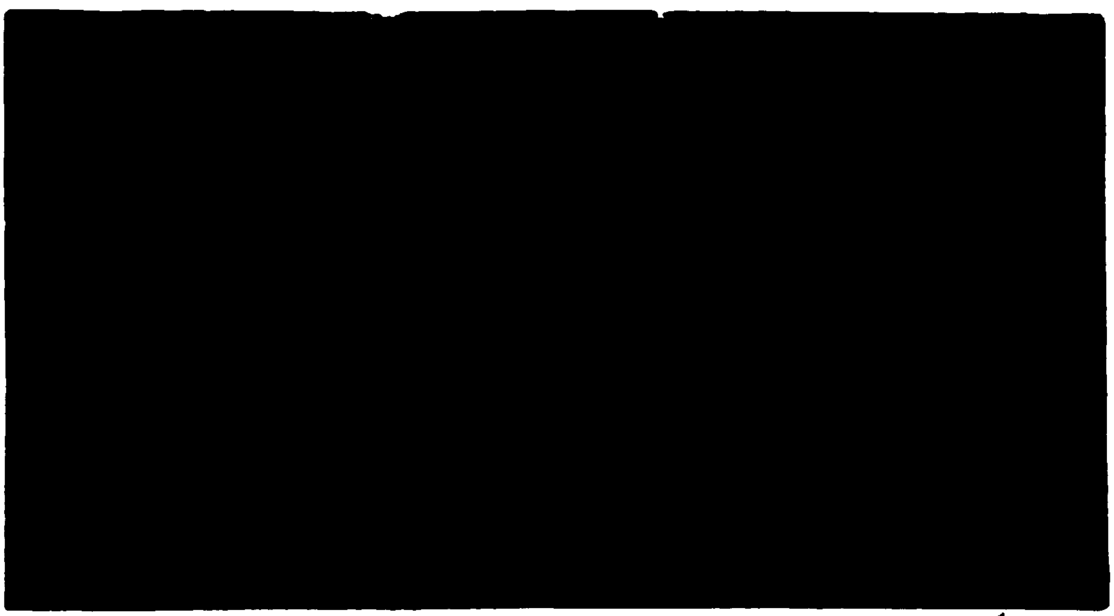

Fig. 28. White water lily, (Nymphaea odorata). fifty-two days after treatment with phenyl acetic acid-2,4-D at the rate of 2.65 pounds 2,4-D per acre, and 25 days after spraying the regrowth with 7.15 pounds of the same formulation.

Fig. 29. Yellow water lily, (*Nuphar advena*), before treatment.

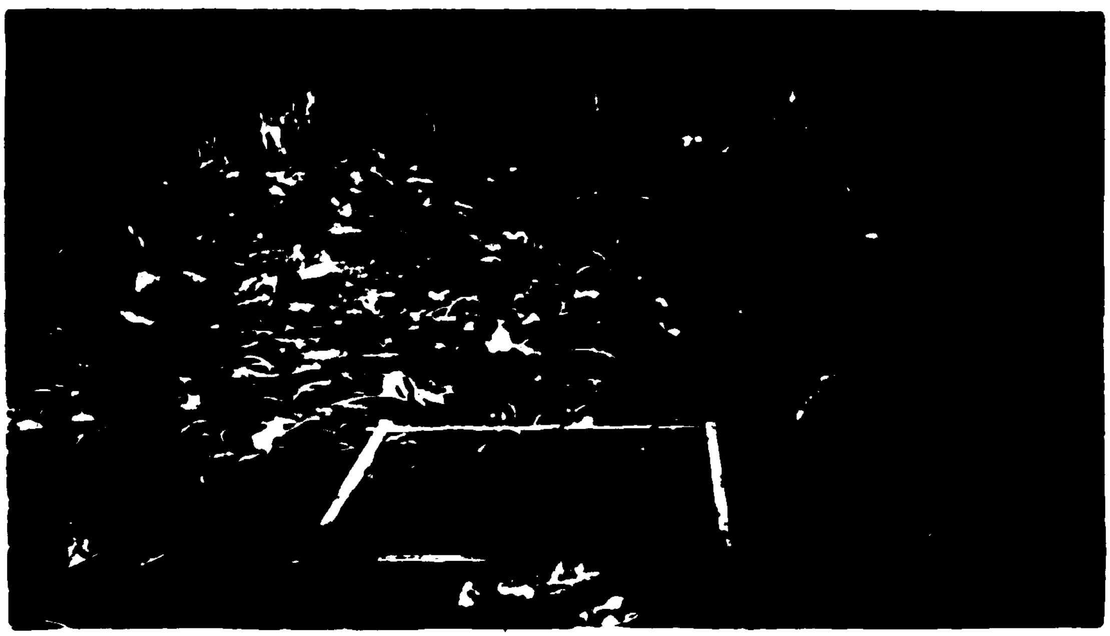

Fig. 30. Yellow water lily, (*Nuphar advena*), sixteen days after treatment with phenyl acetic acid-2,4-D at the rate of 6.89 pounds 2,4-D per acre.

Fig. 31. Narrow-leaved cattail, (*Typha angustifolia*), thirty days after treatment with ammonium thiocyanate at the rate of 320 pounds per acre.

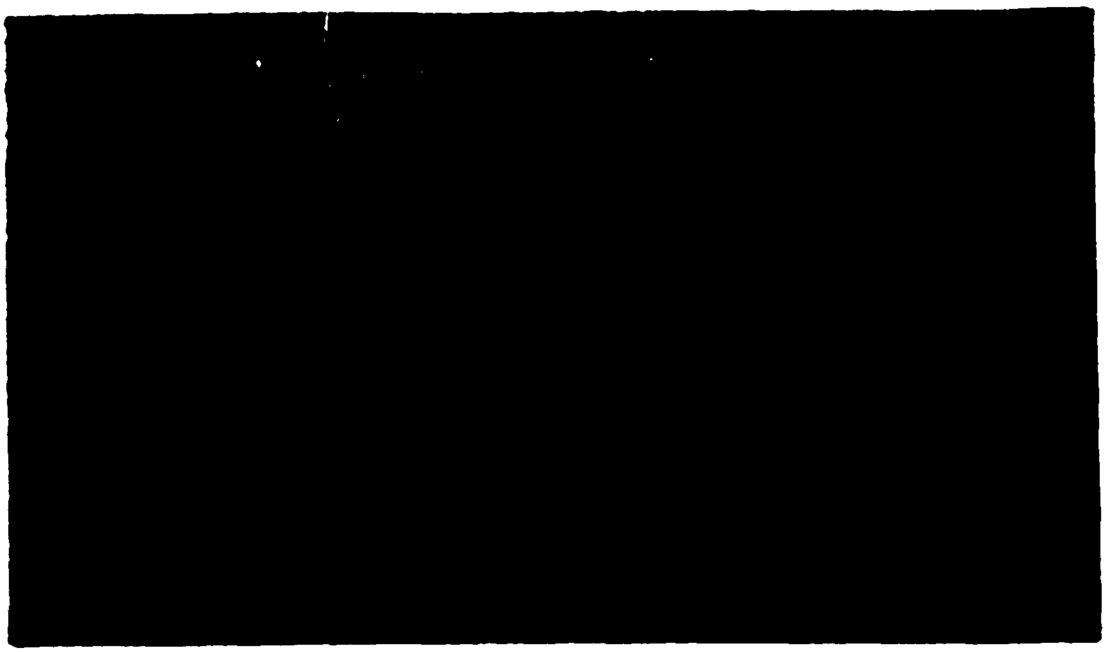

Fig. 32. Narrow-leaved cattail, (*Typha angustifolia*), treated the previous fall with alpha-hydroxy-beta-trichlorethyl sulfonic acid at the rate of 200 pounds per acre. Photographed in July.