nois Natural History Survey Circular 57

Controlling Aquatic Vegetation with Triploid Grass Carp

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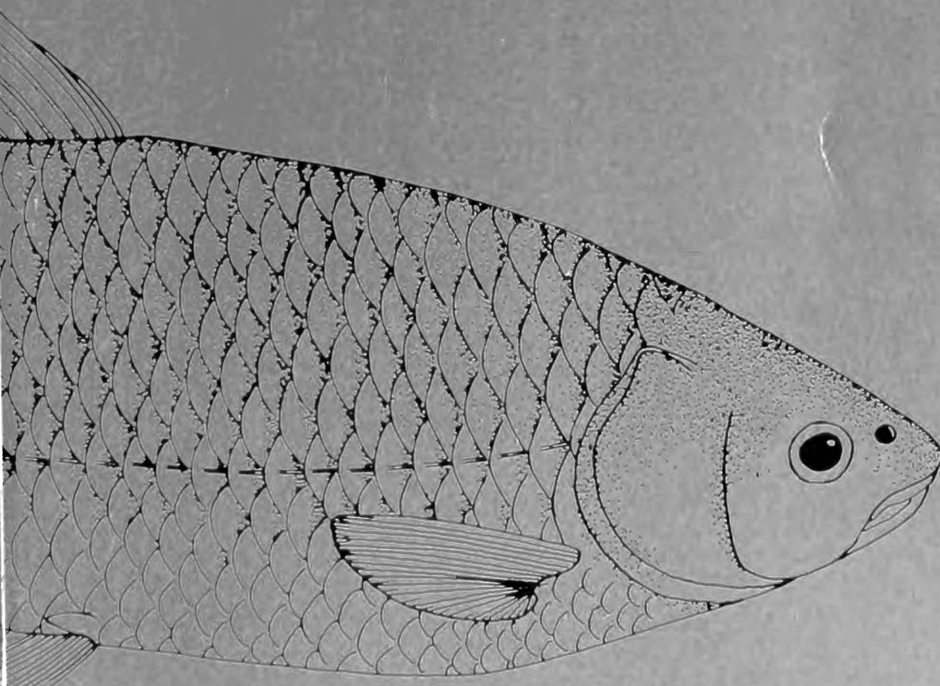

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Section of Aquatic Biology
Illinois Natural History Survey

Triploid grass carp, the sterile genetic derivatives of the diploid grass carp *Ctenopharyngodon idella*, may be used legally to control aquatic vegetation in Illinois, where possession or stocking of diploid grass carp is illegal. Like diploid grass carp, triploid grass carp have a large feeding capacity and a rapid growth rate, characteristics that make them a potent biological control. Unlike their diploid counterpart, triploid grass carp cannot reproduce, thereby eliminating concern about their uncontrolled spread.

In many cases, the use of triploid grass carp provides a feasible and cost-effective alternative to aquatic herbicides, harvesting, and other techniques for managing aquatic plants. Triploid grass carp are generally most effective in warmer climates and when the target plant is a preferred food that is eaten rapidly. In some situations, triploid grass carp are not the most appropriate management technique, primarily when the target plant is less preferred and when the body of water is located in a cooler region of the state. Managers who plan to use triploid grass carp should evaluate their stocking plans carefully. They should define their management objectives and consider the alternatives available to them, including benthic barriers, harvesting, shading chemicals, aquatic herbicides, and fertilization. Integrated management (a combination of techniques) often yields the best results.

This circular provides stocking rates for triploid grass carp in Illinois and a brief discussion of factors to consider when planning to stock them. The stocking recommendations are based on a series of analyses using the Illinois Herbivorous Fish Stocking Simulation System, a computer model developed at the Illinois Natural History Survey. This computer program estimates the level of plant control that can be achieved with various stocking levels by coupling bioenergetic and feeding characteristics of triploid grass carp with seasonal aquatic plant population dynamics (Wiley et al. 1984b; Wiley et al. 1986; Wiley and Wike 1986). Stocking plans for a given pond or lake can be developed by using the rates recommended in this publication.

The development of a stocking plan requires basic information about the body of water to be stocked:

1. Area of the pond or lake
2. Percentage of the pond or lake less than 8 feet deep (the littoral zone)
3. Percentage of the pond or lake that is heavily vegetated when aquatic plant cover is at its peak, typically July or August
4. The dominant plant in the pond or lake or the plant targeted for control
5. The county in which the pond or lake is located

Instructions for using this information to calculate the stocking rate for a given body of water are found in the following pages.

Important Considerations

Determining the number of fish required to control a particular plant is not a simple computation. The decision to use triploid grass carp to control aquatic plant populations immediately requires a second decision—the degree of reduction desired. The triploid grass carp is a potent biological control that is capable of stripping bodies of water of all aquatic plants. Under rare circumstances the total eradication of plants may be acceptable, but in most cases it is neither aesthetically nor ecologically desirable. Stocking rates are the primary means of achieving varied levels of control.

Specifying the desired degree of plant reduction is the first step in developing a stocking plan. The ability of these fish to control plants is based largely on their feeding and growth rates. Several factors that influence the growth rate and plant consumption of carp should be considered.

Size of fish. The effects of differential vulnerability to predators and size-related growth and feeding patterns are such that the number of fish to be stocked is a function of size: The number of fish to be stocked per vegetated acre is always based on the size of the fish. Rates provided here are for 10-inch fish, a size commonly available from fish producers and dealers. Fish stocked should be as close to 10 inches as possible; substituting fish of other sizes will alter the degree of control achieved.

Water temperature. Feeding rates of these fish increase logarithmically as water temperature rises. This variation means that a triploid grass carp in the cooler waters of northern Illinois consumes plants more slowly than an equivalent fish in the warmer waters of southern Illinois. Ideally, stocking rates should be determined for a given body of water based on its measured seasonal temperature profile. Because this determination is not always possible, we provide stocking recommendations adjusted for the general climatic characteristics of four regions in Illinois (Figure 1). Temperature adjustments for each region are based on 30-year weekly mean temperature data collected by the Illinois State Water Survey.

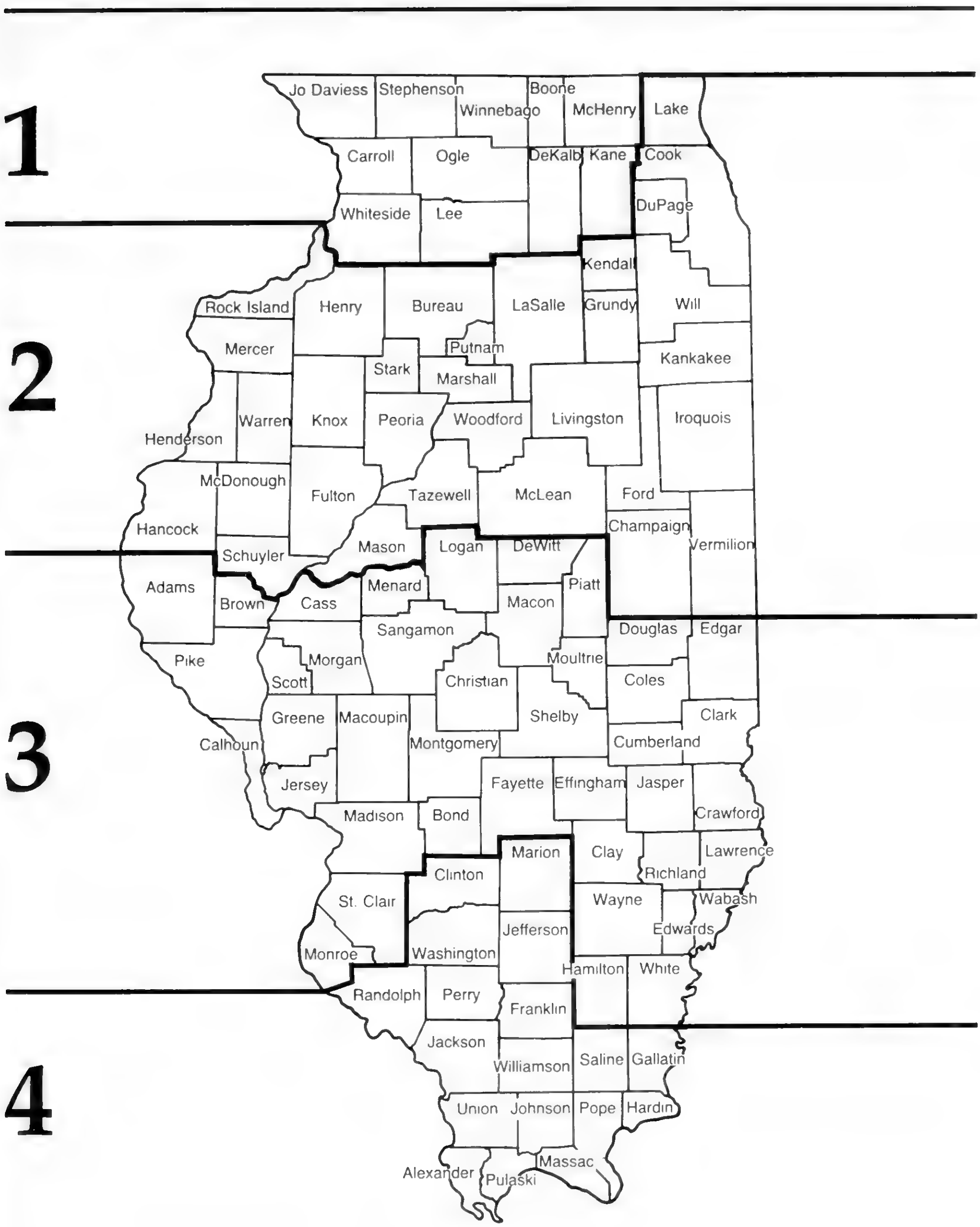


Figure 1. Four climatic regions of Illinois.

Palatability of aquatic plants. Triploid grass carp exhibit strong preferences among aquatic plants (Wiley et al. 1986; Miller and Decell 1984), and the rate at which they feed on a particular species is correlated with that preference. Such highly preferred plants as the naiads (*Najas* spp.) are eaten rapidly. Such unpalatable plants as water milfoil (*Myriophyllum* spp.) are eaten much more slowly and higher stocking rates are required to achieve control.

Stocking rates for five groups of plant communities that typically cause problems in Illinois are given in Tables 1–5. Designations for these groups were based on studies of feeding preference (Wiley et al. 1986). Plants not tested in our studies but known to cause problems in Illinois were grouped using information from other research on feeding preference and according to taxonomic and morphological characteristics of the species.

Site-specific variables. Many other factors that vary from lake to lake or from year to year influence the long-term performance of a particular stocking of triploid grass carp. For example, factors that influence annual variation in growth and regeneration rates of aquatic macrophytes include competition from algal populations, nutrient loadings, and the leaching of herbicides from a surrounding watershed. Other factors also affect the longevity or vigor of triploid grass carp. Abnormal weather may suppress feeding or cause catastrophic mortality (winter or summer kills), and fishing pressure may reduce the number of triploid grass carp below effective levels. None of these factors can be predicted for a particular site and yet any one of them may lead to variations in the effectiveness of a particular stocking level. Because these site-specific variables cannot be predicted, our approach has been to average these variations when possible and to disregard them when necessary. Although correcting stocking rates only for those sources of variation that can be predicted is incomplete, it is far superior to ignoring known sources of variation and stocking blindly.

Users of these recommendations should note that the results of stocking at suggested rates will vary from lake to lake; however, these recommendations provide the best assurance available that stocking triploid grass carp in Illinois will be both cost-effective and ecologically safe.

Stocking Strategies

Serial and batch stocking are two basic strategies in stocking triploid grass carp to control aquatic plants. In serial stocking, a given number of fish are placed in a body of water at specified intervals over a given period of time, for example, two stockings at 5-year intervals over a 10-year period. These stockings form a schedule that is repeated as long as control is desired. Regularly scheduled stockings usually minimize the total number of fish required to achieve a specific level of control over a long period of time. In batch stocking, fish are stocked in a single large batch to compensate for long periods between stockings, for example, stocking once every 10 years. For most situations in Illinois, we recommend serial stocking. It is more efficient and cost-effective, and it allows greater control over the degree of plant reduction to be achieved.

Regardless of strategy, the desired degree of plant control must be specified. Because aquatic plants are important in the management of most Illinois sport fisheries (Wiley et al. 1984a), in sediment stabilization (Wiley and Gorden 1984), and in bank protection, their eradication is seldom desirable. Research on typical bass-bluegill communities suggests that plant cover of 36–40 percent in littoral areas provides an optimal habitat for largemouth bass productivity (Figure 2). In most multiple-use waters, plant cover of 40 percent is the target level of control. To that end, we provide "best management practice" estimates that rely on the serial stocking strategy and are designed to reduce plant cover to approximately 40 percent of the total littoral surface area.

Situations may exist where eradication of all aquatic plants is desired, and triploid grass carp are indeed capable of achieving this. However, we caution against stocking for eradication without a clear understanding of the implications for the production of sport fish and for alterations in water quality.

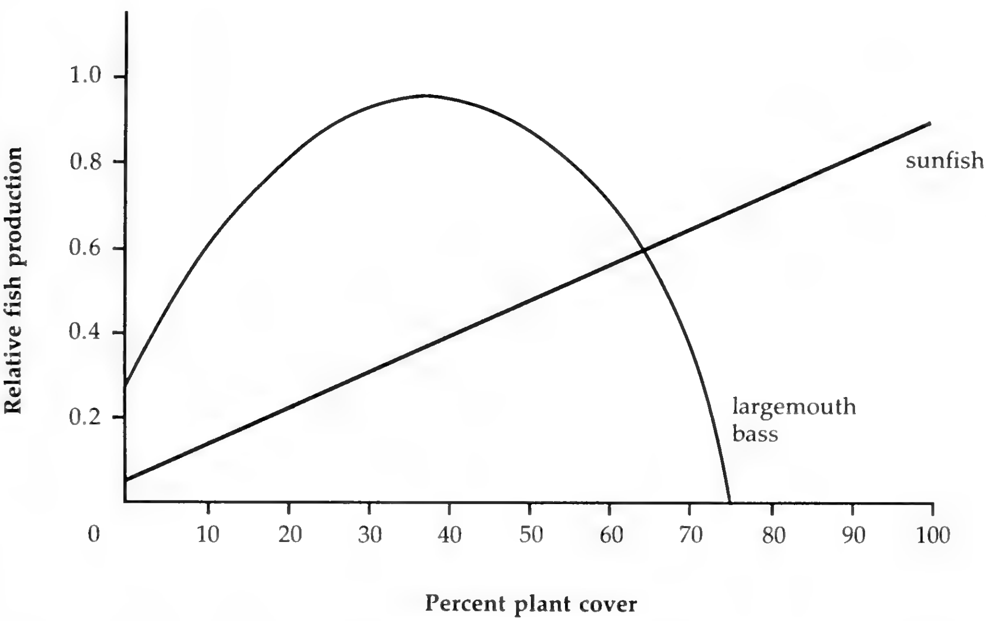


Figure 2. Relative production of piscivorous largemouth bass and insectivorous sunfish as a function of plant cover. Optimal plant cover for bass production is 36–40 percent. Based on a dynamic trophic model and field data (Wiley et al. 1984a).

Table 1. Stocking recommendations for control of naiads (including slender, brittle, and southern naiad), nitella, and *Chara* in Illinois. The 10-year stocking schedule includes an initial stocking and a second stocking 5 or 6 years later, depending on the climatic region.

Stocking Rate
(number of 10-inch fish per vegetated acre)

Climatic region	Initial stocking	Second stocking	Years between initial and second stocking
1	16	12	6
2	12	10	5
3	12	12	5
4	8	8	5

Note: These rates assume a spring stocking. Stocking in April is recommended because it is most cost-effective. If a fall stocking is planned, multiply these rates by 1.5. If continued control is desired, repeat the stocking schedule (two stockings) every 10 years, regardless of the interval between the initial and second stocking.

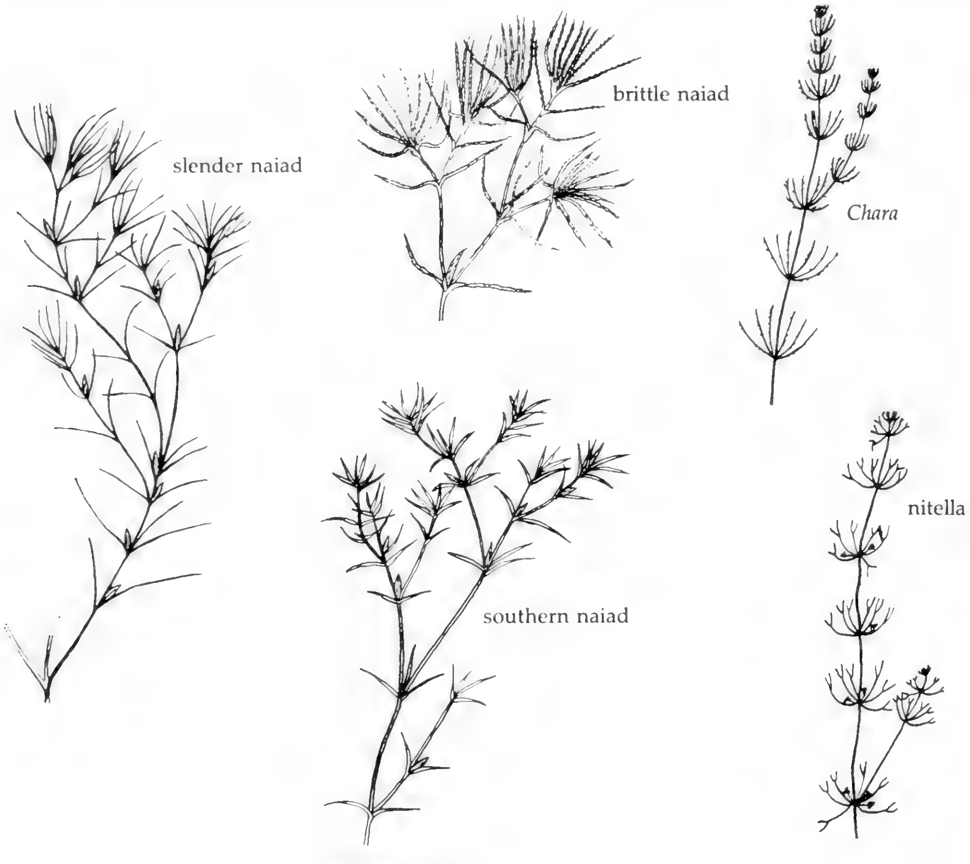


Table 2. Stocking recommendations for control of narrow-leaved pondweeds (including leafy, sago, small, and horned) and American elodea in Illinois. The 10-year stocking schedule includes an initial stocking and a second stocking 5 or 6 years later, depending on the climatic region.

Stocking Rate
(number of 10-inch fish per vegetated acre)

Climatic region	Initial stocking	Second stocking	Years between initial and second stocking
1	16	12	6
2	12	12	5
3	12	12	5
4	16	12	5

Note: These rates assume a spring stocking. Stocking in April is recommended because it is most cost-effective. If a fall stocking is planned, multiply these rates by 1.5. If continued control is desired, repeat the stocking schedule (two stockings) every 10 years, regardless of the interval between the initial and the second stocking.

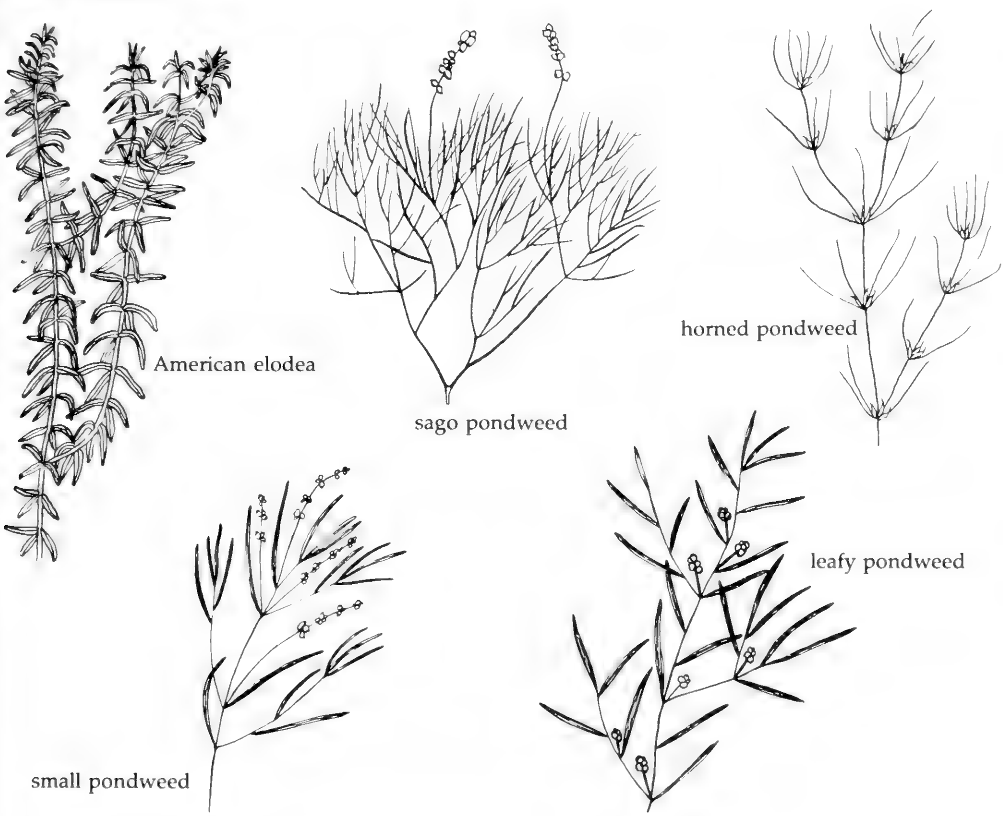


Table 3. Stocking recommendations for control of broad-leaved pondweeds (including curlyleaf, American, Illinois, and largeleaf) and creeping water primrose in Illinois. The 10-year stocking schedule includes an initial stocking and a second stocking 5 years later.

Stocking Rate
(number of 10-inch fish per vegetated acre)

Climatic region	Initial stocking	Second stocking	Years between initial and second stocking
1	19	19	5
2	16	16	5
3	24	24	5
4	17	17	5

Note: These rates assume a spring stocking. Stocking in April is recommended because it is most cost-effective. If a fall stocking is planned, multiply these rates by 1.5. Repeat the stocking schedule (two stockings) every 10 years, if continued control is desired.

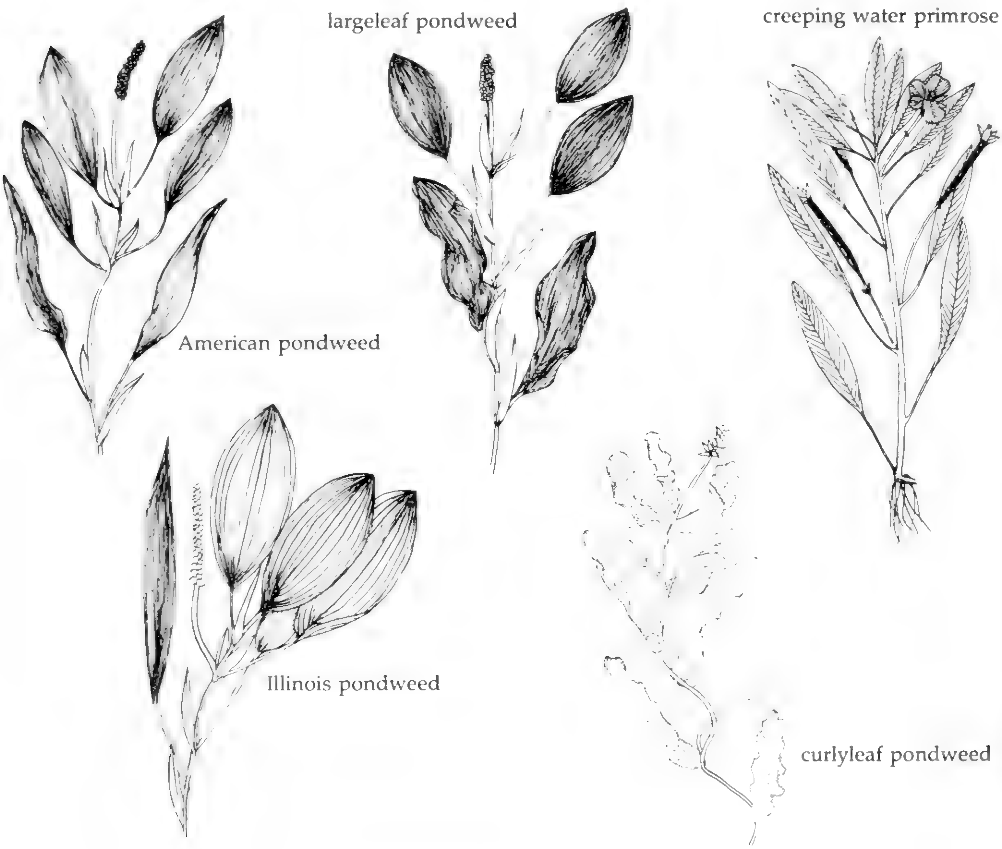


Table 4. Stocking recommendations for control of coontail, water smartweed, American lotus, water lily, and water shield in Illinois. The 10-year stocking schedule includes an initial stocking and a second stocking 6 or 7 years later, depending on the climatic region.

Stocking Rate
(number of 10-inch fish per vegetated acre)

Climatic region	Initial stocking	Second stocking	Years between initial and second stocking
1	77	28	7
2	61	20	6
3	65	20	6
4	69	20	6

Note: These rates assume a spring stocking. Stocking in April is recommended because it is most cost-effective. If a fall stocking is planned, multiply these rates by 1.5. If continued control is desired, repeat the stocking schedule (two stockings) every 10 years, regardless of the interval between the initial and second stocking.

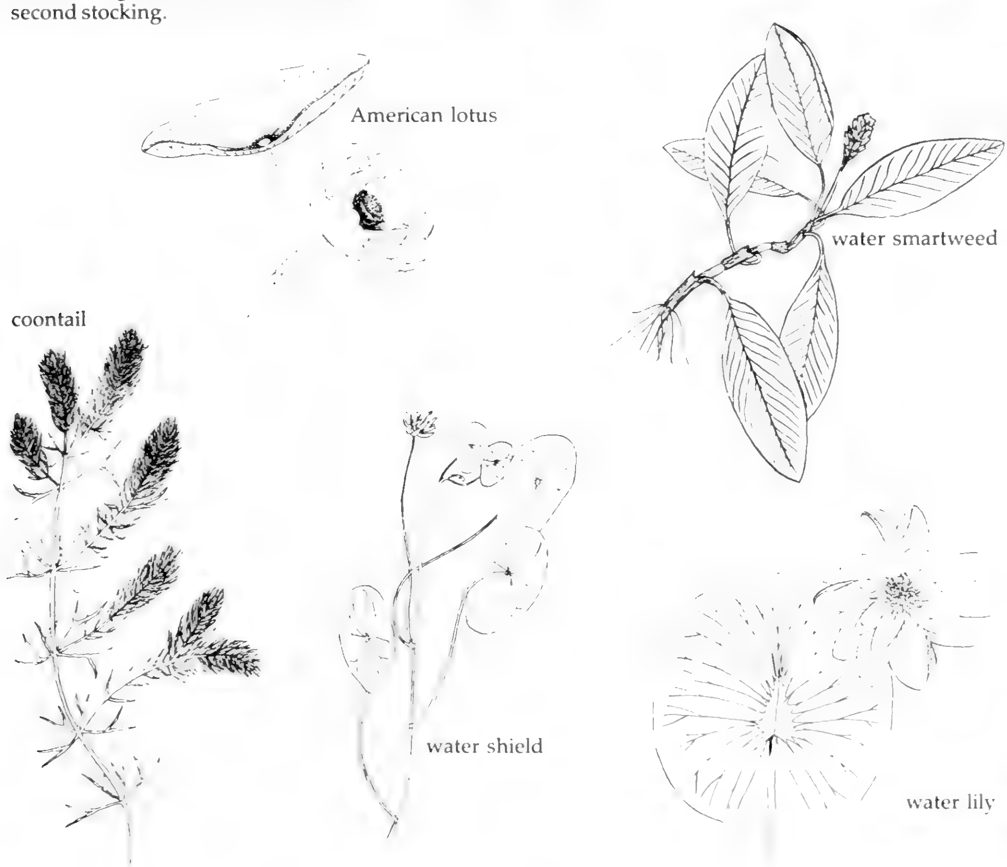
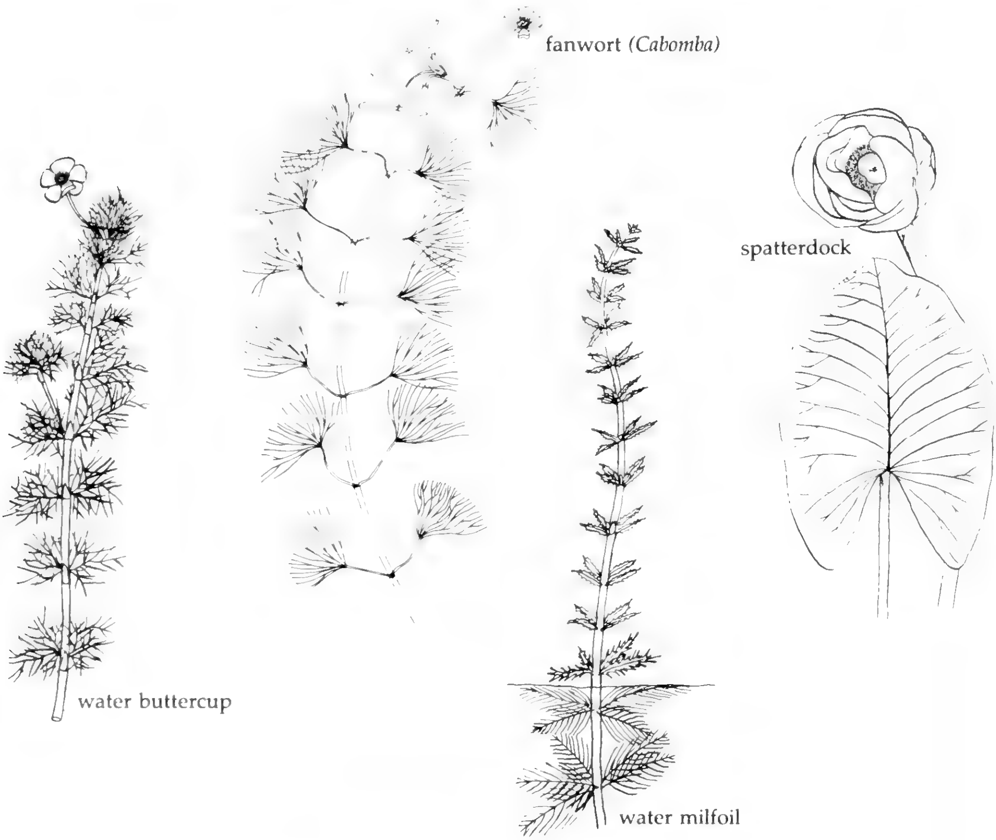


Table 5. Stocking recommendations for control of water milfoil, water buttercup, fanwort (*Cabomba*), and spatterdock in Illinois. The 10-year stocking schedule includes an initial stocking and a second stocking 7 years later.

Stocking Rate
(number of 10-inch fish per vegetated acre)

Climatic region	Initial stocking	Second stocking	Years between initial and second stocking
1	69	28	7
2	61	28	7
3	69	28	7
4	61	32	7

Note: These rates assume a spring stocking. Stocking in April is recommended because it is most cost-effective. If a fall stocking is planned, multiply these rates by 1.5. Repeat the stocking schedule (two stockings) every 10 years if continued control is desired.



Stocking Recommendations for Illinois Waters

The information needed to calculate best management practice stocking rates is provided below. These recommendations are for the stocking of sterile triploid grass carp in Illinois waters and have been derived from extensive analyses and from simulations using the Stocking Simulation System. Because these tables summarize large amounts of data, they are necessarily general in nature. By far the most accurate way to develop a stocking schedule that will achieve a specified level of control in a given body of water is to gather the necessary biological and physical data and to use those data in computer simulation analyses (Wiley et al. 1984b).

Follow these steps to calculate the stocking rate for a specific body of water in Illinois:

1. Determine the surface acres of the pond or lake to be stocked.
2. Determine the percentage of the pond that is heavily vegetated when plant cover is at its peak, typically July or August. We define heavily vegetated as dense aquatic macrophyte growth to the water's surface or to within a foot of the surface.
3. Determine the percentage of the pond that is less than 8 feet deep (the littoral zone).
4. Using the percentages from steps 2 and 3, compute the area correction factor as follows:

$$\text{area correction factor} = \frac{\text{percentage of the pond heavily vegetated}}{\text{percentage of the pond less than 8 feet deep}}$$

This correction factor adjusts the stocking rates in Tables 1–5 to give a target plant coverage of approximately 40 percent of the littoral surface area. The area correction factor should never be greater than 1. If the percentage of the pond that is heavily vegetated is larger than the percentage of the pond that is less than 8 feet deep (littoral), use a littoral percentage equal to the vegetated percentage, thus making the area correction factor 1. **If the area correction factor is less than or equal to 0.40, we do not recommend stocking triploid grass carp.**

5. Identify the climatic region of the pond or lake to be stocked by referring to Figure 1.
6. Identify the dominant submergent plants (the plants targeted for control) in the pond or lake. Examine the drawings accompanying Tables 1–5 and select the stocking table associated with the plants that most closely resemble the ones you wish to control. The scientific names of these aquatic plants are given in Table 6. For further help in identifying plants, consult *Aquatic Plants of Illinois* (Winterringer and Lopinot 1977). Algae and such emergent plants

Table 6. Common and scientific names of aquatic plants prevalent in Illinois listed alphabetically by common name. Additional species can be found in Winterringer and Lopinot (1977).

American elodea, waterweed	*Elodea canadensis* Michx.
American lotus	*Nelumbo lutea* (Willd.) Pers.
coontail	*Ceratophyllum* spp.
common coontail	*C. demersum* L.
prickly coontail	*C. echinatum* Gray
creeping water primrose	*Jussiaea repens* L.
fanwort, *Cabomba*	*Cabomba caroliniana* Gray
muskgrass, *Chara*	*Chara* sp.
naiads	*Najas* spp.
brittle naiad	*N. minor* All.
slender naiad	*N. flexilis* (Willd.) R. & S.
southern naiad	*N. guadalupensis* (Spreng.) Magnus.
nitella	*Nitella* sp.
pondweeds	*Potamogeton* spp., *Zannichellia* sp.
American pondweed	*P. nodosus* Poir.
curlyleaf pondweed	*P. crispus* L.
horned pondweed	*Zannichellia palustris* L.
Illinois pondweed	*P. illinoensis* Morong.
largeleaf pondweed	*P. amplifolius* Tuckerm.
leafy pondweed	*P. foliosus* Raf.
sago pondweed	*P. pectinatus* L.
small pondweed	*P. pusillus* L.
spatterdock	*Nuphar advena* Ait.
water buttercup	*Ranunculus* spp.
water lily	*Nymphaea* spp.
water milfoil	*Myriophyllum* spp.
broadleaf water milfoil	*M. heterophyllum* Michx
northern water milfoil	*M. exalbescens* Fern.
variable water milfoil	*M. pinnatum* (Walt.) BSP.
whorled water milfoil	*M. verticillatum* L.
water shield	*Brasenia schreberi* Gmel.
water smartweed	*Polygonum fluitans* Eaton

as cattail were not tested during our studies. Only those plants that could be included in the designated plant groups based on other available information were included in these recommendations.

7. Refer to the appropriate stocking table to find the initial stocking rate and the rate and year for the second stocking.

8. Use the following formula to calculate the number of fish to stock:

stocking rate (tables 1–5)	×	surface area of pond (step 1)	×	percentage of pond vegetated (step 2)	×	correction factor (step 4)	=	number of fish to stock

All stockings should be done in the spring (April) of the years specified; spring stockings are more economical than fall stockings. The schedule, which usually includes two stockings, is repeated every 10 years.

These eight steps are illustrated in the following example. (1) The pond to be stocked is 10 acres. (2) Fifty percent (0.50) of its surface area is heavily vegetated. (3) Sixty percent (0.60) of its area is less than 8 feet deep. (4) The correction factor is 0.83, computed as follows:

$$\frac{50 \text{ percent (from step 2)} = 0.50}{60 \text{ percent (from step 3)} = 0.60} = 0.83$$

(5) The pond is in Champaign County, which is located in Climatic Region 2. (6) The plant targeted for control is sago pondweed, which is found on Table 2. (7) According to Table 2, the initial stocking rate is 12 10-inch fish per vegetated acre. The second stocking should take place 5 years later at a rate of 12 10-inch fish per vegetated acre. (8) According to the stocking formula, 50 10-inch fish are needed for the initial stocking and 50 for the second stocking:

$(12 \times 10 \times 0.50 \times 0.83) = 50$ 10-inch fish for the initial stocking
$(12 \times 10 \times 0.50 \times 0.83) = 50$ 10-inch fish for the second stocking

Other Midwestern Stocking Recommendations

Stocking rates for triploid grass carp in the Midwest have been suggested by a number of private and governmental organizations. Most of these recommendations fall within the range of 1–20 fish per surface acre of water. Seldom do they refer to climatic conditions and none to our knowledge adjust stocking to compensate for differences in plant palatability, consumption rate, or conversion efficiency. Furthermore, rates based on whole-lake or pond-surface areas do not adjust stocking to reflect the relative amount of plant biomass that is to be controlled.

It should not be surprising, then, that the rates presented in this circular differ from the fixed rates per unit area (for example, 10 fish per acre) that are often given as a stocking "rule of thumb." Particularly for small bodies of water entirely covered with heavy vegetation of a relatively unpalatable species (for example, *Myriophyllum*), our suggested stocking rates are substantially higher than those of fixed-rate plans. This difference is intensified in the northern part of the state where water temperatures, and therefore feeding rates of carp, are lower. It is important to point out, however, that lakes and ponds in Illinois are seldom completely covered with dense vegetation, "heavily vegetated" as defined earlier (step 2 of the calculation). On the other hand, because our stocking rates are adjusted to the amount of plant production that requires control, our rates for larger lakes and ponds tend to be lower than those set by fixed-rate plans. Figure 3 illustrates how fixed-rate recommendations can at first underestimate and then overestimate stocking levels required to achieve comparable levels of plant control.

As an example, consider Red Haw Lake, Iowa. The Iowa Department of Conservation stocked this 72-acre lake with grass carp using a fixed rate of approximately 11 fish per lake acre (Mitzner 1978). After 3 years, the grass carp had removed 91 percent of the vegetation in the littoral zone of the lake, more than was desirable from a fisheries management point of view.

Using stocking recommendations from this circular, we would have stocked Red Haw Lake with about 2 fish per surface acre, 20 percent of the fish used by the Iowa Department of Conservation. The dominant plants in Red Haw Lake at the time of stocking were *Najas flexilis, Potamogeton pectinatus,* and *P. nodosus*. Given roughly equivalent amounts of each, we would have taken the tabled stocking rates (from Region 1) for each and averaged them ($16 + 16 + 19 = 51/3 = 17$). Assuming that the entire euphotic (littoral) zone was heavily vegetated, the area correction factor would have been 1, with 8.6 lake acres (12% of 72 acres) heavily vegetated. The total initial stocking according to our recommendations would have been 147 10-inch fish; 17 fish per vegetated acre or about 2 fish per lake acre. The result would certainly have been a less drastic reduction of plant cover, and an average of 35–40 percent cover in the littoral zone would presumably have been maintained.

The rates provided here estimate the number of fish necessary to achieve a specified level of reduction for a target plant. Every body of water is different, and managers must decide whether a particular stocking rate is acceptable based on their management objectives and on the characteristics of the lake or pond. Stocking extremely large numbers of triploid grass carp, even if that level meets a useful plant control objective, may be neither ecologically nor economically desirable, and we would certainly recommend that alternative control technologies be considered.

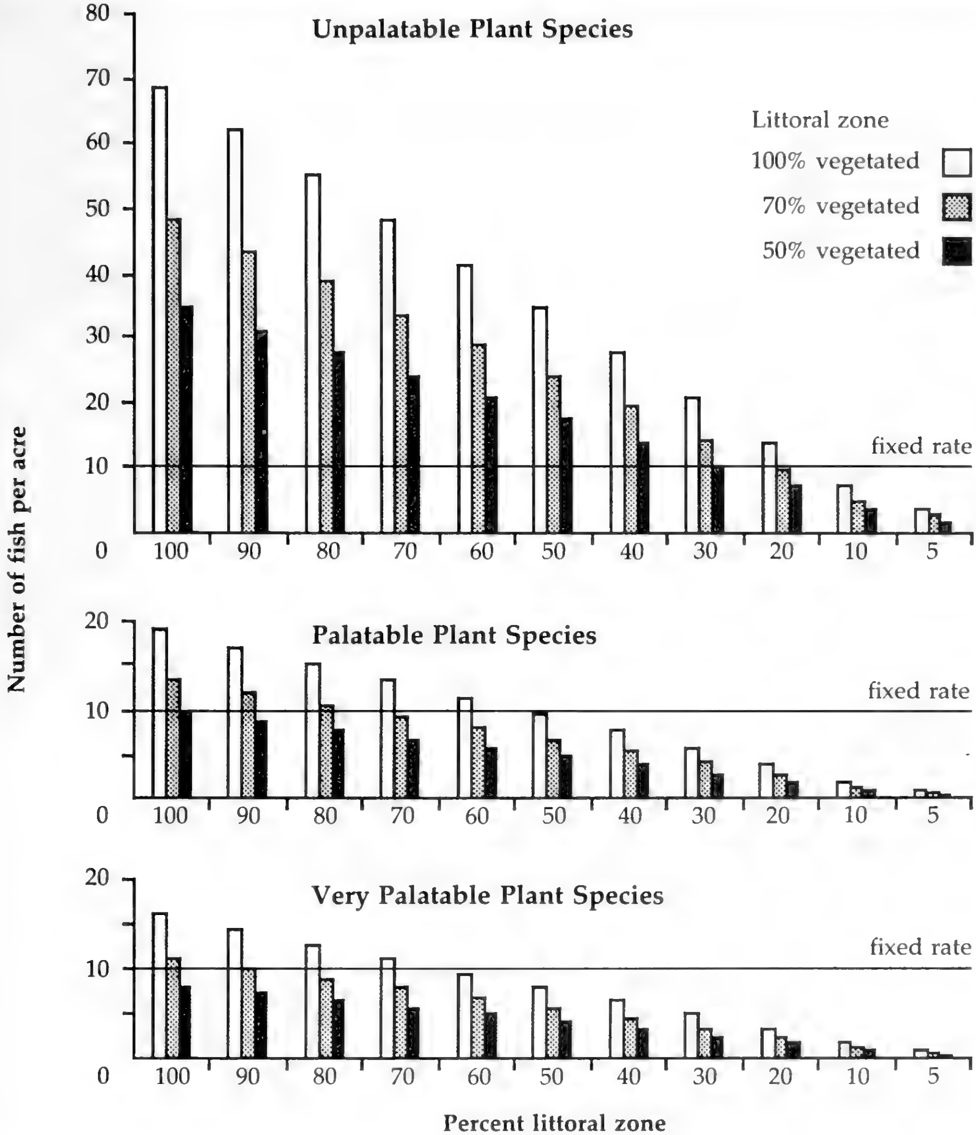


Figure 3. A comparison of fixed-rate (10 fish per acre) recommendations with recommendations from this circular for three categories of plant palatability. Each comparison shows rates for northern Illinois when littoral zones are 50, 70, and 100 percent vegetated. Graphs give stocking rate, in number of 10-inch fish, as a function of percentage of lake littoral zone.

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Literature Cited

Miller, A.C., and J.L. Decell. 1984. Use of the white amur for aquatic plant management. Instruction Report A–84–1, U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi.

Mitzner, L. 1978. Evaluation of biological control of nuisance aquatic vegetation by grass carp. Transactions of the American Fisheries Society 107:135–145.

Wiley, M.J., and R.W. Gorden. 1984. Biological control of aquatic macrophytes by herbivorous carp. Part II. Biology and ecology of herbivorous carp. Final Report, Federal Aid Project F–37–R. Aquatic Biology Technical Report 1984(11), Illinois Natural History Survey, Champaign.

Wiley, M.J., and L.D. Wike. 1986. Energy balances in three types of grass carp. Transactions of the American Fisheries Society 115:853–863.

Wiley, M.J., R.W. Gorden, S.W. Waite, and T. Powless. 1984a. The relationship between aquatic macrophytes and sport fish production in Illinois ponds: a simple model. North American Journal of Fish Management 4:111–119.

Wiley, M.J., S.M. Pescitelli, and L.D. Wike. 1986. Relationship between feeding preference and consumption rates in grass carp/bighead carp hybrids. Journal of Fish Biology 29:507–514.

Wiley, M.J., P.P. Tazik, S.T. Sobaski, and R.W. Gorden. 1984b. Biological control of aquatic macrophytes by herbivorous carp. Part III. Stocking recommendations for herbivorous carp and description of the Illinois Herbivorous Fish Simulation System. Final Report, Federal Aid Project F–37–R. Aquatic Biology Technical Report 1984(12), Illinois Natural History Survey, Champaign.

Winterringer, G.S., and A.C. Lopinot. 1977. Aquatic plants of Illinois. Illinois State Museum Popular Science Series VI. 142 p.

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