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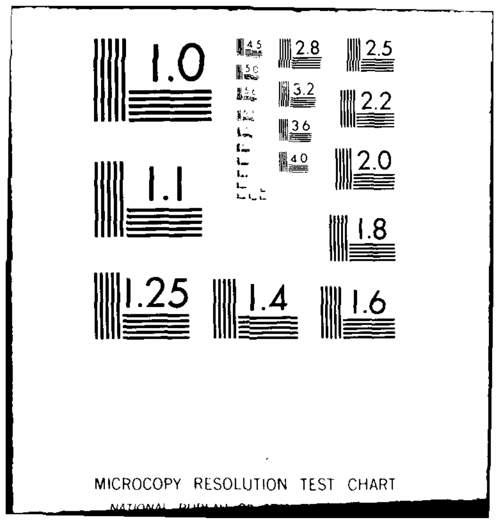
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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

Field	Entry
1. REPORT NUMBER	N/A
2. GOVT ACCESSION NO.	AD-A093 708
3. RECIPIENT'S CATALOG NUMBER	N/A
4. TITLE (and Subtitle)	Nuisance Aquatic Macrophyte Growth in the Northwest
5. TYPE OF REPORT & PERIOD COVERED	N/A
6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s)	Ernie Hesser ~~and~~ E.O. Gangstad
8. CONTRACT OR GRANT NUMBER(s)	DACW68-72-C-0269
9. PERFORMING ORGANIZATION NAME AND ADDRESS	University of Idaho Moscow, Idaho 83843
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	N/A
11. CONTROLLING OFFICE NAME AND ADDRESS	Office, Chief of Engineers Washington, D. C.
12. REPORT DATE	~~December 12,~~ 1980
13. NUMBER OF PAGES	~~Unclassified~~ 22
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	
15. SECURITY CLASS. (of this report)	unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	

16. DISTRIBUTION STATEMENT (of this Report)

Distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

None

DTIC ELECTE JAN 13 1981 S D C

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Aquatic Macrophytes
Nuisance growths

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Aquatic macrophytes of the Columbia and Snake River watersheds were observed at 723 sites in Washington, Oregon, and Idaho and classified according to adjacent land use, water body type, altitude, water temperature, and nuisance growth. The prevalence of eight weed species was subjected to matrix analysis. Nuisance weed growths were most extensive in water bodies where the surrounding land area was near a population center, was heavily grazed by livestock, or received irrigated agricultural runoff.

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Nuisance Aquatic Macrophyte Growth in the Northwest

INTRODUCTION

Nuisance aquatic macrophyte growth is a common occurrence in many of the natural and impounded resource waters of the northwest, the most conspicuous of these are flowering plants. They can be divided into three categories based on the depth of water in which they grow: submergent, floating (attached or unattached), and emergent aquatic plants.

Submersed aquatic plants are found in deep water. They are usually attached to the bottom. Generally they are found entirely under water except for some species which, at flowering time, may protrude a short distance above the surface where the action of wind and insects aid in the pollination of flowers. After pollination, flowers and stalks withdraw to below the surface where the fruits mature. Pondweeds, waterweeds, coontails, and water milfoils are among the common submergents. Many have roots that are simple and delicate, used only for anchoring plants. The nutrients required for growth are obtained from surrounding water.

Floating aquatic plants are found in shallow water. Attached floaters, such as water lilies, watershield, and spatterdock usually are rooted in the mucky bottom and absorb their nutrients from the bottom mud. The leaves and flowers either float or are raised slightly above the surface, and the flowers are pollinated by insects. Thick masses of floating leaves reduce light penetration to the bottom, thus limiting the growth of submerged plants below. Unattached floaters, such as the duckweeds, obtain their nourishment from the water. Wolffia, the smallest of the aquatic flowering plants, may grow in clusters and have a single leaf about the size of a pinhead.

Emergent aquatic plants grow along the shoreline in shallow water and are sometimes called marsh plants. Their roots, imbedded in the bottom of the pond, obtain mineral nutrients from the soil. Their stems, leaves, and flowers protrude well above the water line. Emergents include the cattails, arrowheads, rushes, reeds, and sedges. These may grow in moist bog locations or in water up to several feet deep. Spear-like, grass-like, or arrow-shaped leaves are found on many of the aquatic plants in this group. The variation in leaf form, which is related to water depth, sometimes make identification of certain emergents difficult. For example, the leaves on the same species of arrowhead may vary from straight, spear-like blades to broad, arrow-shaped blades.

Distribution

Some nuisance aquatic plants reproduce from seeds that fall into the water and are carried by currents or birds to new aquatic locations. Other seeds may be disbursed by the wind. Some seeds germinate immediately, while others remain in the bottom mud for years before germinating.

In addition to seed production, many aquatic plants also reproduce vegetatively by runners and fragmentation. Species that reproduce by fragmentation present a peculiar problem in control. Mechanical methods of removal, such as cutting and raking, should not be used. If an under-water mowing machine is employed, fragments of the mowed plant float with the current and may grow new roots, anchor, and thrive in another area. The problem is intesified instead of being eliminated.

Winter buds, or turions (coontail and pondweed) in the late summer and fall are method of reproduction for some species of submerged plants. The winter buds preserve the plant through the rigorous cold season.

Effects of Environmental Factors

Environmental factors which inhibit growth are deep water, steep shoreline slopes, unstable bottoms, cold water, colored or turbid water, and water of low fertility. In contrast, lakes or ponds that are subject to dense aquatic plant growth usually have two or more of the following characteristics: shallow depth, gently sloping shoreline, stable bottoms, warm water, clear water, and water of high fertility.

Soft water has a low mineral content which results in low fertility. Ponds or lakes of this nature often have sparse vegetation composed of pondweeds, bladderworts, water lillies, and some species of milfoils. Hard water has a high mineral content and a correspondingly high fertility. Ponds of this type often support a dense growth of many different species.

Fertility of soft water impoundments may be increased through drainage from fertilized fields, feedlots, or barnyards. Nutrients also may be brought in by effluent from septic tanks and other waste disposal systems.

The bottom soil in lakes and ponds influences the number and species of plants that will grow. Most aquatic plants grow best on a mixture of sand and organic soils. Soft, mucky soils may be unfavorable.

Growth of Algae

Algae are the most common and most uniformly distributed of all aquatic plants. Many species, including representatives of the green, blue-green families, as well as the filamentous and stonewort types grow in natural and impounded waters. When they occur in masses, they can be seen without a microscope. Some appear as thick, filamentous mats, often called pond scum. Others may form a green, fur-like coating on stones and other bottom objects.

Suspended forms of algae make up part of the great number of small plants and animals known as plankton. Plankton algae are the most important plants in all natural bodies of water. These microscopic plants utilize carbon dioxide, water, and sunlight to manufacture carbonhydrates and other energy chemicals. Thus, they serve as the beginning of the food chain which supports most higher forms of aquatic life. In large numbers, plankton algae may color the water brown, yellow, pea-soup green, or even red during the warm seasons of the year. When this occurs, the lake or pond is said to be "working". These blooms may indirectly provide food for fish, but they may also make water undesirable for swimming or fishing, or for use as a domestic water supply. Each ounce of water in this condition contains millions of microscopic algae cells.

Another type of algae, the stonewort or muskgrass, has a strong, musky odor, and stonewort is sometimes encrusted with calcium deposits which give a rough, gritty texture. These plants consist of an erect, central main stem from which sprout clusters of branches at various intervals. They may grow as tall as 2 or 3 feet, and can completely cover a pond or lake bottom. Because of other size and growth, these species of algae may be mistaken for flowering plants.

Energy

Aquatic plants, like all other green plants, use energy from the sun to manufacture carbohydrates. Part of the energy obtained is essential for the growth of the plant itself. The excess energy is stored in the form of carbohydrates, oil, and other products. It is this stored energy that supports most other organisms in aquatic environments. Submerged aquatic plants contriubute to the water environment by taking in carbon dioxide and relasing oxygen during photosynthesis.

Food Chain

Algae and flowering aquatic plants form the base of the food pyramid, or the first link in the food chain. These plants are called producers, and must be presented in great abundance to support the aquatic animal population, termed the consumers. Organisms that feed directly on these plants are called primary consumers. Part of the energy transferred to the consumer through food is used in its own growth, and the excess is stored. The primary consumer is eaten in turn by secondary consumer, and so forth as the cycle of energy utilization and storage is repeated up the food pyramid. As the food pyramid becomes higher, or the food chain longer, fewer individual organisms can be supported.

The stems and leaves of the submerged parts of flowering plants serve as host for a whole community of microscopic organisms, all of which contribute to the food chain of the pond or lake. Bacteria, fungi, algae, diatoms, protozoans, insect larvae, thread worms, bristle worms, rotifers, and small crustaceans are the principal members of the community of organisms that live on and around the larger plants. The population of this community is spread over all leaf and stem surfaces. Increasing in numbers until the end of the summer, this microscopic community provides support for the larger organisms including fish.

Animal Habitat

The underwater plants contribute in another way to the ecological structure of the total pond or lake community. Many of the free-living and swimming creatures, such as fish and amphibians, use plant beds as places to deposit eggs. The young of many fish use these beds for shelter from predators, or they seek the plants as a feeding area since a rich supply of food organisms is usually available there.

Pondweeds, arrowheads, bulrushes, and reeds are important foods for wildlife. The snapping turtle's diet consists of nine-tenths vegetable matter; plants make up two-thirds of the food for the smaller painted turtle. Muskrats eat the rootstocks, tubers, and stems of emergent plants, including cattails, arrowheads, bulrushes, and water lilies.

Filling

In the course of thousands of years, a pond or lake will fill and become dry land. The deeper the lake, the longer it will take to fill. This filling process is aided by the growth of aquatic plants in several ways. The continued cycle of plant growth and decomposition creates a slow building up of organic matter in the basin. Plants also retard the flow of water and thereby cause suspended material to settle to the bottom. As the filling progresses, plants of the shallower zones become established in the former deeper zones. Most bogs and swamps are lakes that are being filled by these processes.

Water Pollution

Pollution associated with aquatic plant growth may be of two types: pollutants which inhibit growth and those which stimulate growth. Although both forms can be serious, this discussion is developed primarily around the growth-stimulating pollutants.

The chemicals that stimulate growth are mainly nitrogen and phosphorus compunds that discharge from sewage plant effluents, home waste disposal systems, food-producing plants, and well-fertilized agricultural watersheds. These material stimulate profuse growth of both algae and flowering aquatic plants.

Depending on conditions, a polluted pond or lake may be either excessively turbid and scum coated or clear and choked with weeds. Either condition indicates water relatively high fertility and optimum conditions for algae or for larger plants. These conditions are often created by wastes from housing subdivisions, cabins, and cottages. Sewage effluent from these installations reaches the stream and lakes of the local watershed. Sewage treatment or disposal systems that meet governmental requirements may not circumvent the problem of increased fertility; nitrates and phosphates remaining is treated sewage stimulate plant growth in receiving waters.

Dense aquatic plant growth may cause oxygen depletion and subsequent fish fills. Warm, calm, and cloudy weather in summer and thick, opaque or snow-covered ice in winter contributes to this hazard. Under these conditons, plants do not photosynthesize and produce oxygen. Instead, they only respire and consume oxygen and some may die and decompose. Organic decomposition occurring throughout the year, makes a continuous demand upon available oxygen. If oxygen is not available through wave action, inflowing water, or photosynthesis, oxygen levels may be reduced to levels inadequate for fish and many of their food organisms.

SURVEY OF NUISANCE AQUATIC-MACROPHYTES

Aquatic macrophytes of the Columbia and Snake River drainages were observed at 723 sites in Washington, Oregon and Idaho, and classified according to adjacent land use, water body type, altitude, water temperature and nuisance growth.

The project had two major objectives:

1. To describe the distribution of aquatic vascular vegetation in the Columbia and Snake River drainage basins.
2. To relate this distribution to general aspects of the habitat of each collection site and to surrounding land use.

The field data were assembled under Contract No. DACW 68-72-C-0289 awarded to the University of Idaho by the Walla Walla District of the Army Corps of Engineers, to fulfill the above objectives. Statistical analysis for nusiance growth of weedy species was made at the Office of the Chief of Engineers, Washington, D. C.

METHODS AND MATERIALS

The survey was conducted by means of a series of 723 site visitations distributed throughout the 20 sub-basins in the study area. Most collections were made in April through September, 1973. Sites were selected so that varied habitats were represented within each sub-basin. Sites were selected with high diversity of plant species, and sites with high standing crops of aquatic vegetation. Particular attention was given to sites with macrophyte development of nuisance proportions. In judgement, sites were selected where growths were aesthetically offensive, impeded water flow in channels, could clog water intakes, hindered boating, swimming, or navigation.

At each collection site, the collectors sampled or identified all aquatic macorphytes observed in a brief overview. On site, a subjective estimate was made of the abundance of each taxa found; rare, sparse, common, heavy, or nuisance. Depending on the water depth, plants were collected by a combination of grab samples, rakes, and scuba diving. Choice of sampling area was dictated by ease of access but in smaller water bodies, the entire water surface or shoreline was sampled. Observations were made on water velocity, water temperature, and surrounding land use. Selection of sample sites was biased toward sites of heavy plant growths so this study is not a truly representative cross-section of all aquatic habitats in the study area. Logical areas of heavy growth were often selected, such as protected bays, shoals or areas of nutrient input.

The "Flora of the Pacific Northwest" was accepted as the taxonomic authority. Identifications were supported by Correll and Correll (1), Fassett (2), Steward, Dennis, and Gilkey (4), and the herbaria at the University of Idaho and Washington State University.

DISCUSSION AND CONCLUSIONS

A scanning of the geographical occurances of the taxa which most often occurred in heavy densities shows little apparent geograpical or river basin zonation with most taxa. The taxa seem to be freely distributed over basin boundaries. All "nuisance" taxa, were very widespread in their distribution. Within the Pacific Northwest, it appears that the presence or absence of a taxa in a specific river drainage is not a question of prior introduction, but whether habitat suitability permits the taxa to persist.

Certain habitat characteristics showed definite relationships to heavy macrophyte growth. Of all small ponds and small lakes sampled, 60.0% and 53.7% respectively had heavy growths while only 30.1, 28.7, and 11.4% of large lakes, rivers, and drawdown reservoirs had heavy growths. Drawdown pools and rivers generally were poor plant habitat. These areas are in contrast with the still moderately deep offshore waters or protected shallow coves offering choice macrophyte growth conditions. Altitude-related density trends are variable, probably because of small sample size in the low and high elevations. Percent heavy growth sites are highest from 1,000-3,000 feet.

Of the five land use categories, irrigated agricultural, sagebrush-grazed, and near-population centers had the highest percentages of heavy sites . . . . . 53.3, 42.7, and 47.9% respectively. Dryland agricultural and forested were 33.3% each. On-site observations further showed that the plant density within heavy or nuisance sites was greater where surrounding land use was greater. These data suggest a strong relationship between macrophyte abundance and nutrient-additive uses on the surrounding land. Heavy growths were a greater percentage of the high temperature sites (75%), decreasing steadily through the cooler water sites (down to 25.7%).

Data for the 723 sites sampled for frequency occurrence and percent occurrence of taxa as heavy growths are presented in Tables 1 for all taxa found. Approximately 70% of the specific problem areas are caused by 8 taxa:

Elodea canadensis Michx.
Potamogeton pectinatus L.
Chara spp.
Ranuculus ssp.
Ceratophyllum demersum L
Myriophyllum spp.
Nitella spp.
Nuphar spp.

A significant point is that despite these taxa causing most of the heavy nuisant growth in the study area, all were also found in "sparse" or "rare" densites. Furthermore, more than 95% of all taxa found were observed in "nuisance densities" at least once. There was not a consistent pattern of taxa diversity among sites. In "heavy" sites, dense growths were just as likely to consist of 6-8 dominant taxa as of one dominant taxon. Likewise, sparse growths might have consisted of one, or of many different taxa. The apparant explanation for these observations is the different habitat requirements of each taxa and their adaptations to the environment.

Many of the water bodies investigated had much adjacent development such as farms, residental sites, and road fill surrounding the shoreline. Extensive development of lake banks may encourage littoral vegetation through the formation of shoal areas by bank slumpage and undercutting by wave action. Growing conditions for aquatic weeds then are optimal since eroded soils supply necessary nutrients and substrate for plant roots to take anchor. Percolation through soil removes solids from pasture runoff, irrigation wastes, and septic tank wastes but these nutrient-laden waters reach water bodies where they may stimulate prolific macrophyte growth in near-shore water. These "disturbed" areas provide the three essentials for prolific plant growth; ample light, suitable substrate, and nutrient-rich waters.

Matrix Analysis

Certain species of aquatic plants are identified as problem species in the same way that certain species are problem plants in the cultivation of domestic crops. These species are to a certain extent domesticated by their situations of growth and have a wider range of adaption to conditions of the habitat than wild species. Observations on adjacent land use, water body type, altitude and water temperature as related to nuisance growth were studied by matrix analysis to determine conditions and indicator plants, as listed in Table 2. The multiple correlation matrix of these factors is given in Table 3 and the statistical analysis of variance is given in Table 4. The multiple regression equation of this data set is:

$$
\begin{aligned}
y = 5.4095 + {} & 0.4333 \; X\ 1 \\
& 0.5322 \; X\ 2 \\
& 0.2248 \; X\ 3 \\
& 0.0215 \; X\ 4
\end{aligned}
$$

The predicted nuisance species using this equation is given in Table 5 for categories of land use and water body type. These predications can be of value as a "rule of thumb" estimate of aquatic plant growth for different recreation sites.

References

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4. Steward, A. N., Dennis, L. R. J. and Gilkey, H. M. Aquatic plants of the Pacific Northwest, with vegetative keys. Oregon State Univ. Press. Corvallis. 261pp. 1963.

5. Hesser, E. and Gangstad, E.O. Nuisance Aquatic Macrophyte Growth. J. Aquat. Plant Manage. 16: 11-13.

TABLE 1. Frequency of occurrence of "heavy" or "nuisance" abundance for aquatic macrophyte taxa. Where several species of a genus occur, these are combined.

Species/Taxon	Number of sites taxon occured	Number of sites taxon abundance was "heavy" or "nuisance"	Percentage "heavy" or "nuisance" sites
ANGIOSPERMS			
Monocotyledons:			
Potamogeton spp. (all data pooled)	208	127	20.9
Typha latifolia & T. angustifolia (all data pooled)	126	20	15.9
Lemna minor	108	27	25.0
Elodea spp. (unidentified) (all data pooled)			
Eleocharis palustris	53	3	5.7
Zannichellia palustris	50	7	14.0
Scirpus acutus	53	7	13.2
Sagittaria spp. (all data pooled)	40	4	10.0
Sparganium spp. (all data pooled)	29	5	17.2
Najas spp. (all data pooled)	30	4	13.3
Spirodela polyrhiza	29	3	10.3
Eleocharis acicularis	20	6	30.0
Juncus balticus	21	1	4.8
Carex rostrata	20	7	35.0
Aiisma spp. (all data pooled)	19	1	5.3
Carex aquatilis	15	2	13.3
Phalaris arundinacea	53	3	5.7
Lemna trisculca	16	6	37.5
Iris pseudacorus	12	3	25.0
Scirpus heterochaetus	9	5	55.6
Eleocharis ovata	8	1	12.5

TABLE 1. (Continued)

Species/Taxon	Number of sites taxon occured	Number of sites taxon abundance was "heavy" or "nuisance"	Percentage "heavy" or "nuisance" sites
ANGIOSPERMS			
Monocotyledons:			
Glyceria borealis, G. elata & G. grandis	9	1	11.1
Wolffia punctata & W. columbiana	6	3	50.0
Rynchospora alba	5	2	40.0
Carex vulpinoidea	3	3	100.0
Districhlis stricta	1	1	100.0
Juncus supiniformis	1	1	100.0
J. tenuis	1	1	100.0
Dicotyledons:			
Ranunculus aquatilis, R. longirostris, R. subrigidus & similar unidentified taxa (all data pooled)	125	33	26.4
Myriophyllum spicatum and its varieties & all other Myriophyllum taxa (all data pooled)	102	28	27.5
Ceratophyllum demersum	60	14	23.3
Nuphar polysepalum, N. variegatum & all unidentified Nuphar taxa (all data pooled)	60	16	26.7
Callitriche spp. (all data pooled)	50	3	6.0
Rorippa nasturitium-aquaticum	47	10	21.3
Salix spp. (all data pooled)	41	2	4.9
Veronica americana, V. anagallis-aquatica, V. catenata & V. scutellata (all data pooled)	39	3	7.7
Mimulus spp. (data of all taxa pooled)	32	1	3.1

TABLE 1. (Continued)

Species/Taxon	Number of sites taxon occured	Number of sites taxon abundance was "heavy" or "nuisance"	Percentage "heavy" or "nuisance" sites
ANGIOSPERMS			
Polygonum amphibium (=P. natans)	31	5	16.1
Utricularia spp. (data of all taxa pooled)	28	1	3.6
Hippuris spp. (data of all taxa pooled)	18	4	22.2
Dicotyledons:			
Nymphaea odorata	15	2	13.3
Polygonum cocineum	13	0	0
Brasenia schreberi	15	5	33.3
Myosotis laxa	12	1	8.3
Rumex laxa	11	1	9.1
Solanum dulcamara	5	1	20.0
PTERIDOPHYTES			
Equisetum spp. (data of all taxa pooled)	90	6	6.7
Marsilea quadrifolia & M. vestita (all data pooled)	5	1	20.0
Azolla filiculoides	1	1	100.0
BRYOPHYTES			
Fontinalis spp.	25	2	8.0
Bryophytes, unidentified to genus (all data polled)	12	2	16.7
Drepanocladus spp.	15	1	6.7
Ricciocarpus sp. & Riccia sp. (data pooled)	6	2	33.3
ALGAE			
Characeae (Chara spp. & Nitella spp.) (all data pooled)	102	36	35,3

TABLE 2. SUMMARY OF ADJACENT LAND USE, WATER BODY TYPE, AND PLANT GENERA IN DECREASING ORDER OF NUISANCE GROWTH EFFECT.

Land Use	Water-Body Type	Nuisance Genera
Population center	Slough	Elodea
Grazing land	Lake	Potamogeton
Irrigated land	Pond	Chara
Forest land	Canal	Ranuculus
Dryland farming	Creek	Ceratophyllum
	Reservoir	Myriophyllum
	River	Nitella
		Nuphar

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TABLE 3. Correlation Matrix Of Indepent Variables.

Variable	1	2	3	4	5
Use	1.000	.0984	.0272	-.1072	.2309
Type		1.000	.1948	-.3649	-.2358
Altitude			1.000	.0493	-.1806
Temperature				1.000	.0324
Plant					1.000

TABLE 4. Analysis of Variance

	DF	Sum of Squares	Mean Square	F Ratio
Regression	4	53,142	13,285	2.740
Residual	67	324,858	4,849	

Variables in Equation

Variable	Coefficient	STD. Error	F To Remove
(Constant	5.4695)		
1	.4333	.1952	4.9256**
2	-.5323	.2697	3.8953**
3	-.2248	.1833	1.5030**
4	-.0215	.0710	.0912**

** highly significant

Multiple Regression .3749

STD. Error of EST. 2.2020

TABLE 5. NUISANCE GENERA AS RELATED TO ADJACENT LAND USE AND WATER BODY TYPE AT 300 METERS ALTITUDE AND 27 DEGREES C.

Land Use	Water-Body Type	Nuisance Genera
Population center	Slough	Ceratophyllum
	Lake	Ranucullus
	Pond	Chara
	River	Chara
	Creek	Potomageton
	Reservoir	Elodea
	Canal	Elodea
Grazing Land	Slough	Ceratophyllum
	Lake	Ceratophyllum
	Pond	Ranucullus
	River	Chara
	Creek	Potomageton
	Reservoir	Potomageton
	Canal	Elodea
Irrigated agriculture	Slough	Myriophyllum
	Lake	Ceratophyllum
	Pond	Ranucullus
	River	Chara
	Creek	Chara
	Reservoir	Potomageton
	Canal	Elodea

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