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CONTROL OF AnUATIC PLANTS IN PONDS AND LAKES

By

Eugene W. Surber

Fishery Research Biologist

Branch of Fishery Biology

The purpose of this leaflet is to aid fish-culturists, pond owners, and operators who have weed-control problems. The methods of weed eradication and control described herein apply to farm ponds, hatchery ponds, and small lakes.

Methods are described for the eradication and control of (1) the submersed plants such as the American waterweed (Anacharis) and the many species of pondweeds (Potamogetons), etc., which are rooted in the pond bottom and grow to the water surface, and (2) the emergent plants, such as cattails, softstem bulrush, burreed, willows, etc. which usually start their growth at the margin of a pond and build up marshes about its border.

Large amounts of submersed or emergent vegetation inevitably lead to overpopulation and stunted fish. The pond with coarse weeds growing over most of the bottom not only produces a smaller total weight of fish, but those present average smaller in size. The goal of the pond operator interested in producing fish, is to raise relatively few fish to edible size within the shortest possible time. Weed control is essential to the maintenance of a proper predator fish-forage fish balance in farm ponds, to production of fish in hatchery ponds, and to the maintenance of recreational values.

Determination of Area and Volume of Water

Reasonably accurate determination of the surface area and average depth of a pond is necessary for good results.

In many instances, the surface area has already been determined from engineering data collected during the construction of a pond. It is recommended that actual measurement of length, average width and average depth precede chemical treatment.

Surface area in irregular ponds can be determined with a plane table or with a transit, or a level with cross hairs, by setting the instrument at a point from which most of the points on the shoreline can be seen. The angles and distances to the different points are measured with the aid of a levelling rod in the hands of a second person. The data may then be transferred to 10 by 10 to the half-inch graph paper where 1/64 inch equals 1 foot and each square 0.5 inch on a side is equal to 0.0235 acre. Area is determined by counting the squares or portions thereof. Average depth should be determined by soundings at regularly spaced intervals both lengthwise and crosswise of the pond. Volume is determined by multiplying the area by the average depth.

For additional information on methods of mapping, the reader is referred to Welch (1948, pp. 3-24).

Control of Submersed Aquatic Plants

Diversity in reproduction and propagation of submersed aquatic plants makes them difficult to control. Most of the coarse weeds are flowering plants. They grow rapidly, and, when they reach the water surface, flowers and seeds are generally produced. Sometimes, as in the case of the common waterweed, Anacharis, the flowers are very small and inconspicuous. The seeds, usually produced on short spikes, are dispersed rapidly by water currents, by the wind, and by animals and birds. Some plants like Anacharis and coontail (Ceratophyllum) have brittle stems. Terminal buds at the tips of stems and sections of stems bearing leaves fragment and produce new plants. A common method of propagation is by means of underground stems, subterranean offshoots of the parent plants, which grow out laterally into the bottom mud. These underground stems, also called rootstocks or rhizomes, have joints or nodes from which new shoots arise. This is why the mere draining of a pond and the mechanical mowing of weeds gives only temporary results. The bottoms of many hatchery ponds usually remain damp enough to preserve these invisible underground stems in a viable condition long after the top soil appears to have dried out.

Once submersed plants have become established in a pond, the only certain means of eliminating them is by shading them out or by killing them with chemicals. "Shading out" is nature's method of elimination. It is done artificially by encouraging the growth of microscopic plants in the open water with fertilizers. The microscopic plants ("waterbloom" algae) are universal in their distribution. They reproduce by means Of minute spores which are wind or water borne. Their rapid increase is often by simple division of the cells.

Submersed plants can be removed mechanically with an underwater mower, such as illustrated in Figure 1, which employs 3 cutter bars operated from a boat which may use an outboard motor or other motor for forward propulsion. This mowing device is reported to give good results along resort beaches and is being used in fish ponds.

A

Grinwald's weed removal machine (Figures 2, 3) used in lakes, employs a hydraulically operated weed lift, a hydraulic press for removal of water from the weeds.

Weed saws, wires, and underwater scythes are other mechanical means of weed removal. They are laborious and often provide only temporary benefit.

The Ziemsen submarine weed cutting saw (Figure 4) has long been in use for hand removal of weeds.

Uhler (1944, p. 298) observed that a single cutting of undesirable perennial plants (such as cattails) at a time when they are in their most vulnerable condition was quite effective in control operations. This occurred during the period immediately following the peak of their flowering season and before the new orop of seeds or fruit ripened. If followed by a second cutting of the sparse re-growth 4 to 6 weeks later, control was often practically complete. Martin and Uhler (1939) described a variety of methods for control of marsh and aquatic plants among which was control by raising the water level 2.0 to 3.5 feet. Steenis and Cottam (1945) described methods of control of giant out-grass, lotus and spatterdock by cutting.

Control with Fertilizers

Fertilization has the advantage over chemical weed poisons in that its addition increases productivity of the pond.

In this method of weed control, the propagation and growth of one group of plants is fostered over the growth of another. Microscopic green or blue-green plants (algae), encouraged by the addition of fertilizers, multiply in the open water where they drift about, thereby shutting out light which might be available for the coarse plants on the bottom. With proper fertilization methods, at least in soft water, available nitrogen, phosphorus, potash, and other elements needed ny the microscopic plants, may be furnished them on a schedule more favorable to their growth than to the coarse plants. This method of weed control for new farm ponds was first suggested by Swingle and Smith (1939) who have also recommended fertilization for control of weeds in ponds where they have already become a nuisance.

For new ponds, the fertilization method is relatively simple: as soon as the pond is filled with water, about 100 pounds per acre of inorganic fertilizer of the combinations listed below, are added at weekly intervals until the water becomes green or brownish from the growth of microscopic plants. This usually requires two to four applications, after which the fertilizer is added at about monthly intervals, or when needed to make the water more turbid. The criterion of "when needed" is transparency to a depth of 12 to 18 inches beneath the surface. When an object such as a white dish or the hand can be seen,at depths greater than about 18 inches, it is time to add more fertilizer. For the production of the microscopic plants in new ponds to prevent growth of coarse weeds, fertilization only during the warm months of the year is necessary. The following fertilizer formulae are recommended for new or old ponds.

Table 1. Inorganic fertilizer formulae (N-P-K), Composition in pounds.

Pounds of fertilizer ingredients	10-6-4	8-8-4	6-8-4	5-10-5
Ammonium sulfate (20 percent N)	50	40	20	25
Superphosphate (20 percent P_2O_5)	30	40	40	50
Muriate of potash (60 percent K_2O)	7	7	7	8
Filler (Powdered limestone, sawdust, peet, sand, etc.)	13	13	33	17
Total pounds	100	100	100	100

The ingredients are listed in Table 1 to enable the pond operator to make up his own fertilizer at low cost. Inorganic fertilizers of similar composition to the above may be purchased in 100 pound bags from most fertilizer dealers. 6-8-4 is used in cotton fields, 10-6-4 in orchards, and 5-10-5 in gardens.

Reclamation of Old Ponds and Lakes

In Southern ponds and small lakes where the submersed aquatic plants have already become abundant, Smith and Swingle (1942) have recommended a fertilization program beginning in December or January. One of the fertilizers listed above may be added at about monthly intervals until warm weather sets in. In this interval, filamentous algae, such as Spirogyra and the semi-microscopic forms attached to the leaves and stems of old plants may develop in abundance, growing over areas formerly occupied by the coarse submersed aquatic plants, or upon old or living plants. At the onset of warm weather, these filamentous algae, stimulated by winter fertilization, begin to decay. In the interval, the growth of the submersed plants or their seedlings or new sprouts has been inhibited. At the onset of warm weather, the intervals between applications may be increased to weekly intervals until the water becomes green with "water blooms". As in farm pond fertilization, the microscopic plants shade out the larger submersed plants.

This method of plant control by fertilization was tried out at a more northern latitude, Deer Lake near Boonton, New Jersey (Surber, 1948) with a program of fertilization beginning as soon as the ice cover left the small (44 acre) recreational lake. The fertilization followed in Deer Lake and other artificial lakes in this area is described below. The project in Deer Lake proved successful in spite of relatively large inflows of water. Seven applications of 5-10-5 fertilizer were made. Applications at the rate of 50 pounds per acre were begun on March 16 (one week after the ice went out). Subsequent applications were made on April 13, May 11, June 8, June 15, June 21, and June 28. The application on June 8, when the weather became warm, was at the rate of 100 pounds per acre instead of the usual 50 pounds. A bloom appeared after the first application, but good blooms were not present until after June 8.

The control of weeds in Deer Lake offered special problems because of the fact that it is used for recreational purposes by 400 families. Almost immediately after fertilization, waterbloom appeared. This feature differed from the results in the South where filamentous algae appeared early and began decaying when warm weather set in.

In Deer Lake, coontail, which occupied the open waters and interfered with sail-boating, was destroyed first. This plant disintegrated, creating a high oxygen demand and probably conditions unfavorable for other plants. Anacharis, bearing abnormally large numbers of adventitious (false) roots floated up in large masses to the surface and was carried ashore by the wind. These objectionable accumulations of vegetation had to be removed from the beach. The loosening of weeds at the bottom was characteristic of Shongun Lake and Dixon's Pond, also located at Boonton, New Jersey. In the former, long shoots of Cabomba (Fanwort) 12 feet or more in length drifted to the windward side of the lake where they were finally removed with forks.

Fortunately for weed control by fertilizers, the water is soft in most ponds and artificial lakes. A program of fertilization carried out in a hard-water pond at Leetown, West Virginia, and in one at Blacksburg, Virginia, merely caused weeds and pond scums to become more abundant. In hard waters, as far as is known at present, control methods with fertilizers are less effective. At Leetown, West Virginia, even 300 pounds of inorganic fertilizer per acre per application failed to produce water blooms after other plants had become established.

Hard-water ponds are likely to remain clear or will clear up more rapidly than soft-water ponds because of the chemical processes which take place in the water. In limestone regions, large quantities of bicarbonates present in the water are broken down by plants, forming precipitates which serve to carry to the bottom suspended materials drifting in the water. This is not true of soft waters where there is little bicarbonate or other mineral compounds to be broken down by plant activity.

Control of Submersed Plants with Chemicals

A large variety of chemicals have come into use in the control of submersed aquatic plants; Dyes, such as nigrosine; hydrocarbons such as orthodiohlorobenzene, trichlorbenzol, dichlorbenzol, and naphtha; plant growth regulators such as 2,4-D and 2,4,5-T; and other chemicals such as ammonium sulfamate; sodium chlorate, copper sulfate and sodium arsenite. Most of these have their disadvantages and these will be mentioned briefly.

The dye, nigrosine, for example, has been used successfully to control submersed aquatic plants, but this dye is too expensive to use, at least in hatchery ponds, and its biological effects have not yet been studied. The hydrocarbons such as orthodichlorobenzene, trichlorbenzol and dichlorbenzol, as well as naphtha, have proven highly toxic to fish and fish-food animals. It has been shown by experimentation that these chemicals will kill fish and their food before they will kill plants. The phenoxyacetic compounds such as 2,4-D and 2,4,5-T are still too expensive to be used as weed killers for submersed plants even though they are not toxic to fish in concentrations required to kill vegetation. 2,4-D imparts a disagreeable flavor to fish flesh making it impossible to eat. Above the water level, and applied to emergent types of vegetation, however, the phenoxyacetic compounds are highly effective and inexpensive.

Ammonium sulfamate, while quite effective on emergent plants, is too expensive to be used on the submersed plants.

Sodium chlorate has the disadvantage of being explosive in nature.

Copper Sulfate for Pond Scum Algae and Chara

Copper sulfate ($CuSO_4 \cdot 5H_2O$) is cheap and has been used extensively in ponds at the Leetown, West Virginia, hatchery, where the water is hard. At 1.0 part per million (p.p.m.) or 8.3 pounds per million gallons of water, copper sulfate may be used for the control of muskgrass (Chara) and the floating pond scum algae which sometimes cover the surfaces of hatchery ponds. In the destruction of muskgrass, which is one of the dominant plants in hard waters of limestone sections, microscopic plants or water-bloom algae usually follow the treatment, and thereafter it is easier to maintain water-blooms by fertilization. Moyle (unpublished Limnological Society Symposium paper, 1947) has produced evidence to indicate that the continued use of copper sulfate over a long period in St. Paul, Minnesota, water supply storage lakes apparently had no harmful effect on fish production in that area. Recent work on the copper content of the bottom muds of some Wisconsin lakes indicates cumulative effects. It seems likely that copper sulfate will continue to be used about pond stations on quite an extensive scale unless the use of this chemical is clearly proven to be deleterious. Toxicity tests by Moore and Kellerman (1905) have demonstrated that sunfish can withstand concentrations up to 1.2 p.p.m. (parts per million), and bass up to 2.1 p.p.m. of copper sulfate in soft water. The limits are apparently much higher in hard water.

There are times when yellowish green or green scums form on the surfaces of ponds making fishing in them almost impossible. The time to control these growths is in the early stages of their development when they first appear on the surface of the pond. Copper sulfate is an effective agent for this, but sodium arsenite has been found just as effective or more effective on thick scums which cover or threaten to cover the entire surface of a pond. Where large areas of the surface of a pond have already been covered with scums, treatment based on the entire volume of water in the pond has beer carried out, but spraying is confined mostly to the surface scums themselves and not to the open water. Treatment of hard-water ponds at Leetown is based on a rate of 1.0 p.p.m. or 8.3 pounds of copper sulfate per one million gallons of water in the pond. In mixing and applying copper sulfate, a painted galvanized tub, wooden tub, or crock may be used. Copper sulfate may be dissolved n a tub of water and the chemical solution broadcast by hand from the front end of a boat by use of a long-handled enamelled dipper. Where pond scums are dense and cover a good portion of the pond surface, it is necessary to use a sprayer and pneumatic tank for the application of copper sulfate in the manner described on page 8 for distribution of sodium arsenite solution.

In ponds at Welaka, Florida, Dr. O. L. Meehean found it convenient to distribute small crystals of copper sulfate,(3 pounds per 1,000 square feet) over the patches of scums by hand to control pond scums as they were getting started.

Muskgrass often invades hard-water ponds, rendering them relatively unproductive of fish. It can readily be destroyed with the use of copper sulfate at a rate not exceeding 1.0 p.p.m.

While copper sulfate can be used in hard waters without danger to fish, its use in soft water should be carried out with caution.

Sodium Arsenite for Control of Submersed Plants

Sodium arsenite is one of the cheapest and most effective chemicals for use in bringing submersed aquatic plants under control. During the warm summer months, 4.0 p.p.m. will kill even the most dense growths of submersed aquatic plants in both hard and soft water. Sodium arsenite has a wide margin of safety as a hazard to fish, since about 11 to 12 p.p.m. are required to kill fish. Where vegetation is very dense, care must be taken in the use of sodium arsenite to avoid the destruction of fish through too rapid decomposition of the treated vegetation. In ponds in midsummer, the critical period for fish occurs about 2 or 3 days after treatment when the plants, which have fallen to the bottom, begin to decay rapidly and use up the oxygen which is also necessary to maintain fish life. In ponds with supply pipes, a moderate amount of fresh water can be turned in after two or three days. In ponds without an inflow, it is recommended that only a section of the pond be treated at one time, up to one-half of the total area of the pond. The congregation of fish along the shoreline or at the surface is an early sign of oxygen depletion. A standby pump of 200 gallons per minute or more capacity can be used for emergency purposes in aerating water where there is no inflow.

Sodium arsenite is sold es a brown or greenish syrupy liquid or as a greyish powder. One gallon of the livid in 64,080 cubic feet of water will yield 1 p.p.m. as arsenious oxide, by weight. A maximum of 4 p.p.m. or 1 gallon in 16,020 cubic feet of water is used for the control of submersed aquatic plants in fish ponds and 2.5 p.p.m. (1 gallon in 25,632 cubic feet of water) will generally give good results if the weeds are not too dense. This chemical apparently is equally effective in hard and soft waters.

The powdered sodium arsenite is used at the same rate. 5.3 pounds of the powdered sodium arsenite (75 percent as As_2O_3) is required to yield 1 p.p.m. in 64,080 cubic feet of water. Therefore, a maximum of about 21 pounds of sodium arsenite for each 64,080 cubic feet of water (4.0 p.p.m.) would be required for the control of submersed plants. At 2.5 p.p.m., 13 pounds 4 ounces of the powdered sodium arsenite are added to each 64,080 cubic feet of pond water.

The simplest method of application of both forms of sodium arsenite solution is by distribution from an unpainted tub placed in the front end of the boat. The sodium arsenite is diluted or dissolved in water and stirred thoroughly with a stick or paddle. The operator should use rubber gloves in the mixing to avoid getting the sodium arsenite solution in open cuts in his hands. Protective covering may be used to prevent damage to clothing. Sodium arsenite solution is broadcast from the tub in the front end of the boat by means of a long-handled enamelled dipper. With some practice, the sodium arsenite solution may be distributed in almost a spray-droplet size by giving a quick jerk to the handle of the dipper as the solution is being broadcast. This method serTres well in mall ponds up to about an acre in area. While simple, it is not as thorough as spraying at 40 to 60 pounds pressure with a penumatic tank and spraying apparatus. In larger ponds, a tree sprayer and pressure tank is recommended. A gun-type sprayer, (Figures 5 and 6) such as is used in apple orchards for spraying individual trees, connected with a 30 to 40 gallon pneumatic tank has been used successfully at the Leetown, West Virginia, station. The tank, which may be a wide, squat type to avoid tipping in a truck or boat, is provided with an air connection to a gasoline-driven air compressor, handles for lifting the tank into and out of the boat, and a gauge which will enable the operator to see how much liquid remains in the tank. In applying the chemical, the tank is partly filled with water before the sodium arsenite solution is introduced into it. The tank is then filled to within a short distance of the top and its contents mixed. An air space is allowed at the top of the tank for air compression. The spray is applied under a pressure of 40 to 60 pounds to the square inch. Sodium arsenite should be diluted sufficiently to obtain good coverage of the pond. The more the solution is diluted, the better the coverage.

Powdered sodium arsenite should be thoroughly dissolved before introduction into spray tanks. Otherwise, this heavy material will settle on the bottom of the tank and will not be dispersed.

Cattle and other grazing animals should be excluded from the pond area for a period of at least one week after spraying. Special care should be taken to prevent the spilling of the concentrated solution on above-water weeds where grazing may occur.

Control of Emergent Aquatic Plants

Cattails, softstem bulrush, arrowheads, plantains, burreed, willows, and various species of spikerush (Eleocharis) are among the common emergent aquatic plants which tend to form marshes about the borders of ponds and make fishing and pond operations difficult. These plants, by growth and decay, as well as by aiding in silt accumulation tend to reduce the area of open water in ponds. It has been found recently that the plant growth regulators such as 2,4-D for herbaceous plants and 2,4,5-T for woody plants are of great value in the control of the emergent aquatic plants. 2,4-D (2,4-dichlorophenoxy-acetic acid) may be used in 0.1 to 0.2 percent solutions at rates as low as 1 to 3 pounds per acre (Hall and Hess, 1947) for control of succulent broad-leafed plants including marsh varieties such as jewelweed, plantains, arrow-heads, water willow (Dianthera americana) and others, but pond operators are usually concerned more with the eradication of erect species such as cattails, softstem bulrushes, burreeds, spikorush, etc. Waterlilies, watershield, cat-tails, water-hyacinths and others have waxy coverings requiring relatively strong solutions containing oil carriers or detergents for better penetration and coverage. For this reason, one percent or half of one percent solutions of 2,4-D are recommended instead of the weaker solutions. Another reason for 1.0 percent solutions is that eradication, rather than control, is the end result desired.

One requirement for effective treatment is thorough coverage with a solvent or carrier which will convey the 2,4-D to sufficient portions of the plant. From 20 to 200 gallons of spray solution per acre are used, depending upon the strength and fineness of the spray droplets and nature of weeds to be controlled. One hundred gallons of spray solution per acre should give good coverage in most cases. In the control of cattails, 2,4-D has been found to be effective when used in quantities as low as one-half of 1.0 percent in tributylphosphate and kerosene when applied at the right time. The sodium salt of 2,4-D which is one of its most convenient forms to use, has been found effective on succulent varieties of plants in concentrations of 1.0 percent in water. The time of application is important for eradication of such plants as cattails, and softstem bulrush, for example. The 2,4-D solutions obtain better results when applied at a time when the plants are actively growing and before the fruits are produced. Treatments are more successful in warm, clear weather. It has recently been observed by Hamner, Lucas and Sell (1947) that the sodium salt of 2,4-D is more effective when used with a strong acid such as phosphoric acid in the acid range of pH 2 to 3. These authors have also pointed out that the use of 2,4-D in too high concentrations so injures the plant tissues that translocation of the 2,4-D into the root system cannot take place. This is important when it is desired to eradicate plants.

Dr. Gladys S. King, formerly of the Southern Regional Research Laboratory (Industrial and Engineering Chemistry, 1948) noted that auxin (plant hormone) moved to the basal buds in water-hyacinth when treated with 2,4-D, enabling the plants to survive. She devised a 2,4-D formula containing phenylacetic acid which competed with auxin, increasing the effectiveness of 2,4-D. Potassium chloride and ammonium phosphate were added to inhibit the effect of the substrate, and eosin was added as a catalyst. This effective solution is now sold commercially.

In its pure condition, 2,4-D is a white powder. [1/] It is insoluble in water, but is readily dissolved in tributylphosphate or triethanolamine. It

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1 / A list of commercial products available may be obtained by writing the author.

is combined with ethyl, butyl, and methyl alcohols to form esters which recuire oil carriers for most efficient distribution. With water, the esters form emulsions. When tributylphosphate is used as a cosolvent, kerosene or other light oils such as fuel oil No. 2 are used as carriers. In the case of triethanolamine, this solvent is readily miscible with water. Low-cost formulae which will eradicate almost all species of emergent aquatic plants are listed below. These are one percent solutions composed as follows:

Table 2. Composition of 2,4-1) spray solutions

Solution: no.	2,4-D (acid powder) Percent	Weight	Cosolvent Name	Volume	Carrier to make 25 gallons
1	1	2 pounds	Tributylphosphate	2 quarts	kerosene
2	1	2 pounds	Triethanolamine	1 quart	water

One volume of these solutions diluted with an equal volume of kerosene in the case of No. 1, or water in the case of No. 2, will yield a 0.5 percent solution of 2,4-D.

For small operations it is often more convenient to mix up and use 5 gallons of the spray solution in a No. 6 or No. 10 earthen crock or other container. Five gallons of the one percent solutions would be comprised as follows:

Table 3. Composition of 2,4-D spray solutions

Solution no.	2,4-D (acid powder) Percent	Weight	Cosolvent Name	Volume	Carrier to make 5 gallons
1	1	6.5 ounces	Tributylphosphate	1 pint	kerosene
2	1	6.5 ounces	Triethanolamine	0.5 pint	water

In making up these solutions, the 2,4-D powder should be dissolved in the cosolvent before making up to the quantity desired.

For destroying plants with waxy coats on their leaves (such as cattails and water lilies) the oil spray will prove more effective because of better penetration.

There is little difficulty in determining which plants have already been sprayed with kerosene, but with a water spray, a water-soluble dye such as ceresine (red) or anthraquinone blue will improve coverage. One-half of 1 percent of these dyes are ample for coloration.

In treating young, growing cattails with 2,4-D, it has been found that as little as one-half of 1.0 percent in tributylphosphate and kerosene is effective. Kerosene has virtually no herbioidal value, but tributylphosphate does have some herbicidal properties that aid in the killing of the plants. This chemical is irritating to eyes and skin and should be promptly removed with soap and water.

One of the Most effective formulations of 2,4 D used to date on waterlilies and other waxy-coated plants is a commercial solution consisting of 35.0 percent 2,4-D and 17.5 percent phenylacetic acid (see page 9). At 7 Ants to the acre (2.6 pounds 2,4D per acre) this formulation has proven effective on waterlilies and virtually all of the common emergent aquatic plants ordinarily found at fish hatcheries. Although this formulation has an objectionable odbr, the chemical solutionmay be diluted with water which is considerably more convenient than an oil such as kerosene. There are many commercial powders and solutions of 2,4 D on the market. They are sold under a variety of trade names (see footnote page 9).

The esters of 2,4-D are more effective than the salts. They require oil carriers suoh as kerosene for most efficient distribution, but dnuted with water and well-shaken, they form emulsions which adhere well to plant surfaces. While they are very effective, they are also more expensive than the basic formulae given above.

One of the most convenient forms of 2,4-D now on the market is a sodium salt of 2,4-D (sodium dichlorophenoxyacetate). This sodium salt is very soluble in water and it is effective on most of the emergent aquatic plants which do not possess a waxy coating such as possessed by the cattails and waterlilies. Such plants as smartweeds, burreed, marsh-marigolds, watercress and Veronica may be readily killed by a one percent solution of the sodium salt of 2,4-D. The essential thing in controlling emergent aquatic plants is to wet them thoroughly, particularly when a dilute solution of 2,4-D is being used.

The usual practice (on lawns, eto.) is to use 0.1 percent solutions containing 1,000 parts per million of the acid. Since 100 gallons of liquid are usually required to obtain good coverage over an acre, the amount of acid powder actually applied is one pound per acre, if 80 percent 2,4-1) is used, or 1 1/4 pounds per acre if a 70 percent 2,4-D formulation is used.

Since 1.0 or 0.5 percent solutions of 2,4-D are recommended for control of cattails and other emergent plants about ponds, Table 4 will be useful in adapting commercial formulations to solutions locally available. The percent of 2,4-D in the commercial brand can be determined from the label. 2,4-D in its pure powder form was recently purchased for $1.05 per pound. This will give the purchaser of solutions some idea of the actual value of the solution purchased.

Table 4. Amounts of commercial solutions to be used per acre.

Percent 2,4-D acid content of herbicide	Amount of herbicide to give 10,000 p.p.m. per 100 gallons of spray	Amount of herbicide to give 5,000 p.p.m. per 100 gallons of spray
	(1.0 percent solution)	(0.5 percent solution)
90	8 lbs. 12 oz.	4 lbs. 6 oz.
85	9 lbs. 6 oz.	4 lbs. 11 oz.
80	10 lbs.	5 lbs.
70	11 lbs. 14 oz.	5 lbs. 15 oz.
60	13 lbs. 12 oz.	6 lbs. 14 oz.
40 (liquid)	2.5 gallons	5 quarts
20 (liquid)	5.0 gallons	2.5 gallons
10 (liquid)	10.0 gallons	5 gallons

In the use of 2,4-D and related phenoxyacetic compounds, the user is cautioned against dangers of destroying valuable plants nearby through air drift. This is particularly true of the sodium salt which may be applied in powder form.

Cleansing of Equipment

Equipment used in spraying should be rinsed with kerosene if oil sprays are used or with a dilute solution of washing soda if aqueous sprays are used. Further rinsing with warm water and soap is recommended, especially if oil carriers have been used in diluting the spray materials. Acetone and ammonia water are other 2,4-D solvents useful in cleansing equipment. One-half ounce of trisodium phosphate per gallon of water is another effective rinse.

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APPENDIX A. --- Chemical control agents and quantities required to kill obnoxious aquatic plants

Name of Plant	C ca oontro agent	te to kill	IForaulati4bn
Floating aquatic plants			
Pond scum algae (Hydrodictyon, Oedogonium, etc.)	(sodium arsenite (copper sulfate	2.5 p.p.m. 1.0 p.p.m.	
Duckweed (Lemna minor L.)	2,4-D	1.0 percent	oil
Water hyacinth (Eichhornia crassipes (Mart.) Solms.	2,4-D	0.5 percent	
Emergent plants			
Cattail (Typha latifolia L.)	2,4-D	0.5 percent	oil
Cowlily (Nuphar advena Ait.)	2,4-D	1.0 percent	oil
Lotus (Nelumbo pentapetala Walt.)	2,4-D	0.5 percent	oil
White Waterlily (Castalia odorata Ait.)	2,4-D	2.0 percent	oil
Alligator weed (Alternanthera philoxeroides (Mart) Griseb.)	2,4-D	1.0 percent	
Bur-reed (Sparganium americanum Nutt. etc.)	2,4-D	1.0 percent	
Soft-stem bulrush (Scirpus vallidus Vahl.)	2,4-D	1.0 percent	oil
Weak rush (Juncous effusus L.)	2,4-D	1.0 percent	
Square-stem spikerush (Eleocharis quadrangula)	2,4-D	0.5 percent	
Parrots feather (Myriophyllum brasiliense Camb.	2,4-D	0.5 percent	
Duck potato (Sagittaria latifolia Willd.)	2,4-D	1.0 percent	
Water cress (Nasturtium officinale R. Br.)	2,4-D	1.0 percent	

Name of Plant	Chemical control agent	Rate to kill	Formulation
Emergent plants cont'd			
Smartweed (Polygonum coccineum Merhl.)	2,4-D	1.0 percent	
Johnson grass (Sorghum Lalepense L. (Pers.)	2,4-D	1.0 percent	oil
Giant outgrass (Zizaniopsis miliacea (Michx.) D. & As.	2,4-D	1.0 percent	oil
Water chestnut (Trapa natans .)	Sodium arsenite	(1 pound powdered sodium arsenite and 1 pound sodium chlorate in 1 gal. to 150 sq. ft.)	
Submersed plants			
Stonewort, Chara (Chara sp (an alga)	Copper sulfate	0.5-1.0 p.p.m.	
Waterweed (Anacharis oanadensis, etc.)	Sodium arsenite	2.5-4.0 p.p.m.	
Hornwort, Coontail (Ceratophyllum demersum L.)	ditto	2.0 p.p.m.	
Parrots feather (Myriophyllum brasiliense Camb.)	ditto	3.0-4.0 p.p.m.	
Water milfoil (Myriophyllum heterophyllum Michx.)	ditto	3.0-4.0 p.p.m.	
White water crowfoot (Ranuoulus aquatilis L.)	ditto	3.0 p.p.m.	
Curly-leaf pondweed (P. crispus L.)	ditto	2.5 p.p.m.	
Pondweed (P. nodosus Poiret)	ditto	2.5 p.p.m.	
Leafy pondweed (P. foliosus Raf.)	ditto	2.0 p.p.m.	
Fine-leaf pondweed (P. filiformis Pers.)	.Utto	2.0 p.p.m.	

Name of Plant	Chemical control agent	Rate to kill	Formulation
Naiad (Najas flexilis R. & S.)	Sodium arsenite	2.5 p.p.m.	
Naiad (Najas guadalupensis (Spreng.) Morong)	ditto	2.5 p.p.m.	
Water stargrass (Heteranthera dubia (Jacq.) MacM.)	ditto	2.5 p.p.m.	
Water purslane (Ludvigia palustris (L.) Ell.)	ditto	3.0-4.0 p.p.m.	
Bladderwort (Utricularia gibba L.)	ditto	2.5 p.p.m.	
Woody plants on banks			
Black willow (Salix migra Marsh.)	2,4-D or 2,4,5-T	0.5 percent	
Sycamore (Platamus oocidentalis L.)	ditto	0.5 percent	
Cottonwood (Populus deltoides Marsh.)	ditto	0.5 percent	
Black locust (Robinia pseudo-acacia L.)	ditto	0.5 percent	
Silver maple (Acer saccharinum L.)	ditto	2.0 percent	
Poison ivy (Rhus toxicodendron L.)	ditto	1.0 percent	
Buttonball (Cephalanthus oocidentalis L.)	ditto	2.0 percent	
Ragweed (Ambrosia trifida L., etc.)	ditto	0.5 percent	

APPENDIX B. --- The Service offers neither recommendation nor endorsement, and assumes no responsibility in listing below, for the convenience of readers, some sources for these materials:

2,4-D

Dow Chemical Company,
Midland, Michigan

Sherwin-Williams,
1800 Guild Hall Building
Cleveland, Ohio and Chicago, Ill

J. T. Baker Chemical Company,
Phillipsburg, New Jersey

California Spray-Chemical Corp.,
150 Bayway
Elizabeth 2, New Jersey

American Chemical Paint Company,
Ambler, Pennsylvania

Amend Drug and Chemical Company,
117 East 24th Street,
New York, N. Y.

American Cyanamid Company,
30 Rockefeller Plaza,
New York 20, N. Y.

Chipman Chemical Company,
Bound Brook, New Jersey

E. I. DuPont de Nemours and Co
Wilmington, Delaware

J. F. M. Chemical Company,
(King-O-Cide)
Bryan, Texas

2,4-D and related compounds

Chipman Chemical Company,
Houston, Texas

Sandoz Chemical Works, Inc.,
San Francisco, California

Thompson-Hayward Chemical Company,
Kansas City, Missouri

J. T. Baker Chemical Company,
180 East California Street,
Pasadena, California

Albuouerque Chemical Company,
Albuquerque, New Mexico

Barada & Page, Inc.,
Kansas City, Missouri

Braun-Knecht-Heiman Company,
San Francisco, California

Mine & Smelter Supply Company,
Denver, Colorado

The Denver Fire Clay Company,
Denver, Colorado

APPENDIX B. con't

Tributylphosphate

Commercial Solvents Corporation,
Terre Haute, Indiana

Amend Drug and Chemical Co.,
117 East 24th Street,
New York, New York

Ohio Apex Company,
Nitro, West Virginia

Triethanolamine

Carbide and Carbon Chemical Corp.,
30 East 42nd Street,
New York, New York

Amend Drug and Chemical Co.,
117 East 24th Street,
New York, New York

Dow Chemical Company,
Midland, Michigan

Dyes

Calco Division of American Cyanamid
Bound Brook, New Jersey

E. I. DuPont de Nemours and Co.,
Wilmington 98, Delaware

Eimer and Amend Company,
Third Avenue, 18th to 19th Street,
New York, New York

Fisher Scientific Company,
Pittsburgh,
Pennsylvania.

Weed Cutting Machines

(Ziemsen weed saw)

Asohert Bros
La Canada, California

(Hookney underwater weed cutters)

George C. Hockney and Company,
Silver Lake, Wisconsin

(Grinwald weed cutter)

Mr. M. E. Grinwald
Hartland, Wisconsin

Copper sulfate 1/

J. T. Baker Chemical Company,
Phillipsburg, New Jersey

Merck and Company, Inc.,
Rahway, New Jersey; St.Louis, Mo.
Los Angeles, Calif; New York, N.Y.

Mallinckrodt Chemical Works,
St. Louis, Mo.; Los Angeles, Calif.;
Chicago, Ill.; Philadelphia, Penn.

1/ Purchase in powder form ($CuSO_4 \cdot 5H_2O$).

Sodium arsenite [2]

Chipman Chemical Company,
Bound Brook, New Jersey

General Chemical Company,
40 Rector Street,
New York, New York.

Los Angeles Chemical Company, Inc.,
1960 Santa Fe Avenue,
Los Angeles, Califorria

Reade Manufacturing Company, Inc.
185 Hoboken Avenue,
Jersey City, New Jersey

Hamilton Manufacturing Co.,
Rahway, New Jersey

Jefferson Chemical Works,
Pine Bluff, Arkansas

James Goode, Inc.,
2107 East Susquehanna Avenue,
Philadelphia, Pennsylvania

2/ Powders contain 75 to 80 percent arsenic trioxide; solutions contain 4 pounds arsenic trioxide per gallon and are sold in 5 and 50-55 gallon drums.

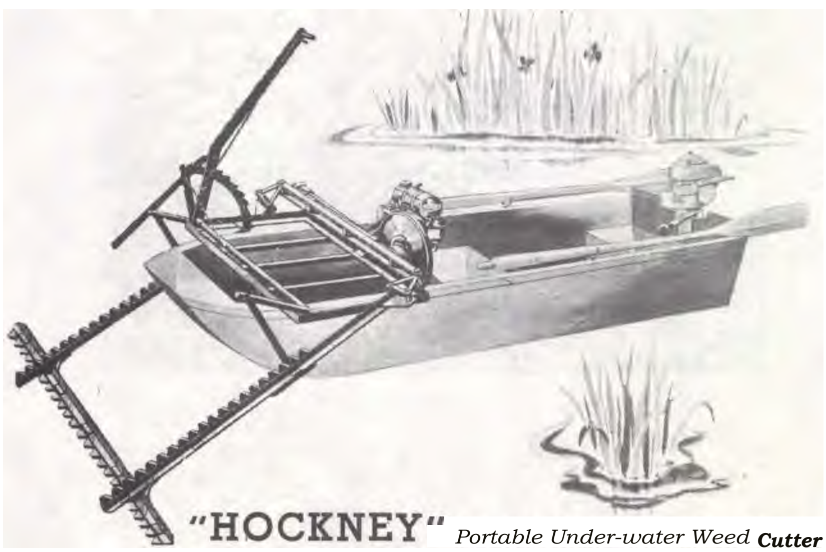

Figure 1. Two views of Hockney under—water weed cutter.

Figure 2. Two views of Grinwald weed removal machine.

Figure 3. Grinwald weed remover lifting load from weed bed.

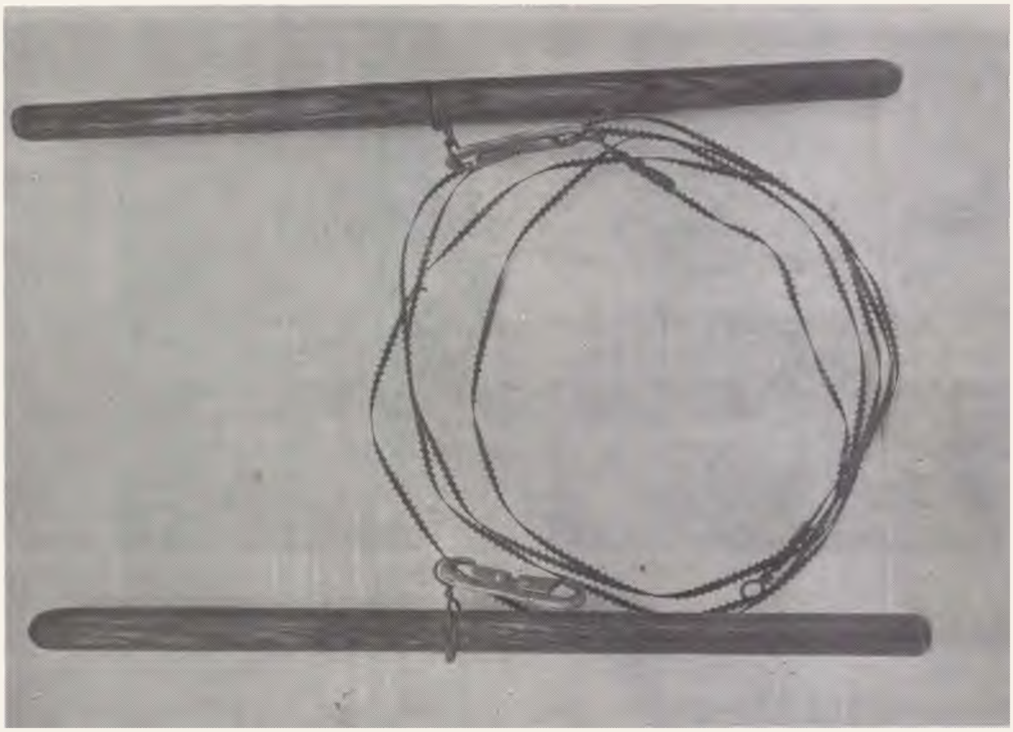

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Figure 5. Gun-type sprayer, pneumatic tank, and air compressor used in weed-control operations.

Figure 6. Gun-type sprayer in operation.