IMPROVING SPORT FISHING by CONTROL of AQUATIC WEEDS

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BY CONTROL OF AQUATIC WEEDS

By

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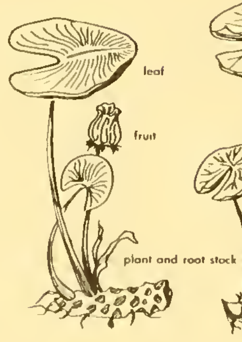

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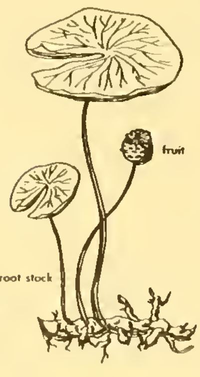

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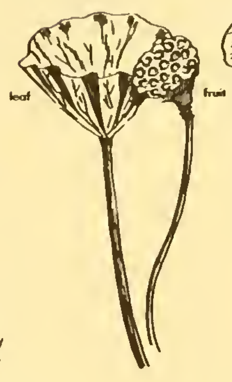

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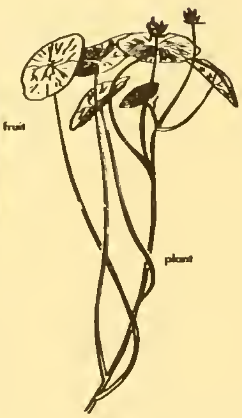

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INTRODUCTION

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

Methods are described for the control of (1) pond scums and other algae; (2) emergent plants, such as cattails, softstem bulrush, burreed, manna grass, water hyacinths, etc., which usually start at the margin of a pond and build up marshes about its border; and (3) the submersed plants such as American waterweed (Elodea) and the many species of pondweeds (Potomogetons), etc., which are rooted in the pond bottom and grow to the water surface.

Large amounts of submersed or emergent vegetation in ponds inevitably lead to over-population and stunted fish. There is abundant evidence that ponds with coarse weeds growing over most of the bottom produce smaller total weights of fish. The goal of the pond operator interested in producing food or game fish, is to raise fish to large or 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 occasionally to the maintenance of recreational values along lake front properties. The preferred method of weed control in ponds is by fertilization of the water.

DETERMINATION OF AREA AND VOLUME OF WATER

Reasonably accurate determination of the surface area and average depth of a pond or lake to be treated is necessary for good results in controlling aquatic weeds. In many instances, the surface area has already been determined from engineering data collected during construction. It is recommended that actual measurements of length, average width and average depth to determine water volume precede chemical treatment.

1/ Prepared while the author was a staff member of the Branch of Federal Aid. He is now employed by the U. S. Public Health Service, Division of Water Supply and Pollution Control, Cincinnati, Ohio.

A white clothes line 200 feet long, marked at 10-foot intervals with India ink and provided with floats 20 feet apart, and a 7-foot pole marked in feet and tenths of a foot, are useful items for depth measurements. The clothes line is stretched across the pond at regular intervals, and depths are obtained with the pole by sounding at 10-foot or 20-foot intervals, depending on the evenness of the bottom and the size of the body of water. Average depth is equal to the total of the cross soundings divided by the number of soundings.

Surface area of an irregular pond is easily determined after an accurate map is prepared. Maps may be prepared by using a plane table or by the stadia method. The stadia method is illustrated in Figure 1.

This method requires a transit equipped with stadia cross-hairs and a levelling rod. The transit is set-up, if possible, at a point where the entire shoreline is visible. Two or more stations may be used where the pond is very irregular. The angles and distances to several points on the pond-edge are measured by sighting on the rod. A reading is necessary at each point where the pond-edge changes direction. The field data are then plotted on grid paper (one hundred squares to the inch is easy to work with) to a scale of one inch equals one hundred feet. After all points have been plotted, they are connected by smooth lines to form the line representing the pond-edge.

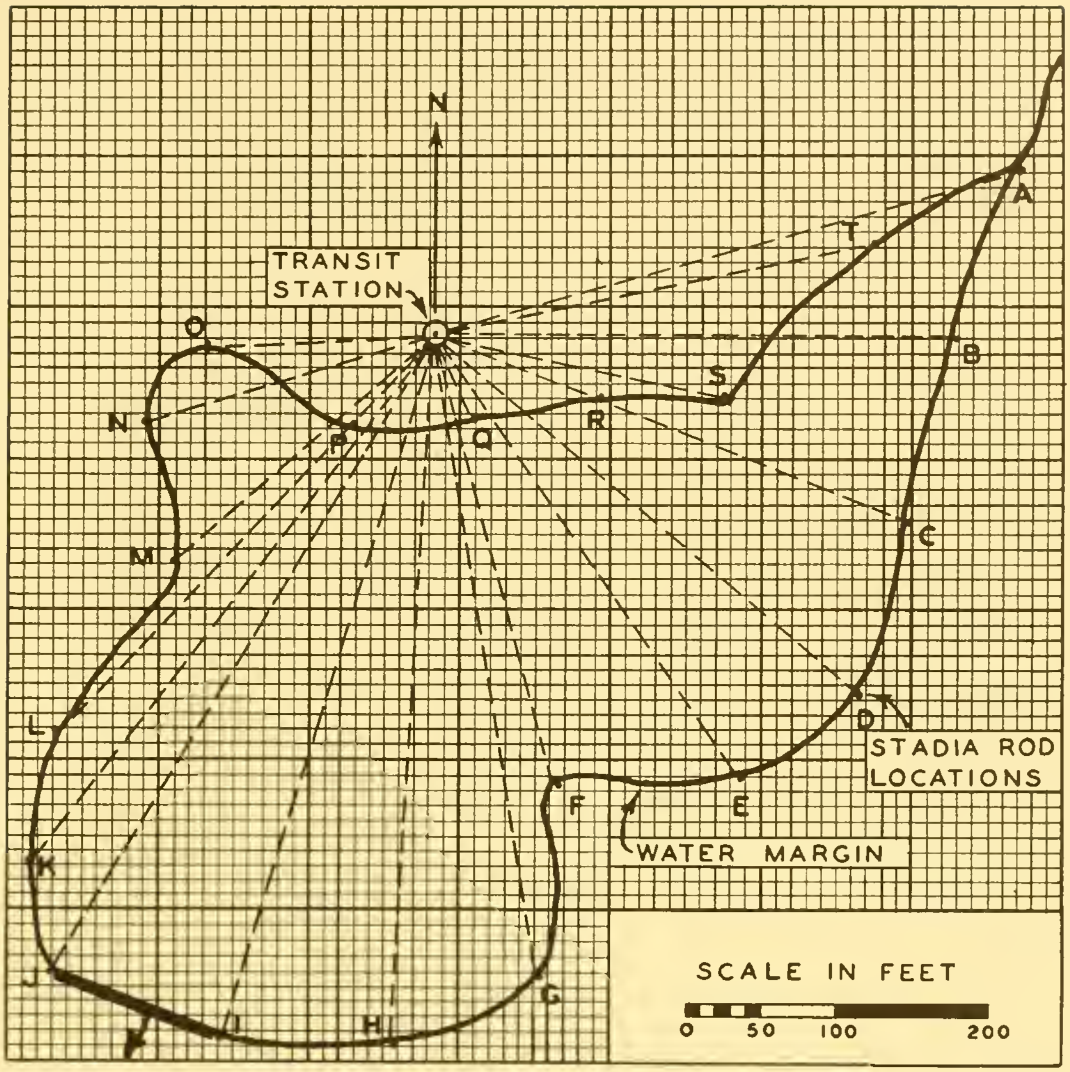
Determination of the surface area is now simply a matter of counting the squares and multiplying by their area (the one-tenth inch squares in Figure 1 are each equal to .00229 acres). The number of squares in the pond area of Figure 1 was found to be 1898.

1898 x .00229 = 4.35 acres

When available a compensating polar planimeter is an excellent instrument for determining area of irregular ponds. This device can be used on maps of any scale, is fast, and gives accuracy more than adequate for this purpose. Current aerial photographs are available in County Agricultural Stabilization and Conservation or Soil Conservation Service offices from which surface areas of ponds may be obtained with reasonable accuracy with this instrument.

USEFUL UNITS OF MEASUREMENT

One acre = 43,560 square feet; One acre foot = 43,560 cubic feet
Acre feet = Area in acres x average depth in feet
One acre foot = 2,718,144 pounds; One part per million (p.p.m.) = 2.7 pounds
One cubic foot = 7.5 gallons = 28.32 liters = 62.42 pounds of water



FIELD NOTES

STATION	AZIMUTH	DISTANCE	STATION	AZIMUTH	DISTANCE
A	75°	397'	K	218°	433'
B	91°	341'	L	224°	358'
C	111°	333'	M	230°	224'
D	131°	362'	N	255°	196'
E	146°	350'	O	268°	149'
F	168°	307'	P	224°	62'
G	172°	427'	Q	156°	59'
H	184°	464'	R	110°	118'
I	197°	482'	S	102°	196'
J	212°	488'	T	78°	295'

Figure 1.--A method of measuring the area of an irregular pond, using a transit.

One pound = 453.6 grams
One gallon = 3,785 grams = 8.3 pounds
One gallon = 128 fluid ounces = 8 pints
One quart = 2 pints = 946 c.c.
One pint = 473 c.c. = 0.550599 liters = 16 fluid ounces
One part per million = 8.3 pounds per million gallons of water
One part per million = 1 milligram (mg.) per liter
1 gram = 100 mg; one microgram = 0.000001 mg. = 0.001 p.p.m.

CONTROL OF POND SCUMS AND OTHER ALGAE

When yellowish-green or green scums form on the surfaces of ponds, fishing in them becomes almost impossible. Examples of scum-forming filamentous green algae are *Hydrodictyon*, *Pithophora*, *Cladophora*, *Oedogonium*, *Zygnema*, *Mougeotia* and *Spirogyra*. 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 equally effective, or even more effective, on thick scums that cover the entire water surface. Sodium arsenite treatments at 4.0 p.p.m., based on the entire volume of water in the pond, have been used effectively, but spraying is confined mostly to the surface scums. Copper sulfate treatments of hard-water ponds at Leetown, West Virginia, were based on a rate of 1.0 part per million (p.p.m.) or 8.3 pounds of copper sulfate ($CuSo_4 \cdot 5H_2O$) per one million gallons of water in the pond. Half that quantity should be used in soft water. Snow (1959) recommends 0.33 p.p.m. copper sulfate applied daily for five days to control *Hydrodictyon* and *Pithophora*, if treated in an early stage of development.

When heavy algal growths in ponds are suddenly killed, serious oxygen depletion may follow. Treatment of a section of a pond at a time, or the turning (or pumping) into the pond of additional fresh water at the proper time will prevent loss of fish.

The early toxicity tests by Moore and Kellerman (1905) indicated that sunfish could withstand concentrations up to 1.2 p.p.m., and bass up to 2.1 p.p.m. of copper sulfate in soft water. The limits are apparently much higher in hard water.

Recent (1959) toxicity tests, however, by John R. Anderson (unpublished) 1/ conducted in aquaria at Marion, Alabama, showed that two-inch bluegills begin to die at a concentration of 0.25 p.p.m., but that 100 per cent mortality did not occur until the concentration of copper sulfate reached 0.8 p.p.m. in soft water having a total hardness (TH) of 15 p.p.m. In contrast, water having a total hardness of 132 p.p.m. and a total alkalinity of 1544 p.p.m. did not kill bluegills until a 10 p.p.m. level was reached. Seventy p.p.m. was required to obtain 100 per cent mortality. The 48-hour

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1/ These results are quoted with the permission of John R. Anderson, U. S. Fish and Wildlife Service, Fort Worth, Texas.

LD 50's for four sources of water supply were 0.6 p.p.m. at TH 15 p.p.m.; 8 p.p.m. at TH 68 p.p.m.; 10 p.p.m. at TH 100 p.p.m.; 45 p.p.m. at TH 132 p.p.m. Total alkalinities in the four waters were 18.7, 166, 245, and 1544 p.p.m., respectively. Therefore, copper sulfate treatments of soft-water hatchery ponds should be undertaken with caution.

Muskgrass (Chara), a form of algae attached to the bottom, often invades hardwater 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. Following destruction of muskgrass, which is one of the dominant plants in hard waters of limestone regions, microscopic plants or "water-bloom" algae often follow the treatment, and thereafter they may be maintained by fertilization.

In mixing and applying copper sulfate, which is highly corrosive, a galvanized tub, painted with asphalt varnish, a wooden tub, or a crock may be used. Copper sulfate may be dissolved in a tub of water and the chemical solution broadcast by hand from the front end of a boat by use of a long-handled enameled dipper when treating small ponds or water areas. Where pond scums are dense and cover a good portion of the pond surface, it is desirable to use a sprayer and pneumatic tank for a thorough application of copper sulfate in the manner described on page 32 for distribution of sodium arsenite solution. The use of brass or plastic fittings in the spraying equipment will reduce corrosion.

In treating surface scums with sodium arsenite, one gallon of 40 per cent sodium arsenite solution (4.0 pounds As_2O_3 equivalent) for each 16,020 cubic feet of the entire volume of water in a pond may be used for effective control.

Where the surface area is known in acres, or the body of water to be treated is irregular and surface area is unknown, calculations may start from the area in acres, which may be determined by methods previously described. The quantity of sodium arsenite required may also be determined by this formula:

Area in acres x average depth in feet x 2.7 x parts per million required ÷ 4 = gallons of sodium arsenite to use.

As little as 2.5 p.p.m. will often give good control, but 4.0 p.p.m. is positive. It requires about 11.0 to 13.0 p.p.m. to kill fish, but most bottom animals are destroyed by high rates of application and the minimum quantity (usually 2.5 to 4 p.p.m.) needed to control problem weeds should be used. Early treatments obviate the need for using high treatment rates which may contaminate ground-water aquifiers. Copper sulfate and sodium arsenite are the most thoroughly tested chemicals for algae control. However, other newer chemicals such as dichlone (whose trade name is Phygon-XL and whose technical name is 2,3-dichloro-1,4-naphthoquinone) and Hyamine 2389 (40 per cent methyl dodecyl benzyl trimethyl ammonium chloride and 10 per cent methyl dodecyl xylene bis-trimethyl ammonium chloride) have given good results under certain conditions.

Control of Algae with Dichlone

Dichlone has sometimes given amazing results in control of both blue-green algae (for which it is specific) and green algae. Suggested treatments are given in Table 1.

Table 1.--Rates of treatment with dichlone

Kind of algae	Rate p.p.m.	Per acre foot	Per 100,000 cu. feet of water	Per million gallons of water
Blue-green, bloom-producing forms	0.05	2.3 ozs.	5.3 ozs.	6.4 ozs.
Green algae, surface scums	0.15	6.4 ozs.	1 lb.	1¼ lbs.

Bond et. al (1960) showed the 24 hours median tolerance limit (TL_m) of largemouth bass to be 0.08 p.p.m. The margin of safety is therefore close, and any use of dichlone should be preceded by careful measurements of areas to be treated. In spite of the close margin of safety, field applications have produced few fish kills. The larger quantities required for treatment of surface scums is most safely applied by spraying with the aid of gun and pneumatic tank as illustrated in Figures 7 and 8.

Hyamine for Algae Control

Hyamine 2389 [alkyl (C_9-C_{15}) totyl methyl trimethyl ammonium chloride] is a promising algicide for use in tanks or ponds with obstinate growths of algae which have not responded to copper sulfate treatment, or where the latter can not be used. Swimming pool operators use it instead of copper sulfate because the latter may form mordants with certain clothing and hair dyes. The amount recommended by the manufacturer for algae control is 0.001 per cent (by weight), or 10 p.p.m. One gallon of 10 per cent solution in 10,000 gallons of water will kill heavy growths of algae. Estes (unpublished report 1/), who worked with Hyamine as a fungicide,

1/ Estes, Ray Don. 1957. The effectiveness of certain fungicides on goldfish and goldfish eggs. (M.S.) 75 pp. Auburn University, Alabama found that 1.0 p.p.m. would kill goldfish. Field tests in fish ponds and bio-assays on pond fishes with this chemical apparently have not yet been carried out.

Biological Control of Aquatic Vegetation

Species of *Tilapia* have been experimented with (Swingle 1957, 1958, 1960) in this country to determine their potential for algae and weed control, as well as food and sport-fish production. In Alabama ponds, effective filamentous algae and weed control, as well as outstanding fish production, has been obtained by stocking eighty, 4-7 inch *Tilapia* per acre in April, or two thousand 1-2 inch fingerlings per acre in June, for the production of this fish. Smaller numbers of stocked fish would be required in ponds already stocked with bluegills and bass.

These fish are sensitive to cold weather, and *Tilapia mossambica* is killed when the temperature descends as low as 48°F. They may be wintered-over in troughs in heated rooms, as has been done at the School of Fisheries at Auburn University, Alabama.

CONTROL OF WATER-BLOOM ALGAE

The water-bloom algae are microscopic, free-floating plants which create turbidity in the water, making it appear green, brown, or blue-green in color. Fish ponds are fertilized to stimulate their growth. These algae are usually desirable in shallow lakes, because the turbidity they create by their growth and multiplication tends to shade out the coarser weeds, thereby maintaining more space for the growth of fish. Many species of midgeflies, which are a staple food of fish, cannot become abundant on the bottom where muskgrass and coarse weeds have become very dense.

Water-bloom algae, usually blue-greens, sometimes become a problem in the larger lakes of fertile agricultural areas or where sewage effluents, or other wastes, have abnormally increased the natural productivity of the water. In Iowa, for example, most of the kills of livestock, waterfowl, and fish brought about by excessive growths of blue-green algae have been traced to very abundant growths of *Anabaena flos-aquae* or *Aphanizomenon flos-aquae* (Rose, 1953). However, a number of species of algae can create hazards to domestic stock, fish, and wildlife under certain conditions (Ingram, 1954).

In fish ponds, water-bloom algae sometimes become so abundant the fish are killed during the night due to exhaustion of the oxygen supply. During the daylight hours, plants give off oxygen as a by-product of their photosynthetic activity, but at night they require oxygen as do other living organisms, thereby sometimes creating oxygen deficiencies below the level necessary to maintain fish life.

Another phenomenon which normally accompanies excessive algae growth is high pH. This is brought about by exhaustion of free and half-bound carbon dioxide and the formation of alkaline carbonates or hydroxides. High pH (9.5-10.5) may not kill fish per se, but fingerling bass and bluegills often cease growing and become emaciated under the extreme conditions that bring it about. The alkaline death point for fish is pH 11.0. Fish production becomes reduced in the pH range 9.5 to 10.5 according to Swingle (1959).

The two most important water-bloom algae that give trouble in fish ponds appear to be Microcystis and Anabaena. The former causes fish ponds to take on a "muddy" appearance, while the latter give off a pig-pen odor when wave action deposits scums on the shores. Either dichlone (Phygon-XL) at 0.05 p.p.m., or copper sulfate at 0.3 p.p.m. is recommended for their control. Recently Lawrence (in a personal communication, 1960) reported that he had obtained good results in the control of Microcystis by suspending 0.8 - 1.0 pound copper sulfate per acre in cloth sacks.

Lake Treatments of Water-bloom Algae

In lakes, copper sulfate is still most widely used. In Minnesota, lake treatments are made at a rate of 5 pounds per surface acre.

In Wisconsin (Mackenthun, 1958), copper sulfate applications to lakes are varied according to alkalinity. Where the methyl orange alkalinity is less than 50 parts per million, 0.3 p.p.m. is used. Where the M.O. alkalinity is greater than 50 p.p.m., one part per million is used to treat the upper two feet of surface water. This is equivalent to 5.4 pounds per surface acre.

Dragging burlap bags containing copper sulfate crystals suspended from boats, is a common method of large-scale treatment.

More efficiency is obtained in lake treatments with equipment illustrated by Mackenthun, (1958), which is reproduced in Figure 2. In this method, water is pumped from the lake with a pump aboard a barge or platform placed across two boats fastened side by side (Figure 3) or mobile trailer (Figure 4) as used by Domogalla (Anonymous, 1959). The use of barges or platforms propelled by an outboard motor, permits transport of larger supplies of chemicals, thereby saving frequent trips to shore. On the discharge side of the pump in this equipment, water is conducted to a drum and sprayed

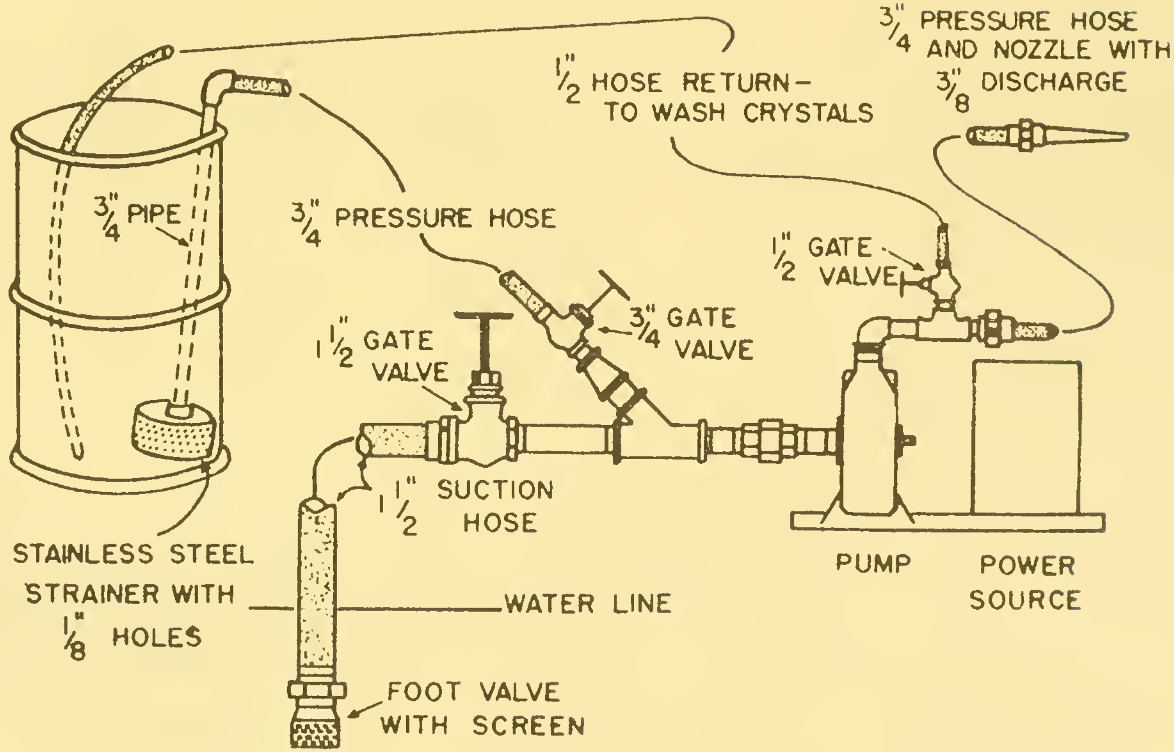

Figure 2.--Equipment design for algae control. Small blue vitriol crystals are placed over perforated drum in chemical solution tank. (after MacKenthun, 1958).

Figure 3.--Trailer barge loaded with sodium arsenite drums leads large scale submersed weed control operation (courtesy of Outboard Marine International and Dr. Bernard Domogalla).

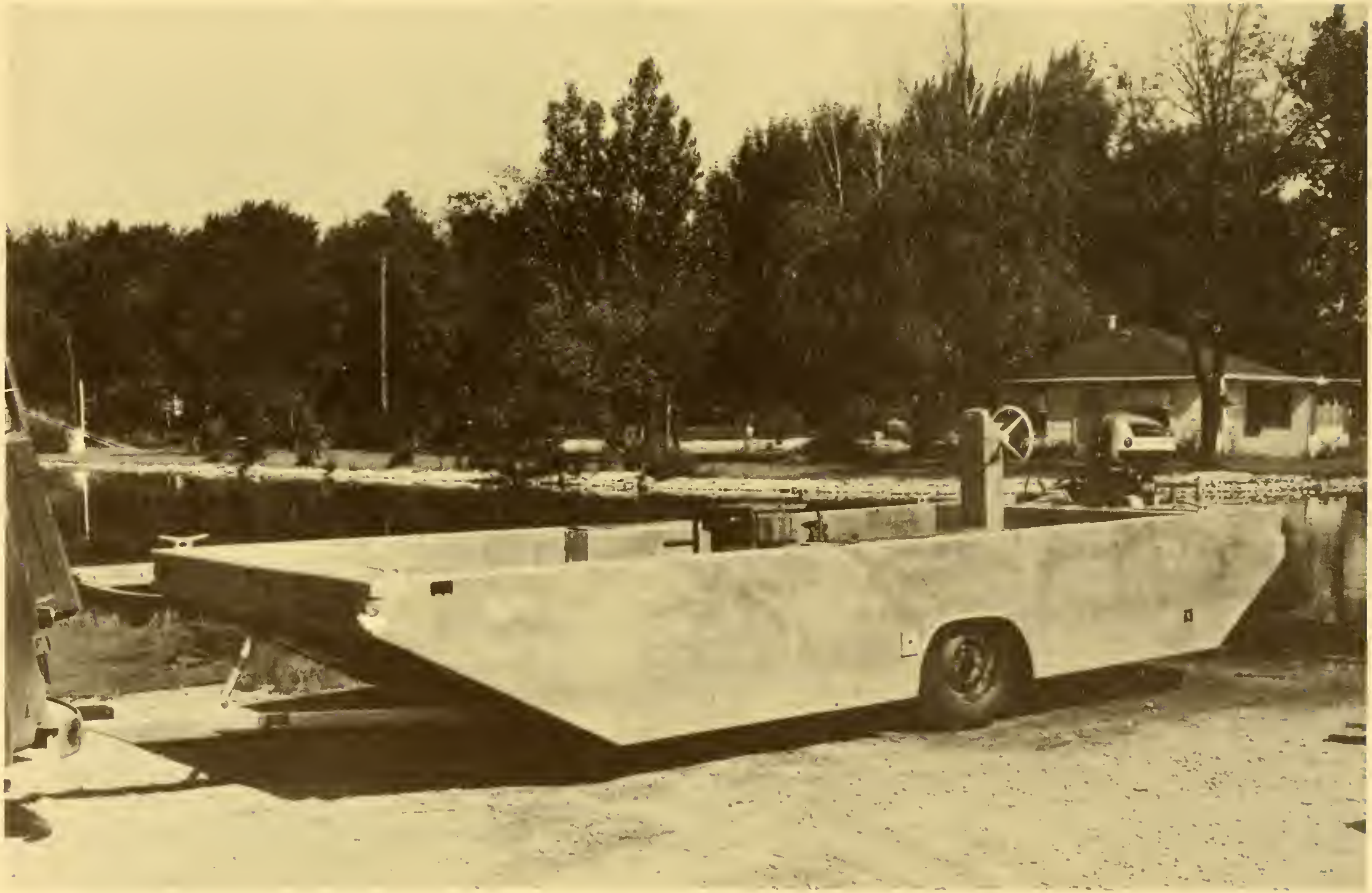

Figure 4.--Trailer barge used for weed control operations. (Courtesy of Outboard Marine International and Dr. Bernard P. Domogalla).

over copper sulfate crystals held near the top of the drum by a bag or basket. Water with the dissolved copper sulfate is picked up by means of a connection with the suction line to the pump. Valves on both lines permit regulation of both intake of water from the lake and volume of flow from the copper sulfate reservoir. Spraying is done with a smooth fire hose (3/4" I.D., pressure) and 3/8" (I.D.) nozzle.

Because of the highly corrosive nature of copper sulfate, pumps and fittings with non-corrosive parts should be used. These have stainless steel or brass parts containing high percentages of copper. The life of the equipment can be considerably prolonged by thorough cleaning after each run.

Bartsch (1954) gives the gallons of saturated copper sulfate solution from the reservoir drum, required per minute to give one p.p.m. in lake water to a depth of one foot, using two spray widths 60 and 80 feet, obtained with 3/8 or 1/2 inch openings, respectively, in the fire hose nozzle.

Table 2.--Gallons of saturated solution of copper sulfate required per minute to give one p.p.m. (after Bartsch, 1954)

Speed of boat	60-foot width of spray			80-foot width of spray		
(miles per hour)	15°C	20°C	25°C	15°C	20°C	25°C
1	.21	.19	.17	.28	.25	.23
2	.42	.38	.35	.56	.51	.47
3	.62	.57	.52	.83	.76	.69
4	.83	.76	.70	1.11	1.01	.93
5	1.03	.95	.87	1.37	1.27	1.16
6	1.24	1.14	1.04	1.65	1.52	1.39

CONTROL OF EMERGENT AND FLOATING-LEAFED AQUATIC PLANTS

The two kinds of plants are considered jointly, because of similarity in control methods.

Cattails, softstem bulrush, arrowheads, plantains, burreed, willows, spikerush, alligator weed and manna grass, are some of the common emergent aquatic plants which tend to form marshes about the borders of ponds. They encroach upon the fish-producing areas and provide unneeded shelter for them. The removal of fish by draining or seining is also made difficult. Spikerush (Eleocharis), for example, may start growing along the wet shores, then, after the pond has been drained and left exposed for some time, spread rapidly over the entire bottom. In succeeding periods of operation, removal of fingerling fish then becomes difficult, for they become stranded until too late to follow the receding water. Stampeding is common in fingerling bass, and it may be fatal in the late stages of draining a pond as the young fish may hide until stranded.

Willows are a constant concern to fish culturists, because they often establish themselves on the banks of ponds where they become hideouts for muskrat burrows or fish enemies, or a hindrance to the cutter bars of mowing machines.

Among the important floating-leafed aquatic plants in ponds and small lakes are water lilies, water hyacinths, watershield, water lettuce, and the duckweeds. Many of these plants have waxy coatings on their leaves which resist penetration of chemicals unless oil carriers or sticker-spreaders are used.

2,4-D, 2,4,5-T, etc.

One of the most effective, economical, and safest herbicides for control of emergent and floating-leafed aquatic plants is the phenoxyacetic compound 2,4-dichlorophenoxyacetic acid (2,4-D). This is the growth regulator type of weed killer which is absorbed by affected plants and translocated to all of their parts. 1/ Effects on aquatic plants are manifested in a number of ways. For example, the petioles, the long slender stems which support the leaves of water lilies, curl when affected by 2,4-D. In the pond weeds (Potomogetons), effects are manifested by rapidly-growing shoots which appear in the axils of leaves, or by defoliations of the stems. Plants affected by this chemical may grow themselves to death, or simply wilt and die from the toxic effects. Most emergent plants turn brown when affected, but in cattails and many other erect plants, the test of effectiveness of treatment is examination of the underground stems, which are a means of propagation or storage of food for new growths. If these root-stocks are in the process of decay, the plants are dead. Even an effective treatment may not kill all plants in a single application.

2,4-D in its pure form as an acid powder is insoluble in water, but it is readily dissolved in the co-solvents triethanolamine and tributylphosphate, one pint and one quart, respectively, of which will dissolve a pound of 2,4-D acid powder. The former solvent is used for introduction of the chemical into water solutions, while tributylphosphate solutions are readily miscible with kerosene, diesel and other oils.

1/ Seaman (1958, p. 212) records work in his department that indicates that 2,4-D moves upward better than downward in alligator weed.

The commercial preparations of 2,4-D are available in the form of (1) esters, which are of two kinds: (a) high volatile esters of methyl, ethyl, propyl, isopropyl, butyl, amyl and pentyl alcohols, the use of which may be restricted in some states, and (b) low volatile esters such as propylene glycol butyl ether ester (Dow), butoxy ethanol ester (AmChem), ethyl hexyl ester and butoxy ethoxy ester (Diamond Alkali); (2) water soluble sodium salts, and (3) water soluble amines which are the liquid salts of the acids.

2,4-D esters are readily introduced into oil solutions, which make them effective on such waxy-coated plants as cattails, water lilies, softstem bulrush, duckweeds and others.

Esters are combinations of the 2,4-D acid and the alcohols. Ester formulations contain emulsifiers for introduction into water. They represent the most common contact herbicides on the market for use on farmlands, lawns, golf courses, etc. The 2,4-D content of ester formulations varies from about 14 to about 40 per cent.

Wetting or spreading agents are sometimes added to 2,4-D as a means of getting the insoluble compound introduced into water as a carrier. In addition they aid adhesion to plant surfaces and penetration.

Several common detergents "Tide", "Surf", mahogany soap, and sodium secondary-alcohol sulphate have been used as wetting agents or spreaders. The detergent concentration runs about 0.25 per cent. The amounts of wetting agents vary from 0.05 to 0.3 per cent, depending upon the kinds of plants to be sprayed. Plants with waxy coats require more of the wetting agent than do more succulent species with relatively unprotected leaf surfaces.

The sodium and amine salts are directly soluble in water and are easy to handle, but they are less effective on the waxy-coated species.

A new technique in the application of organic chemicals, such as the formagens, is the invert emulsion. This is the water-in-oil instead of the conventional oil-in-water emulsion. The invert emulsion is a viscous material with thick creamy appearance. It is less likely to drift and falls to the water surface or ground more quickly and with fewer fine particles than do conventional sprays. Its distribution from aircraft is described by Kirch (1959). Once the invert emulsion has been formulated, it must be kept stirred to keep the components from separating out. According to Seaman (1958), these water-in-oil materials have sticking and penetrating properties superior to many oil-carrier sprays, with only 10 to 15 per cent of the oil being required.

The effectiveness of formagenic formulations is dependent, in general, upon the 2,4-D acid equivalent in them. Container labels show acid equivalents, and, in making purchases, comparisons should be made between price and per cent of 2,4-D acid equivalent advertised on the label.

In treating water lilies, cattails, and many other plants, often several pounds of 2,4-D per acre are required for control. Volumes of herbicide range from 50-300 gallons per acre in ground or boat spraying. Lower gallonage, 50 - 100 per acre, is generally required of oil sprays.

Aerial spraying with 2,4-D is most economical in spraying large areas such as those infested with water hyacinths, requiring only 5 - 10 gallons of herbicide volume per acre.

The following table shows amounts of commercial formulations of 2,4-D or volume of solutions per 100 gallons of spray to be used per acre with 1.0 per cent and 0.5 per cent solutions:

Table 3.--Amounts of commercial 2,4-D formulations to be used per acre

Percentage 2,4-D acid content of herbicide (from label)	Amt. of herbicide to give 10,000 p.p.m. per 100 gallons of spray - 1.0% solution	Amt. of herbicide to give 5,000 p.p.m. per 100 gallons of spray 0.5% solution
90	8 pounds 12 ounces	4 pounds 6 ounces
85	9 pounds 6 ounces	4 pounds 11 ounces
80	10 pounds	5 pounds
70	11 pounds 4 ounces	5 pounds 15 ounces
60	13 pounds 12 ounces	6 pounds 14 ounces
40 (liquid)	2.5 gallons	5 quarts
20 (liquid)	5 gallons	2.5 gallons
10 (liquid)	10 gallons	5 gallons

Note: This table does not allow for interpolations. See Appendix B for methods of more precise calculations.

One-half per cent solutions of 2,4-D (ester or amine) in water carriers will control arrowheads (Sagittaria), or pickerel weed (Pontederia), smartweed (Polygonum), willows (Salix), and many other marginal plants, that do not have waxy coatings on their leaves, when the plants are well wetted. For small scale treatments, 1 pint of 40 per cent 2,4-D in 10 gallons of water will give the desired concentration. The formulation 2,4,5-T is generally regarded as more effective on woody plants than 2,4-D.

For such plants as lotus (Nelumbo), water lilies (Nympheae and Nuphar), watershield (Brasenia), bulrush (Scirpus), cattail (Typha), parrots feather (Myriophyllum), and duckweed (Lemna), the same quantity of 40 per cent 2,4-D ester (1 pint) per 10 gallons of No. 2 fuel oil are suggested. Snow (1949, 1959) observed that sprays containing as low as 0.25 per cent 2,4-D esters in No. 2 fuel oil, or in water containing a detergent (Tide) as a surficant were effective in controlling arrowheads, parrot feather, duckweed, and willows.

Dalapon at 10 - 20 pounds acid equivalent per acre, or 5 pounds amitrole plus 5 pounds dalapon per acre is effective on cattails, reedgrass and other resistant forms. Timmons et. al (1958, p. 408) described the advantages of split applications of amitrole and dalapon in control of cattail. The first treatment was made at a pre-heading stage late in June, and the second treatment was made in early September before the first killing frost. Rates of 5 pounds per acre of amitrole and 10 + 10 of dalapon in a split treatment give effective control.

Water hyacinths can most effectively be controlled by low-pressure spraying of the amine salt of 2,4-D at 4 pounds of acid equivalent per acre and 80 - 100 gallons of solution per acre, but good control is often obtained with 2 or 3 pounds acid equivalent per acre. The reader is referred to "Improving Duck Marshes by Weed Control" by Martin et al. (1957), for methods of control of several important marsh plants that are less frequently encountered by the pond owner or operator. Snow (1958) also gives the results of experiments in control of marginal weeds about ponds, together with recommended treatment rates.

Danger of Aerial Drifts in Spraying of the Formagenic Compounds

Spraying with 2,4-D or 2,4,5-T and similar powerful chemicals can produce serious damage to many valuable agricultural crop plants, such as cotton and grapes, if done at a time when the chemical can be drifted by breezes or winds. Local damage to such garden plants as tomatoes and cucumbers is possible when marginal plants about fish ponds are sprayed on windy days.

The problem of extreme sensitivity of some crop plants to 2,4-D has been met by the formulation of less-volatile compounds such as the sodium salts of 2,2-dichloropropionic acid (dalapon) and 2(2,4,5-trichlorophenoxy) propionic acid (silvex). The former is now used at a rate of 7 pounds acid equivalent per acre to control phragmites, and the latter is used in rice fields for control of herbaceous plants.

Since phenoxyacetic, and perhaps related compounds, can cause polyneuritis when allowed prolonged contact with the human hands or body, care must be taken in handling to keep them off body surfaces.

Cleaning of Equipment Used in Spraying Formagenic Compounds 2,4-D; 2,4,5-T; Sodium Dichlorophenoxyacetate, etc.

Equipment used in spraying should be thoroughly 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 teaspoonful of powdered activated charcoal per gallon is a good rinsing combination. One-half ounce of trisodium phosphate per gallon of water is another effective rinse.

CONTROL OF SUBMERSED AQUATIC PLANTS

Diversity in methods of reproduction and propagation of submersed aquatic plants makes them difficult to control. Most of the coarse weeds are flowering plants 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, including birds. Some plants, like *Anacharis* and coontail (*Ceratophyllum*), have brittle stems. Terminal buds at the tips of stems and sections of stems bearing leaves break off 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 ponds 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 ("water-bloom" algae) are universal in their distribution. They reproduce by means of minute spores which are wind or water-borne. Their rapid increase is often accomplished by simple division of the cells.

Mechanical Methods of Control

Submersed plants can be removed mechanically with an underwater mower, such as illustrated in Figure 5, which employs 3 cutter bars operated from a boat which may use an outboard motor, air motor, or other means of forward propulsion. This mowing device gives good results along resort beaches and is occasionally used in small lakes and fish ponds, but the benefits are usually temporary.

The Ziemsen submarine weed-cutting saw (Figure 6) has long been in use for hand removal of weeds.

Control with Fertilizers

Fertilization has the advantage over chemical weed poisons, because its addition increases productivity of the pond.

In this preferred 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 (N), phosphorus (P), potash (K), and other elements needed by the microscopic plants, may be furnished them on a schedule more favorable to their growth than it is 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. If the new pond is completed late in the fall, fertilization should begin when the weather begins to warm in the spring. The following fertilizer formulas are recommended for new or old ponds:

Figure 5.--Hockney underwater weed cutter (courtesy George C. Hockney).

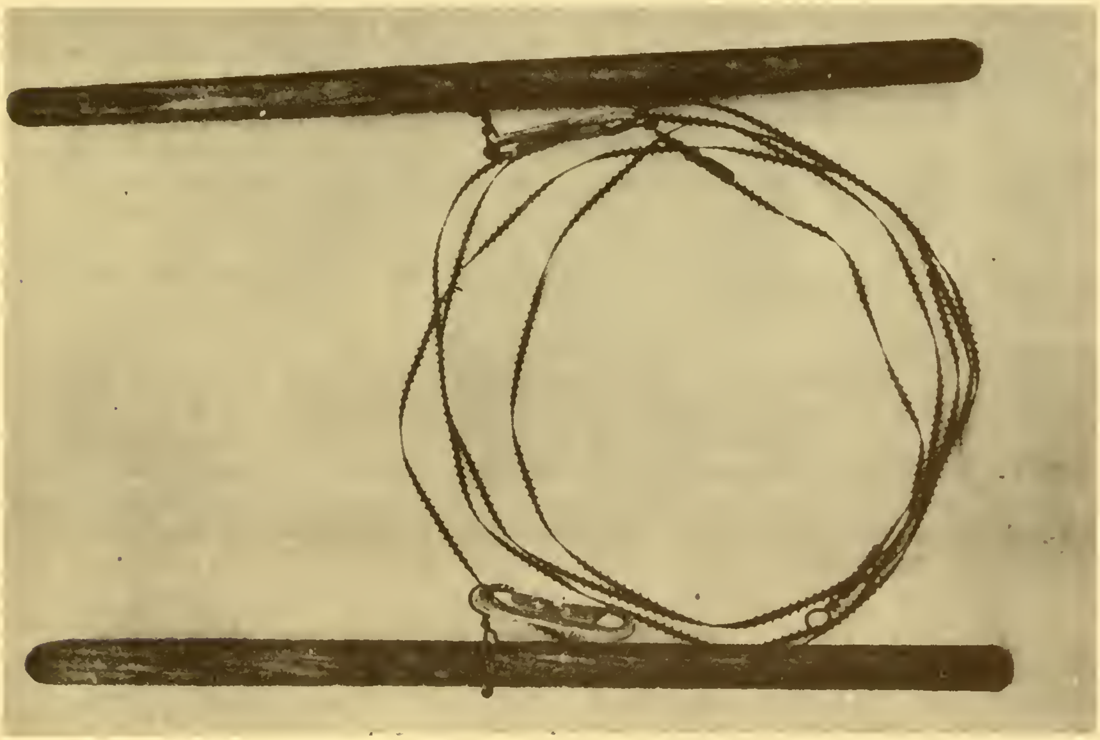

Figure 6.--Ziemsen submarine weed cutting saw.

Table 4.--Inorganic fertilizer formulas (N-P-K), composition in pounds per acre

Pounds of Fertilizer ingredients	10-6-4	8-8-2	6-8-4	5-10-5
Ammonium nitrate (33.5% N) 1/	30	24	18	15
Superphosphate (20% P_2O_5)	30	40	40	50
Muriate of potash (60% K_2O)	7	3.5	7	8
Filler 2/ (powdered limestone, sieved marl, sand, peat, etc.)	33	32.5	35	27
	100	100	100	100

1/ In hard or alkaline waters, ammonium sulfate (20% N) should be used. Pounds per acre for the four above formulas are 50, 40, 30, 25 pounds, respectively.

2/ Filler not needed when above N-P-K fertilizer components are added directly to the pond.

The former practice in applying fertilizers was to broadcast them from the shore, or a boat, into the water. This may still be done, but limnological observations in farm ponds in the south showed that pond waters become stratified during the warmer months and that often there is a non-circulating layer of low-oxygen water near the bottom. Lawrence (1954) recommended the construction of horizontal platforms of about 3.5 feet square area placed one foot below the water surface with a walkway leading out to it. These platforms were located 12-15 feet from shore at the end of catwalks at points where wave action of the surface waters could dissolve away the fertilizer. The sacks of fertilizer are placed on them with the uppermost sides ripped off. Fertilizers were thus dissolved into the surface layer of water where most needed for the stimulation of phytoplankton growths. One such platform located at a point where wave action or movement of waters is greatest suffices in ponds of 1 to 5 acres. One platform for 8 to 10 acres in larger ponds is recommended.

Owners of small ponds may find it more convenient to buy more concentrated fertilizer such as 20-20-5 in smaller (40 pound) sacks, the total contents of which produce results equivalent to the active ingredients within the 100 pound bags.

Where ponds do not respond to fertilization by the above methods, liming may be required. Where the water has a total hardness of less than 15 p.p.m., Zeller and Montgomery (1958) recommended about 1000 - 1500 pounds per acre of agricultural lime or basic slag.

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. Meanwhile, the growth of the submersed plants or their seedlings or new sprouts has been inhibited. With warm weather, the intervals between applications may be increased to weekly periods until the water becomes green with "water-bloom". As in farm pond fertilization, the microscopic plants shade out the larger submersed plants. Rooted plants may break loose and float, forming a scum on the water surface. Oxygen depletion sometimes occurs from too much fertilizer being added at this time. The addition of more nitrogen in fertilizing materials may speed up the decaying process.

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 plan, 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 it was used for recreational purposes by 400 families. Almost immediately after fertilization, water-bloom algae 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.

Chemical Control of Submersed Plants

During the past several years, many new chemicals have been tried for control of submersed aquatic plants. Several of these have proven effective, but such promising herbicides as Diquat, Silvex, Endothal, Simazine, Hyamine 1622, and granular 2,4-D need more extensive field testing before their true value is known. Cost is another very important consideration. Considering these factors, sodium arsenite continues to be the most economical and certain of satisfactory results. A few of the promising new herbicides are listed below. None are known to be harmful to man or livestock.

Diquat (FB.2)

Diquat (1,1'ethylene-2,2'-dipyridylium dibromide) is one of the most promising of the newer chemicals, but it is expensive, costing about $7.00 per pound. Bond observed that it would kill *Elodea densa* at one p.p.m. The 48 hour TL_m for chinook salmon fingerlings was 28 p.p.m., so it is apparent that its safety margin in toxicity to fish is highly satisfactory. Blackburn (1961), in a personal communication, reported that he obtained 100 per cent control of southern naiad (*Najas guadlupensis*) in laboratory experiments at 2.5 p.p.m. and good control in a field experiment in a non-flowing Florida ditch at 3.0 p.p.m.

Endothal

Experiments by Charles R. Walker, Missouri Conservation Commission 1/ with Endothal Weed Killer (2 pounds active ingredient per gallon) showed that 10 pounds per acre (1.0 p.p.m.)were adequate to control coontail (*Ceratophyllum demersum*) through an entire season. *Najas flexilis* was controlled through a four-month period by 2.0 p.p.m. of the same liquid formulation.

Granular formulations of sodium endothal (5 per cent active ingredient) gave 90 to 100 per cent control of *Potamogeton americanus* at 5.0, *P. diversifolius* at 0.5, *P. foliosus* at 5.0, *P. pusilus* at 1.0 parts per million, respectively. Pounds per acre applied ranged from 5 pounds to 50 pounds.

1/ Data furnished through the courtesy of the Missouri Conservation Commission was obtained by their Dingell-Johnson Project F-1-R-9.

Walker observed that over 40 p.p.m. of sodium endothal failed to kill fish when this chemical was used in the liquid and 5 per cent granular form. No adverse affects upon the numbers of bottom animals were noted from treatments to control the above pondweeds.

Hyamine 1622

Bond (1960) considers Hyamine 1622 (paradiisobutyl phenoxy ethoxy ethyl dimethyl benzylammonium chloride) a promising herbicide for control of Elodea densa in ponds and ditches. He considered the cost of the material probably too high for use in large (300 to 3,000 acres) lakes. His laboratory screening tests showed it to be toxic to Elodea densa at 2 p.p.m. and open plot applications in dense stands of this plant indicated that Hyamine 1622 will control Elodea at about 4 p.p.m. The 48-hour TL_m for coho salmon fingerlings is 53 p.p.m. in soft water.

Simazine

Simazine is available in 50 and 80 per cent wettable powders (Simazine 50 W and 80 W) and in an 8 per cent pelletized form. In Missouri Federal Aid Project F-1-R-9 experiments, Charles R. Walker observed that the above-named species of Potamogetons treated with 50 per cent wettable powder as a spray, at a rate of 10 p.p.m. active ingredient, gave most effective results. The minimum lethal concentration of this chemical to fish was over 40 p.p.m. At about $3.00 per pound, the treatment of an acre five feet deep could be very expensive, costing about $240 per acre.

When 20 pounds active ingredient per acre of the 8 per cent pelletized Simazine was tried, good results were also obtained. Ten pounds (1.0 p.p.m.) per acre of this material controlled Potamogeton diversifolius in a pond throughout a season. No adverse effects upon numbers of bottom animals were noted by Walker for either Simazine or sodium endothal.

Silvex

One of the promising new chemicals is 2-(2,4,5-trichlorophenoxy) propionic acid or Silvex. Younger (1958) found that 2.0 parts per million controlled such species as waterweed (Anacharis), mud plantain (Heteranthera), water milfoil (Myriophyllum) and bladderwort (Utricularia). One part per million controlled yellow water lily (Nuphar) and 0.5 p.p.m. white water lily (Nympheae).

Thomaston, et. al (1960) obtained control of Myriophyllum brasiliense, M. heterophyllum, and Utricularia with 1.0 part per million. Three pounds active ingredient per acre controlled white water lily (Nympheae), lotus (Nelumbo), watershield (Brasenia) schreberi), and softrush (Juncus effusus).

Both Younger (1958) and Snow (1959) have noted that the pondweeds (Potamogetons), are somewhat resistant to this chemical in rates up to 2.5 p.p.m. Another disadvantage is that fish in treated ponds occasionally may be rendered unpalatable for some time after treatment. It should not be used in irrigation systems.

On the credit side, Silvex under 5.0 p.p.m. is not hazardous as a poison to humans, livestock or fish.

Granular 2,4-D and Silvex

Granular or pelletized 2,4-D and Silvex have been found effective for control of parrots feather, water lilies, watershield, bladderwort, etc., when applied at rates of 20 to 40 pounds acid equivalent per acre. The rate of 150 to 200 pounds of 20 per cent 2,4-D granules has been found to be effective but slow acting, sometimes requiring as much as 4 to 6 weeks to clear an area. Prolonged residual effects may follow. Truchelut and Williams (1960) have observed that pH of the water affects the success of 2,4-D applications which are more successful under acid conditions. Lack of consistent results with pelletized 2,4-D may be due in part to this ecological factor.

Sodium Arsenite

Sodium arsenite is a cheap and very effective chemical for control of nearly all species of submersed aquatic plants. During the warm summer months, 4.0 parts per million will kill even very dense growths in both hard and soft waters. Where the vegetation is not dense, 2.5 parts per million will provide adequate control. If the vegetation is dense, a sudden and complete kill of vegetation should be avoided, particularly if the pond does not have a fresh supply of water which can be turned in to meet the oxygen demand of decaying vegetation.

In the control of weeds along the shorelines of large lakes, where there is the maximum of diffusion, up to 10 p.p.m. are required for successful treatment. In the treatment of fish ponds, sodium arsenite has a wide margin of safety in its toxicity to fish. About 11 to 12 parts per million are required to kill fish.

In fish ponds, in midsummer, the critical period for fish occurs about 3 days after treatment, when the plants which have fallen to the bottom, begin to decay rapidly. The decomposition uses up oxygen which is also necessary to maintain fish life. In ponds with supply pipes, a moderate amount of fresh water can be turned in, if necessary. In ponds without an inflow, it is recommended that not more than one-half of the total area of the pond be treated at one time. The congregation of fish at the surface or along the shoreline 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.

Rates of Application of Sodium Arsenite

Sodium arsenite is sold in both liquid and powder form. The liquid form is preferable, because it is readily diluted. The greyish sodium arsenite powder is more difficult to handle, because it is not readily dissolved. In cold water, the powder dissolves very slowly at rates over 1/10 pound per gallon.

The heavy, syrupy, strongly-caustic sodium arsenite solution now generally used weighs about 12.63 pounds per gallon and contains 4 pounds arsenious trioxide (As_2O_3) equivalent per gallon, although 9-pound material is coming into more general use. Parts per million of this solution are calculated in relation of gallons of weed killer to cubic feet of water. One gallon of 4-pound weed killer to 4,000,000 pounds of water equals 1 part As_2O_3, by weight, to 1,000,000 parts of water. Four million divided by 62.42 (weight of 1 cubic foot of water) equals 64,082 cubic feet. Therefore, when one gallon of weed killer is added to 64,082 cubic feet of water, the mixture contains one part As_2O_3 per million parts of water.

The quantity of chemical required for a treatment may be calculated as follows: Since one gallon in 64,080 cubic feet equals one part per million, a 4 part per million treatment (the usual recommended rate) requires 64,080 ÷ 4 = one gallon per 16,020 cubic feet of water. Tables 5 and 6 give gallons of sodium arsenite to use when area in acres and average depth in feet are known.

Table 5.--Sodium arsenite application, using four-pound material

Parts per million (p.p.m.)	Gallons four-pound sodium arsenite solution per acre required							
	Average depth of water in feet							
	1	2	3	4	5	6	7	8
2.5	1.7	3.4	5.1	6.8	8.5	10.2	11.9	13.6
4	2.7	5.4	8.2	10.9	13.6	16.3	19.0	21.7
5	3.4	6.8	10.2	13.6	17.0	20.4	23.8	27.2
8	5.4	10.8	16.4	21.8	27.2	32.6	38.0	43.4
10	6.8	13.6	20.4	27.2	34.0	40.8	47.6	54.4

Table 6.--Sodium arsenite application, using nine-pound material

Parts per million (p.p.m.)	Gallons nine-pound sodium arsenite solution per acre required							
	Average depth of water in feet							
	1	2	3	4	5	6	7	8
2.5	.75	1.5	2.25	3.0	3.75	4.5	5.25	6.0
4	1.2	2.4	3.6	4.8	6.0	7.2	8.4	9.6
5	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0
8	2.4	4.8	7.2	9.6	12.0	14.4	16.8	19.2
10	3.0	6.0	9.0	12.0	15.0	18.0	21.0	24.0

Methods of Application

The simplest method of application of sodium arsenite solution is distribution with a long-handled dipper from an unpainted tub placed in the front end of a boat. With some practice, the solution may be distributed in almost a spray-droplet size by giving a quick jerk of the wrist to the handle of the dipper as the solution is being broadcast. This method serves well in small ponds up to about two acres in area. While simple, it is not as thorough as spraying at 40 to 60-pounds pressure with a pneumatic tank and spraying apparatus, but it is safer because of larger droplet sizes.

Another simple method is to mix the commercial material with water and allow the mixture to flow from the container through a weighted piece of garden hose as a boat is rowed in parallel lanes 10 to 20 feet apart over the area to be treated. No dilution is needed if the amount used is large.

A gun-type tree sprayer, Figures 7 and 8, such as is used in apple orchards, connected by a 15-foot length of pressure hose to a 30 or 40-gallon pneumatic tank has been used successfully for several years for treating hatchery ponds. The tank, which may be a wide, squat type to avoid tipping, is provided with an air connection to a gasoline-driven air compressor, handles for lifting the tank into and out of a boat or truck, and a glass steam guage which enables the operator to see how much liquid remains in the tank. Before applying the chemical, the tank may be 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 the contents mixed. An air space should be 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. The entire apparatus, consisting of tank, tree sprayer and connecting hose, tank and air compressor, can be placed in a boat or in the back of a pickup truck from which the spraying of long narrow ponds, 50 to 60 feet wide, can be done by driving about them.

At 50 pounds pressure, with the gun illustrated in Figures 7 and 8, distances up to 50 feet from the boat or truck can be reached for spraying. The type of spray can also be regulated from a fine mist spray to a stream which is usually used because it reaches farther and produces less spray drift.

Precautions in Handling

The operator should use rubber gloves in the mixing to avoid getting the sodium arsenite solution in open cuts in his hands. Protective covering, such as face shields, goggles, coats, etc.,

Figure 7.--Gun-type tree sprayer, air compressor and pneumatic tank used in weed control operations.

Figure 8.--Spraying scum-covered pond with gun-type sprayer.

should be used to protect the body and to prevent damage to person and clothing. If a painted boat is used, care should be taken to protect the paint since it is readily removed by the strongly caustic sodium arsenite solution. If spray reaches the eyes, they should be rinsed immediately, both with water and with boric acid solution.

The strongly caustic solution has a sweet odor which is attractive to livestock. Cattle will either lick or eat treated vegetation at every opportunity. Therefore, every precaution should be taken to prevent spills on the shores of treated waters, and to prevent access of cattle to treated vegetation. To be on the safe side, cattle should be excluded from a treated pond for at least one week. Treatments of water hyacinths with sodium arsenite in the south was abandoned many years ago because of the danger to cattle which waded out into the waterways to feed on the succulent plants.

The fatal dose of arsenic (As_2O_3) to man is 1 to 3 grains (60 to 180 milligrams per liter, or parts per million). In a fish pond treated at 4.0 p.p.m., a man would have to drink from 15 to 45 quarts of freshly treated water to get a fatal dose. The hazard to man is virtually non-existent in most waters where treatments are likely to occur. An antidote is British Anti Lewiste (B.A.L.).

In early treatments with sodium arsenite in upper Mississippi River sloughs, successful control of submersed aquatic plants was obtained with slightly less than 2.0 parts per million, a low rate compared with present day treatments. This rate permitted many plankton organisms and bottom animals to survive (Surber 1932, Surber and Meehean 1931). Midgefly larvae, a staple item in the food of young fishes, even increased in number following treatments. Higher rates of application produce more spectacular results in killing weeds, but rates greater than 4.0 p.p.m. in fish ponds exceed the quantity of sodium arsenite that can be survived by many aquatic animals (Lawrence 1958).

Lake Shoreline Spraying with Sodium Arsenite

Submersed weeds often grow to such density along lake front properties that they interfere with boat passage to and from docks, as well as with bathing and fishing.

The recreational values of beach areas in lakes invaded by weeds can be restored by treatment with sodium arsenite at concentrations ranging from 5 to 10 p.p.m., depending upon the size of the lake, average depth of water, and the exposure of the beach to wind and wave action. In general, sodium arsenite treatment is not practical where the average depth exceeds 8 feet, and where the length of shoreline to be treated is less than about 200 feet (Mackenthun, 1958).

In the spraying of lakeshore properties, efforts are usually made to get property owners to join in combined efforts to rid their shorelines of weeds by treating adjoining beaches simultaneously.

In large scale operations, the heavy drums of sodium arsenite are placed on a barge or upon a platform placed upon two boats secured side by side and propelled by outboard motors. Domogalla (1926, 1935, 1959), a pioneer in the field of large scale weed control treatments, has used a trailer for lake work (see Figure 3).

Thorough mixing of chemical and water in a large operation may be brought about by pumping water directly from the lake by means of a self-priming centrifugal or gear pump, which also draws a regulated volume of sodium arsenite from a drum of the concentrated chemical at the same time. Water from the lake is drawn through a suction hose hung over the side of the barge or platform. On the intake side of the pump, the hose is connected to a 45° Y-branch to which a second hose, connected with a sodium arsenite drum, is also attached. Valves are located in each intake hose line ahead of the Y-branch for controlling rate of dilution of the chemical. The mixed chemical is delivered under pressure from the discharge side of the pump to distances of 40 to 50 feet from a fire hose nozzle held in the hands of the operator.

Figure 9 illustrates the equipment used in Wisconsin (Mackenthun, 1958) and elsewhere in spraying extensive areas with sodium arsenite where a pump with 1½ inch suction and one inch discharge is used.

For a pump with a 1½ inch suction and one inch discharge, the following fittings are used on the suction end: strainer and foot valve; about 7 feet of 1½ inch (I. D.) suction hose; 1½ inch gate valve on intake line; nipple connection to a 1½ inch 45° Y-branch, nipple connection to a second 1½ inch 45° Y-branch where a connection is desired to a second sodium arsenite drum so spraying will not be interrupted in switching to a new drum of chemical; nipple, and union connection to suction end of pump. On the discharge end of pump: a 1 3/4 inch reducer; nipple, union, and nipple; a sufficient length of 3/4 inch pressure hose attached to a smooth fire hose nozzle with 3/8 inch opening to allow freedom of movement in directing the spray from the deck of the barge or platform.

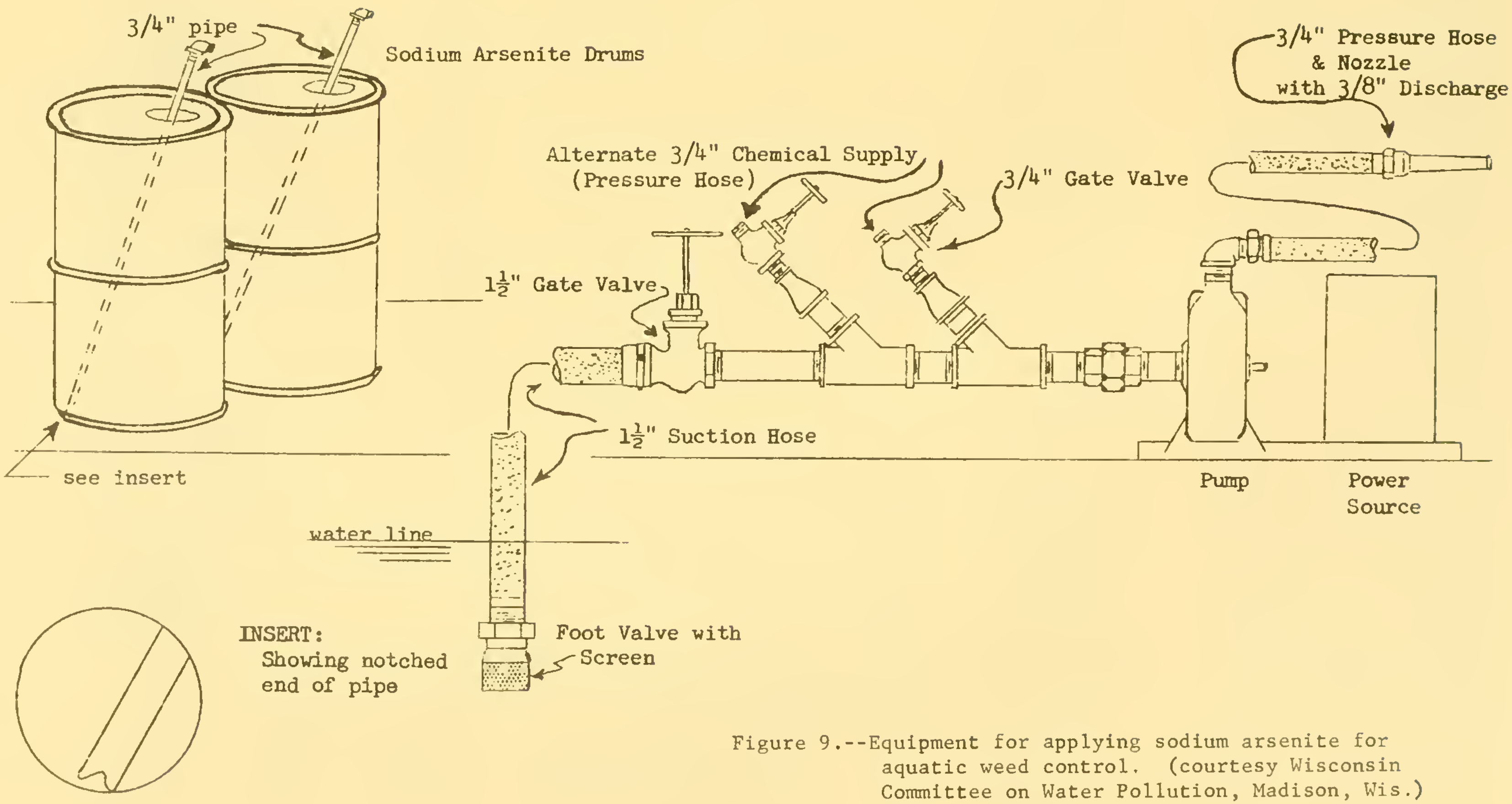

Figure 9.--Equipment for applying sodium arsenite for aquatic weed control. (courtesy Wisconsin Committee on Water Pollution, Madison, Wis.)

The following fittings are used on the supply lines from the sodium arsenite drums; 3/4 inch pipe, long enough to reach to the bottom of the chemical drum after insertion through the bung, notched at the suction end; 3/4 inch right angle elbow; pressure hose to reach to 3/4 inch gate valve; nipple; reducer 1½ to 3/4 inch, nipple for connection to a 1½ inch 45° Y-branch.

A larger pump with 2 inch suction and 1½ inch discharge, powered by a 5 h.p. gasoline engine has been used with success in large operations. A ½ inch smooth fire hose was used on the discharge end with this pump.

SUMMARY

Following the advent of 2,4-D immediately after World War II, many chemicals, mostly organic, were formulated and tested as herbicides. Few have proven more valuable and economical than copper sulfate for algae, 2,4-D for control of emergent and broad-leafed aquatic plants and sodium arsenite for submersed weeds.

Dalapon is proving valuable for control of hard-to-kill grasses, cutgrass, manna grass, cattails, etc.

Silvex appeared for a while to be the answer to the pond operator's dream of a chemical to use for submersed weed control; non-toxic to man, domestic animals, and fish, and safe to handle. It has most of these good points, but is expensive (about $12 per gallon); apparently, it is not as effective on the Potamogetons (largest group of submersed plants) as first thought; it has a higher toxicity to fish than was apparent at first and a phenolic contaminant sometimes causes the off-flavoring of fish in treated ponds. On the definite credit side, however, is its use at low rates of application to kill cowlilies, white water lilies, parrots feather and watershield.

Diquat, available in limited quantities and expensive (about $7 per pound), has the attributes of the ideal herbicide for submersed plants, including low rates of application for pondweeds and low toxicity to fish.

Another promising herbicide for submersed weeds is Hyamine 1622, which is much less expensive (costing about $1.35 or less per pound). It has a low toxicity to fish, but like Diquat, remains to be thoroughly field tested.

Endothal has low toxicity to fish and bottom animals and in limited field tests has proven effective for control of submersed pondweeds at rates varying from 1.0 to 5.0 p.p.m.

Copper sulfate is still most economically, safely, and widely used as an algicide. In situations where the nuisance algae do not respond well to treatments, Dichlone and Hyamine 2389 may be used although their margins of safety in toxicity to fish appear to be small. The latter chemical is effective in killing those swimming pool, raceway, or pond species of algae or diatoms unaffected by chlorine or copper sulfate. Dichlone killed common blue-green algae at rates as low as 30 parts per billion, but the algae came back as is their habit because they are spore formers and because the plant nutrients responsible for their growth in the first place were still there.

No chemical will be perfect in all situations because the problem is biological, involving many ecological factors. Copper sulfate is an example. Where one part per million may destroy the heavy scums of Hydrodictyon in hard water at one pond station, three to five treatments at 0.3 p.p.m. will prove safest in soft water at another.

Fertilization to stimulate phytoplankton growths which shade out the coarse weeds is the most efficient method of weed control and promotes increased biological productivity. Moyle (1949) showed that Aphanizomenon apparently built up resistance in some way to copper sulfate treatments over a period of 26 years of treatment in the Fairmont lakes of Minnesota. In 1921, the species was controlled with dosages between 0.15 to 0.25 p.p.m. In the period 1943-46, 0.5 to 0.8 p.p.m., or more than double the amount was required.

Much progress has been made, particularly in the treatment of emergent and floating-leafed aquatics. The search continues for the perfect algicide and submersed weedicide. Definite and rapid progress is being made and more extensive field testing may show that they are actually at hand.

Appendix A lists many of the effective herbicides used in aquatic weed control work today, together with the quantities recommended for control of nuisance plants.

American lotus or yonkapin

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Pickerel weed

Water hyacinth

Appendix A.--Chemical Control Agents and Quantities Required to Control Aquatic Plants

Name of plant	Chemical control agent	Rate to kill (parts per million, pounds per acre, or per cent active ingred.)	Carrier
Algae:			
Blue-green algae			
Microcystis, Anabaena,			
Aphanizomenon, etc.	Hyamine 2389	10.0 p.p.m.	Water
	Dichlone	0.05 p.p.m.	"
	Copper sulfate	0.3 p.p.m. (soft water)	"
	Copper sulfate	1.0 p.p.m. (hard water)	"
Green algae (general)			
Spirogyra, Oedogonium,			
Hydrodictyon, Cladophora			
Pithophora, etc.	Hyamine 2389	10.0 p.p.m.	"
	Roccal	0.1-0.2 p.p.m.	"
	Dichlone	0.15 p.p.m.	"
	Copper sulfate	1.0 p.p.m. (hard water)	"
	Copper sulfate	0.3-0.5 p.p.m. (soft water)	"
	Sodium arsenite	4.0 p.p.m.	"
Musk grass (Chara)	Copper sulfate	1.0 p.p.m. (hard water)	"
	Copper sulfate	0.5 p.p.m. (soft water)	"
Emergent plants:			
Cattail (Typha)	Dalapon	10-20 lbs. per acre	"
	Amitrole	10 lbs. per acre	"
	Amitrole	5+5 lbs. per acre (split season)	"
	2,4-D isopropyl ester	5 lbs. per acre 1/	Diesel oil 2/
	Dalapon	10+10 lbs. per acre (split season)	Water
	2,4-D ester	0.5 per cent(ground treatment)	

1/ In aerial spraying, three applications of 5 gallons of carrier per acre are made about a month apart.
2/ Oil carrier may be #2 fuel oil, kerosene, or diesel oil.

Appendix A.--Continued

Name of plant	Chemical control agent	Rate to kill (parts per million, pounds per acre, or per cent active ingred.)	Carrier
Emergent plants (cont'd):			
Pickerel weed (*Pontederia*)	Silvex	2-4 lbs. per acre (A.I.)	Water
	2,4-D esters, amines, salts	0.5% 3/	"
Cutgrass (*Leersia*)	Dalapon	20 lbs. per acre (acid equiv.)	"
Lotus (*Nelumbo lutea*)	2,4-D esters	0.5%	Oil
Alligator weed (*Alternanthera philoxeroides*)	2,4-D esters	(0.5%)	Water
	and Silvex	(2.0 p.p.m.)	"
Burreed (*Sparganuim*)	2,4-D esters, amines	0.5%	"
Arrowhead (*Sagittaria latifolia*)	2,4-D esters, amines, salts	0.5%	"
Softstem bulrush (*Scirpus validus*)	2,4-D esters	0.5%	Oil
Soft rush (*Juncus effusus*)	Silvex	3.0 lbs. per acre	Water (1-80)
Needlerush (*Eleocharis acicularis*)	2,4-D acetamid	10 lbs. per acre	"
	2,4-D esters	0.5%	Oil
	Silvex	0.25 p.p.m.	Water
Manna grass (*Glyceria*)	Dalapon	10 lbs. per acre	Water (1-10)
Marginal grasses and sedges	Amatrole-dalapon	5 lbs. per acre of each	Water
	2,4-D esters	1.0%	Oil

3/ A 0.5 per cent solution of 40% 2,4-D (See Table 3) will contain about 4 pounds of active ingredient per 100 gallons of carrier for a one acre treatment.

Appendix A.--Continued

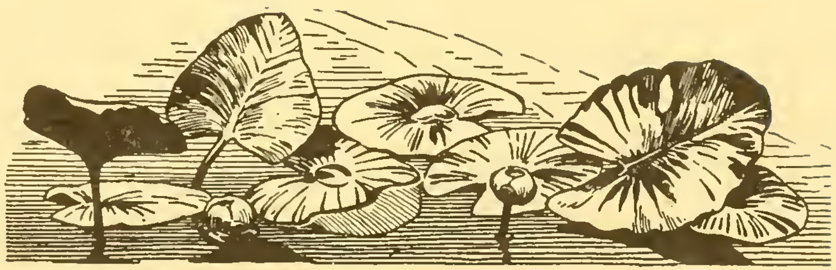
Name of plant	Chemical control agent	Rate to kill (parts per million, pounds per acre, or per cent active ingred.)	Carrier
Emergent plants (cont'd):			
Parrots feather (Myriophyllum brasiliense)	2,4-D esters	0.5%	Oil
	Silvex	2.0 p.p.m.	Water
Johnson grass (Zizaniopsis miliacea)	Dalapon	40-60 lbs. per acre	Water (50-150 gal. p/ac.
Water chestnut (Trapa natans)	2,4-D esters	1.0%	Oil
Floating-leafed plants:			
Duckweed (Lemna minor)	2,4-D esters	0.25%	Oil
Water hyacinth (Eichornia crassipes)	2,4-D amine	0.5%	Water
	2,4-D esters	0.5%	"
Water primrose (Jussiaea)	2,4-D esters	1.0%	"
Water lettuce (Pistia stratiotes)	2,4-D esters	0.5%	Oil
Water shield (Brasenia Schreberi)	2,4-D esters	0.5%	Oil
	2,4-D granulated (20% act. ingr.	100 lbs. per acre	
	Silvex	3.0 lbs. per acre (acid equiv.)	Water
Cowlily or Spatterdock (Nuphar)	2,4-D esters	0.5%	Oil
	Silvex	6.0 lbs. per acre (acid equiv.)	Water
White waterlily (Nymphaea)	2,4-D esters	0.5%	Oil
	Silvex	3.0 lbs. per acre (acid equiv.)	"
	2,4-D granulated 20%	100 lbs. per acre	"

Appendix A.--Continued

Name of plant	Chemical control agent	Rate to kill (parts per million, pounds per acre, or per cent active ingred.)	Carrier
Submersed plants:			
Stonewort (*Chara*)	Copper sulfate	0.3 p.p.m. (soft water)	Water
	Copper sulfate	1.0 p.p.m. (hard water)	"
Waterweed (*Elodea*)	Diquat	1.0 p.p.m.	"
	Hyamine 1622	4.0 p.p.m.	"
	Sodium arsenite	2.5-4.0 p.p.m.	"
Coontail (*Ceratophyllum demersum*)	Sodium endothal	1.0 p.p.m.	"
	Sodium arsenite	2.0-4.0 p.p.m.	"
Water milfoil (*Myriophyllum heterophyllum*)	Silvex	1.0 p.p.m.	"
	Sodium arsenite	4.0 p.p.m.	"
White-water crowfoot (*Ranuculus aquatilis*)	Sodium arsenite	3.0-4.0 p.p.m.	"
Pond weeds (all varieties)	Sodium arsenite	4.0 p.p.m.	"
Curly-leaf pondweed (*P. crispus*)	Sodium arsenite	4.0 p.p.m.	"
Leafy pondweed (*P. foliosus*)	Sodium arsenite	4.0 p.p.m.	"
Fine-leaf pondweed (*P. filiformis*)	Sodium arsenite	2.0-4.0 p.p.m.	"
Naiad (*Najas flexilis*)	Sodium arsenite	4.0 p.p.m.	"
Naiad (*Najas guadalupensis*)	Diquat	3.0 p.p.m.	"
	Sodium arsenite	4.0 p.p.m.	"
Water stargrass (*Heteranthera dubia*)	Sodium arsenite	2.5-4.0 p.p.m.	"
Bladderwort (*Utricularia gibba*)	Silvex	1.0 p.p.m.	"
Fanwort (*Cabomba caroliniana*	Sodium arsenite	4.0 p.p.m.	"

Appendix A.--Continued

Name of plant	Chemical control agent	Rate to kill (parts per million, pounds per acre, or per cent active ingred.)	Carrier
Woody plants:			
Black willow (*Salix nigra*)	2,4-D, 2,4,5-T esters or amines	0.5%	Water
Poison ivy (*Rhus toxicodendron*)	2,4-D esters	1.0%	"
Buttonbush (*Cephalanthus occidentalis*)	2,4-D, 2,4,5-T esters	2.0%	"
Ragweed (*Ambrosia trifida*)	2,4-D esters, amines or sodium salts	0.5%	"



Yellow pondlily or spatterdock

Appendix B. Application Formulas

The product description usually gives an account of its composition and directions for use. Appendix A shows effective rates of treatment and tables in the text supply data from which needed quantities of herbicides may be determined. They do not allow for interpolation, however.

The following formulas from Martin et al (1957, p. 12) are repeated for more precise calculations:

POUNDS-PER-ACRE FORMULAS: MAKING SPRAY SOLUTIONS FOR A PARTICULAR NUMBER OF POUNDS PER ACRE OF ACID EQUIVALENT OR ACTIVE INGREDIENTS:

Using liquid herbicide:

The pints needed per 100 gallons of solution =

$$\frac{\text{wanted lbs. acid equiv. or act. ingr. per acre} \times 800}{\text{gals. spray per acre} \times \text{lbs. acid equiv. or act. ingr. in 1 gal.}}$$

Example: If a 2,4-D formulation containing 4 pounds acid equivalent per gallon is to be applied at 5 pounds acid equivalent in 120 gallons of solution per acre, the pints needed per 100 gallons of solution are:

$$\frac{5 \times 800}{120 \times 4} \text{ or 8.3 pints}$$

The milliliters needed per gallon of solution =

$$\frac{\text{wanted lbs. acid equiv. or act. ingred. per acre} \times 3785}{\text{gals. spray per acre} \times \text{lbs. acid equiv. or act. ingr. in 1 gal.}}$$

Using solid (dry) herbicide

The pounds needed per 100 gallons of solution =

$$\frac{\text{wanted lbs. acid equiv. or act. ingred. per acre} \times 100}{\text{gals. spray per acre} \times \text{\% acid equiv. or act. ingred.}}$$

Example: If a formulation of Dalapon containing 71% acid equivalent is to be sprayed at the rate of 30 pounds acid equivalent in 200 gallons of solution per acre, the pounds of herbicide needed per 100 gallons of solution are:

$$\frac{30 \times 100}{200 \times .71} \text{ or 21.1 pounds}$$

POUNDS-PER-100-GALLONS FORMULAS: MAKING SPRAY SOLUTIONS WITH A PARTICULAR NUMBER OF POUNDS OF ACID EQUIVALENT OR ACTIVE INGREDIENTS PER 100 GALLONS:

Using liquid herbicide:

The pints needed per 100 gallons of solution =

$$\frac{\text{wanted lbs. acid equiv. or act. ingred. per 100 gals.} \times 8}{\text{lbs. acid equiv. or act. ingred. in 1 gal. herbicide}}$$

Example: If a 2,4,5-T formulation containing 4 pounds acid equivalent per gallon is used to prepare a solution with 5 pounds acid equivalent per 100 gallons, the pints needed per 100 gallons are

$$\frac{5 \times 8}{4} \text{ or 10 pints}$$

Using solid (dry) herbicide

The pounds needed per 100 gallons of solution =

$$\frac{\text{wanted lbs. acid equiv. or act. ingred. per 100 gals.}}{\text{\% acid equiv. or act. ingred. in the herbicide}}$$

Example: If an Ammate formulation containing 95% active ingredients is used to prepare a solution with 60 pounds active ingredients per 100 gallons of solution, the pounds per 100 gallons are:

$$\frac{60}{0.95} \text{ or 63.2 pounds}$$

Appendix C. Herbicide Products and Sources

Chemical Name	Product Name	Manufacturer
Algicides		
Alkyl dimethyl-benzyl ammonium chloride	Roccal	Winthrop Stearns Chem. Co. 17 Varick St. New York, N. Y.
Copper sulfate ($CuSO_4 . 5H_2O$)	Copper sulfate	J. T. Baker Chem. Co. Phillipsburg, N. J.
"	"	Merck & Co., Inc. Rahway, N. J.; St Louis, Mo.; Los Angles, Calif.; New York, N. Y.
"	"	Mallinckrodt Chem. Works St. Louis, Mo.; Los Angeles, Calif.; Chicago, Ill.; Philadelphia, Pa.
"	"	Phelps Dodge, Corp. 300 Park Ave. New York 22, N. Y.
2,3-dichloro-1,4-naphthoquinone (dichlone)	Phygon-XL	Naugatuck Chen. Co. Naugatuck, Conn.
Alkyl (C_9-C_{15}) totyl methyl trimethyl ammonium chloride	Hyamine 2389	Rohm and Haas 712 Locust St. Philadelphia, Pa.
Herbicides		
Alkanolamine salts of 2,4-D (of the ethanol and Isopropanol series)	2-4 Dow Weed Killer, Formula 40	Dow Chem. Co. Agri. Chemical Sales Dept. Midland, Mich.
Amine salts of 2,4-D (liquid)	DuPont 2,4-D 74% Amine Weed Killer	E. I. duPont de Nemours Co. Grasselli Chem. Dept. Wilmington 98, Del.
3-Amino-1,2,4-triazole	Amitrol	American Chem. Paint Co. Ambler, Pa.
Butoxy ethoxy ester of 2,4-D		Diamond Alkali Co. 300 Union Commerce Bldg. Cleveland 14, Ohio

Chemical Name	Product Name	Manufacturer
Butyl ester of 2,4-D	Weedestroy 40	Riverdale Chemical Co. Harvey, Ill.
Butoxy Ethanol esters of 2,4,5-T and 2,4-D	Weedone Brush Killer 32	American Chem. Paint Co. Ambler, Pa.
Butyl ester of 2,4,5-T	Esteron 245	Dow Chemical Co.
2,2-dichloropropionic acid sodium salt	Dalapon	Dow Chemical Co.
3,6-endoxo hexohydrophthalic acid	Endothal	Pennsalt Chemical Corp. Tacoma, Wash.
1,1'-ethylene-2,2'-dipyridylium dibromide	Diquat	California Spray Chemical Richmond, Calif.
Ethyl ester of 2,4-D	Weedone Concen trate 48	American Chem. Paint Co. Ambler, Pa.
Ethyl ester of 2,4-D	Weed-No-More	Sherwin Williams 1800 Guild Hall Bldg. Cleveland,Ohio; Chicago, Ill.
Paradisobutyl phenoxy ethoxy ethyl dimethyl benzylammonium chloride	Hyamine 1622	Rohm and Haas 712 Locust St. Philadelphia, Pa.
Ethyl hexyl ester of 2,4-D		Diamond Alkali Co.
Isopropyl ester of 2,4-D	Esteron 44	Dow Chemical Co.
Isopropyl ester of 2,4-D	Pittsburgh Ester Weed Killer No. 44	Dow Chemical Co.
Methyl ester of 2,4-D	Ded-Weed "Me 5"	Thompson-Hayward Chem. Co. Kansas City, Mo.
Propylene glycol butyl ether ester of 2,4-D		Dow Chemical Co.
Sodium salt of 2,4-D	Sodium 2,4-D (83%) Weed Killer	Dow Chemical Co.
Sodium salt of 2,4-D	DuPont 83% Sodium 2,4-D weed Killer	E. I duPont de Nemours Co.

Chemical Name	Product Name	Manufacturer
Sodium arsenite 1/	Atlas "A"	Chipman Chem. Co., Inc. Bound Brook, N. J.
Sodium arsenite	Sodium Arsenite	Reade Mft. Co., Inc. 185 Hoboken Ave. Jersey City, N. J.
Sodium Arsenite	Sodium Arsenite	General Chemical Co. 40 Rector Street New York, N. Y.
"	"	Jefferson Chemical Works Pine Bluff, Ark.
"	"	Hamilton Mfg. Co. Rahway, N. J.
"	"	James Goode, Inc. 2107 E. Susquehanna Ave. Philadelphia, Pa.
"	"	Los Angeles Chemical Co.
"	"	Pennsylvania Salt Mfg. Co. 100 Widener Bldg. Philadelphia 7, Pa.
Sodium trichloroacetate	Sodium T C A (90%)	Dow Chemical Co.
2-chloro-4,6-bis(ethylamino)-s-triazone	Simazine	Geigy Agricultural Chem. Yonkers, N. Y.

Wetting Agents or Spreaders

Product Name	Manufacturer
DuPont Spreader-Sticker	E. I. duPont de Nemours & Co.
Household detergents (Tide, Vel, Surf, Etc.)	

1/ Solutions containing 4 pounds arsenic trioxide per gallon are sold in 5 and 55 gallon drums.

Product Name	Manufacturer
In-181-P, DuPont Wetting Agent	E. I. duPont de Nemours & Company
Tergitol Wetting Agent-4	Union Carbide & Carbon Co., 30 E. 42nd St., New York 17, N. Y.
Vatsol OS, 66% paste	American Cyanamid & Chemical Corp. 30 Rockefeller Plaza, New York 20, N. Y.
Emulsifiers 1/	
Anatrox A-400	General Aniline & Film Corp., 230 Park Ave. New York 17, N. Y.
California Spray Emulsifier, No. 5	California Spray-Chemical Corp., Leucas and Ortho Way Richmond 4, California
Dressinate 91	Hercules Powder Co., 923 King St. Wilmington, Delaware
G-1255 and G-1283	Atlas Powder Co.
Clyceryl Laurate 3909	Glyco Products, Inc. 26 G Court St. Brooklyn 2, N. Y.
Intracol "M"	Synthetic Chemicals, Inc., 355 McLean Blvd. Paterson 4, N. J.
Mulsors	Synthetic Chemicals, Inc.
Mulsor V 7	Synthetic Chemicals, Inc.
Neutronyx 834	Onyx Oil and Chemical Co., Jersey City New Jersey
Oil Soluble petroleum sulfanate (Mahogany soaps)	California Spray-Chemical Corp.

1/ See "Detergents and Emulsifiers", John W. McClutcheon, Inc., 475 Fifth Ave., New York, N. Y.

Product Name	Manufacturer
Petromix 9	L. Sonneborn Sons, Inc. 300 4th Ave., New York 10, N. Y.
Spans 40,60,65,80,85 (non-ionic)	Atlas Powder Co. Wilmington 99, Del.
Sterox SK	Monsanto Chemical Co. 1700 S. 2nd St. St. Louis 4, Mo.
Triton	Rohm and Haas Co.
Tweens 40,50,65,80,85 (non-ionic)	Atlas Powder Co.
<u>Solvents for 2,4-D</u>	
Tributylphosphate	Amend Drug & Chemical Co. 117 East 24th St., New York, N. Y.
"	Commercial Solvents Corp. Terre Haute, Ind.
"	Ohio Apex Co. Nitro, W. Va.
Triethanolamine	Dow Chemical Co. Midland, Mich.
"	Carbide and Carbon Chemical Corp. 30 East 42nd St., New York, N. Y.
"	Amend Drug & Chemical Company
<u>Weed Cutting Machines</u>	
Ziemsen Weed Saw	Aschert Brothers, LaCanada, California
Hockney Underwater Weed Cutters	George C. Hockney & Co. Silver Lake, Wis.

NOTICE

The listing of these products and manufacturers does not denote an endorsement by the United States Fish and Wildlife Service or the writer. In many cases, the products listed are only a few of many products, or an example of these products. The manufacturers are listed in a number of catalogs. The manufacturer's address is not repeated where it has already appeared above in these lists.

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