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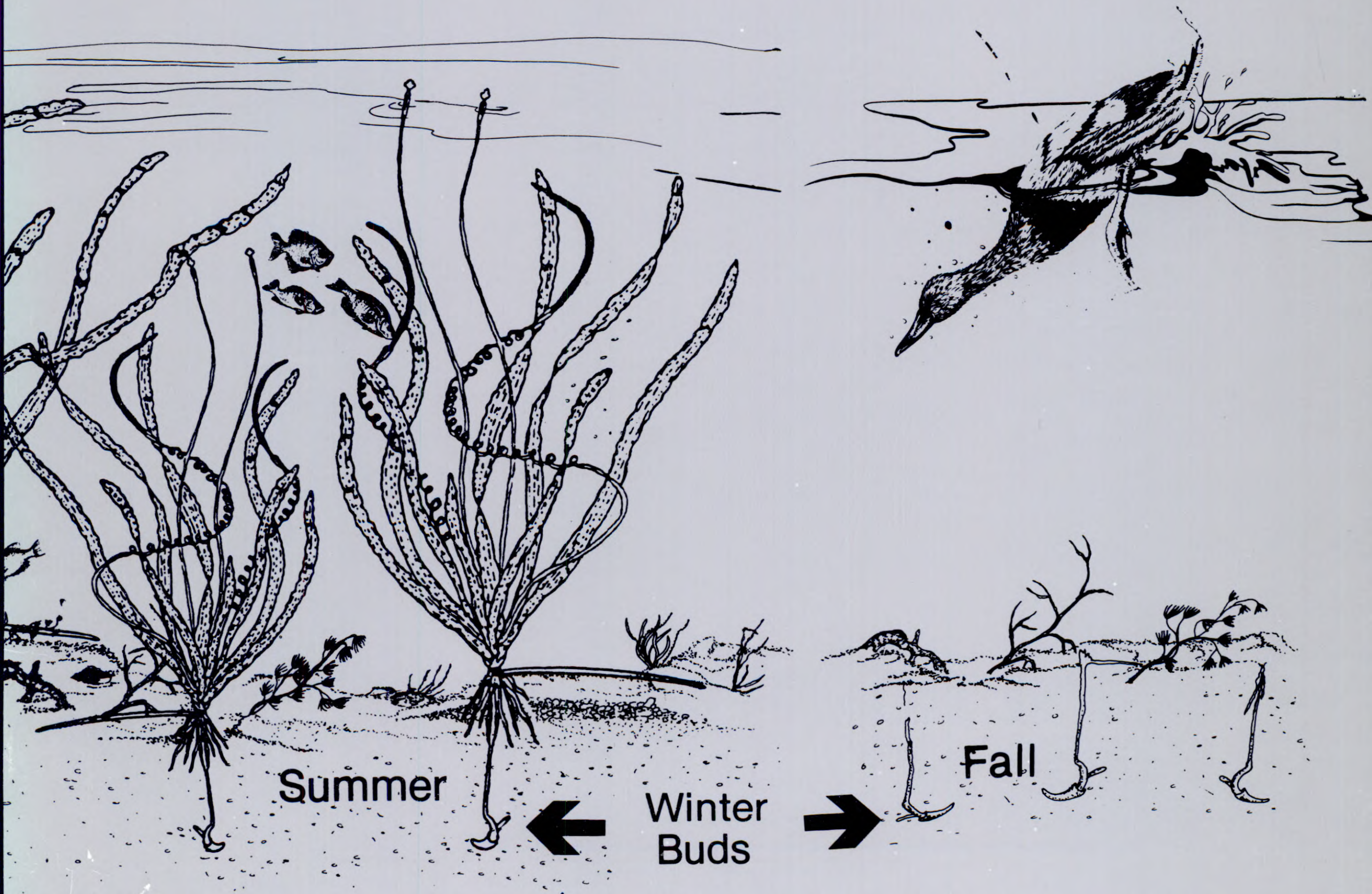
# American Wildcelery (*Vallisneria americana*): Ecological Considerations for Restoration

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UNITED STATES DEPARTMENT OF THE INTERIOR
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*Fish and Wildlife Technical Report* 19

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# American Wildcelery (*Vallisneria americana*): Ecological Considerations for Restoration

By Carl E. Korschgen
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# Contents





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# American Wildcelery (*Vallisneria americana*): Ecological Considerations for Restoration

by

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## Abstract

The success of vegetation management programs for waterfowl is dependent on knowing the physical and physiological requirements of the target species. Lakes and riverine impoundments that contain an abundance of the American wildcelery plant (*Vallisneria americana*) have traditionally been favored by canvasback ducks (*Aythya valisineria*) and other waterfowl species as feeding areas during migration. Information on the ecology of *V. americana* is summarized to serve as a guide for potential wetland restoration projects. Because of the geographic diversity and wetland conditions in which *V. americana* is found, we have avoided making hard-and-fast conclusions about the requirements of the plant. Rather, we present as much general information as possible and provide the sources of more specific information. *Vallisneria americana* is a submersed aquatic plant that has management potential. Techniques are described for transplanting winter buds from one location to another. Management programs that employ these techniques should define objectives clearly and evaluate the water regime carefully before initiating a major effort.

Habitat management projects for restoring and managing lakes and riverine impoundments for waterfowl in general, and canvasback (*Aythya valisineria*) migration and wintering habitats in particular, have led to a better understanding of one of the most important components of this habitat—the American wildcelery plant (*Vallisneria americana*). We compile and summarize information related to the ecology of American wildcelery and provide recommendations for its propagation. Habitat management programs based on natural succession patterns and an understanding of ecological tolerances of target species produce the most ecologically and economically sound results.

According to Cottam (1939), the scientific name of the canvasback derives from association with the American wildcelery plant. McAtee (1917) wrote about the value of this plant as a waterfowl food.

> "The names wildcelery and canvasback duck have been closely associated in the annals of American sport. To a certain extent this association is justified, since the canvasback evidently is very fond of the subterranean propagating buds of this plant. However, the assertion that the flavor of the canvasback is superior to that of any other duck and that this depends on a diet of wildcelery is not proved, to say the least. The scaups, or bluebills, and the redhead also are very fond of wildcelery, and are fully as capable of getting the delicious buds as is the canvasback. Several other ducks get more or less of this food, the writer finding that even the scoters on a Wisconsin lake in fall lived almost exclusively on it for the time. All parts of the plant are eaten by ducks, but the tender winter buds and rootstocks are relished by most. Wildcelery buds can usually be obtained only by the diving ducks, as the bluebills, redhead, canvasback, and scoters. The nondiving species, as the mallard, black duck, baldpate and the geese, get an occasional bud, but more often they feed upon the leaves. Wild fowl not thus far specifically mentioned which also feed upon wildcelery include wood ducks, pintail, ruddy duck, buffle-head, whistler, green-winged and blue-winged teals, greater and lesser scaups or bluebills, white-winged and surf scoters, and whistling swan."

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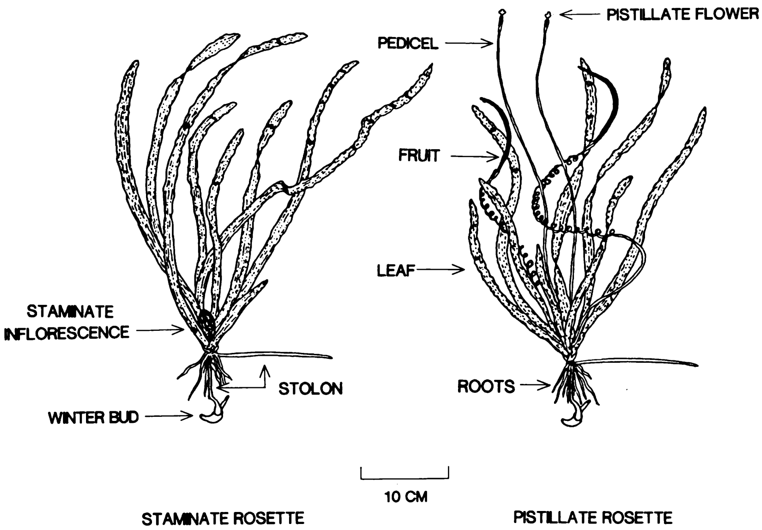


**Fig. 1.** Schematic of *Vallisneria americana* (Donnermeyer 1982). (About 0.25 scale.)

# Description

## *Taxonomy*

Often referred to as wildcelery, tape grass, or eel-grass, *Vallisneria americana* (Michx.) is a dioecious (bearing staminate and pistillate flowers on different plants) freshwater perennial aquatic plant having fibrous roots (Lowden 1982). Along with *Limnobium spongia* and *Elodea* spp., American wildcelery belongs to the Hydrocharitaceae family.

In 1803 Michaux first described the North American *Vallisneria* plant as a distinct species, *Vallisneria americana* (Fernald 1918). However, many authors (e.g., Gray 1848, 1874; Chapman 1883; Britton and Brown 1913) named the plant a variety of the European species *V. spiralis*. Flower morphology and differences in pollination appear to be the major differences between the two species (Svedelius 1932; Kausik 1939). Sculthorpe (1967) suggested that *V. americana* may be a geographical race of *V. spiralis*. Current treatment recognizes the North American population as a separate species under the name *V. americana* (Lowden 1982). Lowden (1982) lists probable synonyms for *V. americana* Michaux var. *americana* as *V. spiralis*, *V. gigantea*, *V. asiatica*, *V. subulispatha*, *V. neotropicalis*, *V. higoensis*, and *V. natans*.

## *Morphology*

*Vallisneria americana* has linear submerged or floating leaves that are strap- or tape-shaped (Fig. 1), and may extend 2 m or more depending on water depth. The stem is vertical with a short axis and bears stolons. Lowden (1982), who provided a detailed morphological description of *V. americana* from many North American locations, recognized both narrow- and broad-leaved forms of *V. americana*. In the former, leaves are less than 10 mm wide with 3–5 prominent longitudinal veins and margins entire to finely toothed. The leaf blade has perceivable to invisible transverse pigmented striations. This form is found in freshwater inland waterways, lakes, and lagoons. The broad-leaved form has leaves 10–25 mm wide with 5–9 veins and conspicuously toothed margins. The leaf blade has many visible transverse pigmented striations. This form is found in coastal freshwater inlets or spring-fed waterways subject to nearly constant temperatures. Many of these areas receive brackish water at high tide.

# Distribution

*Vallisneria americana* is found primarily in eastern North America, occurring west from Nova Scotia to South Dakota and south to the Gulf of Mexico (Fassett 1957). The plant has recently been reported in the western States of Washington, Nebraska, New Mexico, and Arizona (Lowden 1982; Fig. 2). Table 1 provides specific citations of selected distribution records throughout its geographical range.

# Reproduction

Although *V. americana* is a plant capable of both asexual and sexual reproduction, it lives in a habitat where asexual reproduction is apparently favored (Titus and Stephens 1983).

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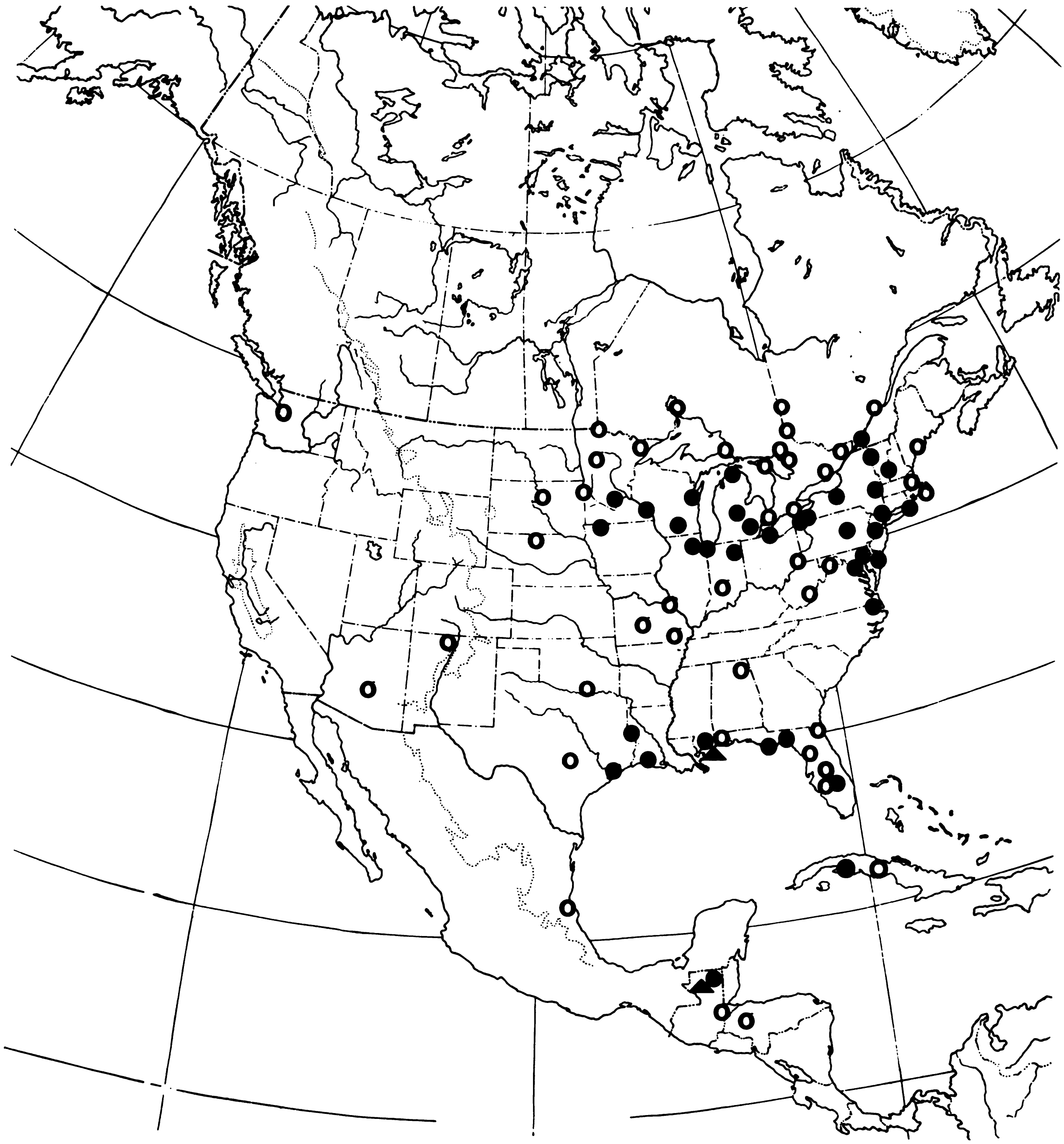

**Fig. 2.** Distribution of *Vallisneria americana* in North America: bisexual populations with solitary female flowers (*solid circles*), umbel or spikelike inflorescences (*triangles*), and representative unisexual or sterile collections (*open circles*; Lowden 1982).

## *Sexual*

The pistillate flower is borne on a pedicel that increases length by cell elongation to carry the flower to the air–water interface for pollination in late summer (Donnermeyer 1982). Male inflorescences are borne submerged in the axils of leaves. Each inflorescence consists of about 2,000 flowers, each less than 1 mm long (Wylie 1917).

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Table 1. *Annotations on the distribution of* Vallisneria americana.

| Location | Source | Page | Annotation |
|---|---|---|---|
| New England | Crow and Hellquist 1982 | 13 | Shows distribution in six States |
| Maine | Seymour 1969a | 53 | Occasional; ponds and rivers with muddy or sandy bottoms in Oxford, Kennebec, and Androscoggin Counties |
| | Bean et al. 1948 | 9 | Found in Penobscot, Somerset, Oxford, Washington, Waldo, Androscoggin, Sagadahoc, Kennebec, and York Counties |
| Vermont | Seymour 1969b | 44 | Occasional in ponds and rivers of Franklin, Chittenden, Groton, Addison, and Rutland Counties |
| New Hampshire | Seymour 1969a | 53 | Occasional; ponds and rivers with muddy or sandy bottoms in Coos County |
| Massachusetts | Seymour 1969a | 53 | Occasional; ponds and rivers with muddy or sandy bottoms in Essex, Middlesex, Bristol, and Hampden Counties |
| Connecticut | Seymour 1969a | 53 | Occasional; ponds and rivers with muddy or sandy bottoms in New London, Hartford, and Litchfield Counties |
| Delaware | Tatnall 1946 | 17 | Common in ponds and slow streams of the Coastal Plain |
| Pennsylvania | Wherry et al. 1979 | 26 | Shows State distribution |
| New York | Ogden 1974 | 13 | Quiet water of ponds and slow streams, usually with muddy or sand and coarse silt bottoms |
| | | 41 | Shows State distribution |
| Rhode Island | Seymour 1969a | 53 | Occasional; ponds and rivers with muddy or sandy bottoms in Little Compton and South Kingston |
| Maryland | Haramis and Carter 1983 | | Distribution in the tidal Potomac River |
| Virginia | Massey 1961 | 22 | Found in quiet waters of Accomac, Arlington, Northhampton, and Princess Ann Counties |
| West Virginia | Strausbaugh and Core 1970 | 64 | Found in the Cacapon, Gauley, Greenbriar, Little Kanawha, and Ohio rivers and other streams and springs of the State (Calhoun, Greenbriar, Hampshire, Hardy, Marion, Monogalia, Ohio, Pocahontas, Summers, Tucker, and Webster Counties) |
| North Carolina | Beal 1977 | 72 | Infrequent in lakes, streams, and sounds of the Coastal Plain |
| | Radford et al. 1968 | 56 | Shows State distribution |
| South Carolina | Radford et al. 1968 | 56 | Shows State distribution |
| Florida | Godfrey and Wooten 1979 | 74 | Found in many of the large springs and spring-fed streams in which the water is cool and remains at very nearly a constant temperature (about 21° C) throughout the year |
| | Burkhalter et al. 1973 | 63 | Thrives in many spring-fed streams throughout Florida |
| Louisiana | Chabreck and Condrey 1979 | 106 | Locally abundant in bayous, ponds, and lakes with salinities ranging from fresh to brackish |
| Mississippi | Jones 1974 | 366 | Found in freshwater streams near the coast that may be brackish at high tides |
| | | 368 | Shows State distribution |
| Kentucky | Braun 1943 | — | Found in Kentucky River |
| Tennessee | Sharp et al. (n.d.) | 2 | Found in water bodies of valleys of East Tennessee and the Cumberland Plateau |
| Indiana | Deam 1940 | 92 | Infrequent to common in the lakes of the area; shows State distribution |
| Ohio | Cooperrider 1982 | 41 | Found in shallow to deep quiet water ponds, lakes, and rivers; bays of western Lake Erie, northeast, and scattered elsewhere |
| | Braun 1967 | 60 | Shows State distribution |
| Upper Mississippi River | Minor et al. 1977 | T2-11 | Distribution on photomaps of Navigation Pools 2–10 |
| | Hagen et al. 1977 | T2-27 | Distribution on photomaps of Navigation Pools 11–26 |

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Table 1. *Continued.*

| Location | Source | Page | Annotation |
|---|---|---|---|
| | Mohlenbrock 1983 | 221 | Distribution records for counties bordering the Upper Mississippi River in Minnesota, Wisconsin, Illinois, Iowa, and Missouri |
| Illinois | Mohlenbrock and Ladd 1978 | — | Shows State distribution |
| | Ladd and Mohlenbrock 1983 | 18 | Adds to citation above |
| | Winterringer and Lopinot 1977 | 106 | Distributed in northern part of the State |
| Missouri | Steyermark 1975 | 67 | Found mostly in streams (Meramec, Gasconade, Black, and Current river drainage of the Ozarks); locally introduced north of the Missouri River in Boone County |
| Iowa | Beal and Monson 1954 | 26 | Shows State distribution |
| | Crum and Bachman 1973 | 152 | Table showing abundance in northwestern Iowa lakes |
| | Lammers and Van Der Valk 1979 | 141 | Shows State distribution |
| Michigan | Voss 1972 | 106 | Shows State distribution |
| | Schloesser and Manny 1982 | — | Distribution in the St. Clair–Detroit River |
| Wisconsin | T. Cochrane (personal communication) | | Shows State distribution |
| Wisconsin | Zimmerman 1953 | 12 | Distribution in selected lakes |
| Minnesota | Game Lake Surveys, Minn. Dep. Nat. Resour. (unpublished) | — | Distribution in game lakes |
| | Ownbey and Morley (personal communication) | — | Shows State distribution |
| | Moyle and Hotchkiss 1945 | 42 | Common in lakes and larger streams throughout the State except in the southwest and extreme west |
| North Dakota | Stevens 1963 | 52 | Only record is from Wood Lake, Benson County |
| Texas | Correll and Johnston 1970 | 102 | In lakes and beds of flowing streams, rare in the eastern half of State |
| Arizona | Correll and Correll 1975 | 161 | Recently discovered in Maricopa County |
| New Mexico | Martin and Hutchins 1981 | 95 | Shows State distribution |
| | Correll and Correll 1975 | 161 | Found in Rio Arriba County |
| Washington | Hitchcock et al. 1977 | 153 | Introduced in Dry Fall Coulee (Grant County) and Lakes Washington, Terrell, Shaver, and Hicks |
| Manitoba | Scoggan 1978 | 217 | Found north to Elphinstone about 80 km northwest of Brandon |
| Ontario | Scoggan 1978 | 217 | Found north to Lakes Nipigon and Abitibi |
| Quebec | Scoggan 1978 | 217 | Found north to Lake Timiskaming and the Quebec City District |
| New Brunswick | Scoggan 1978 | 217 | Found near St. John |

Upon maturity, the male flowers break from the pedicels and float to the surface (Kaul 1970). The male flowers are spread about by air and water currents on the surface where they may encounter a female flower. Male flowers may be captured inside the perianth of the female flower as it closes during temporary immersion by a wave (Sculthorpe 1967). After pollination the pedicel contracts into a spiral, thus retracting the flower underwater where fruit development takes place. In late summer or early fall, some of the fruit capsules rupture and release a gelatinous matrix containing seeds. This mass settles to the bottom in close proximity to the parent plant (Kaul 1978). Other fruits do not rupture until the plants have broken free of the substrate and floated away, thereby providing a dispersal mechanism (J. E. Titus and C. E. Korschgen, unpublished data).

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Choudhuri (1966) determined that 30–35° C (86–95° F) was the optimum germination temperature for *V. spiralis* seeds near Varanasi, India. He concluded that germination was favored by a shortened day but was not affected by light intensity. Muenscher (1936) however, found that seeds of *V. americana* exposed to bright light were slow to germinate, whereas those kept in diffuse light germinated more uniformly. Dried seeds gave almost no germination.

During the 1978 growing season in Chenango Lake, New York, only 24% of the *V. americana* rosettes sampled by Titus and Stephens (1983) flowered, yielding a population mean of less than 0.6% of dry weight allocated to sexual reproduction. Zamuda (1976) noted no germination from *V. americana* seeds in the Pamlico River estuary, North Carolina. However, at seven deep-water stations (4.2–6.2 m) in Douglas Lake, Michigan, Bromley (1967) found growing *V. americana* that had seed coats still attached to the rooting structures, thus indicating origin from seeds. C. E. Korschgen (unpublished data) has observed seedlings in Lake Onalaska of the Upper Mississippi River.

### *Asexual*

Shoots of *V. americana* emerge in late spring from overwintering buds (morphologically called turions). Winter buds become dormant during winter and resume growth in spring when water temperatures reach 10–14° C (Zamuda 1976). Winter buds are buried in the sediment about 8–10 cm in Lake Mendota, Wisconsin (Titus 1977) and 5–27 cm (mean 15 cm) in the Potomac River (Carter et al. 1985) but depth is governed by the type of substrate. In very organic sediments, the buds might be buried more than 15 cm (C. E. Korschgen, unpublished data). In spring, the second internode of the winter bud elongates to form a stolon that carries a compact rosette of ribbonlike leaves to the sediment–water interface (Wilder 1974). In a favorable experimental environment, one winter bud may produce as many as 20 rosettes during a growing season (C. E. Korschgen, unpublished data). The ribbonlike leaves usually reach the water surface (water depth, 95–120 cm) in early to midsummer at southern Wisconsin latitudes (Donnermeyer 1982). Near the close of the growing season in late summer, the production of rosettes ceases and some rosettes develop one or more winter buds on stolons (Fig. 3) that grow down into the sediment (Titus and Stephens 1983). After winter bud formation, the remaining stem tissue degenerates, breaks free of the substrate, and floats until it decomposes (Titus and Adams 1979a).

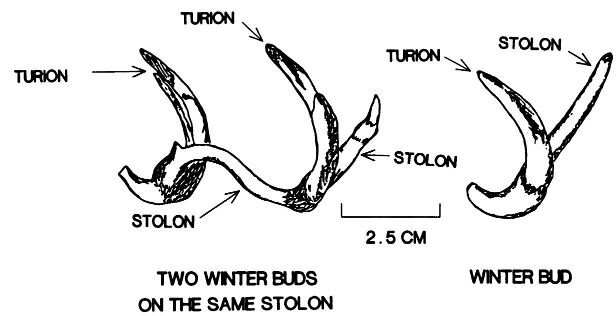


**Fig. 3.** Gross morphology of *Vallisneria americana* winter buds (from Donnermeyer 1982). (About 1.5 scale.)

## Phenology

Donnermeyer (1982) observed the following phenology for *V. americana* in Navigation Pool 9 of the Upper Mississippi River: Production was low early in the growing season. Primary production increased by midsummer and peaked during the second half of July. Maximum seasonal biomass was observed at the beginning of September. The greatest rate of shoot production occurred from late June to mid-July. The maximum nonphotosynthetic production (stolons and winter buds) rate was from mid-August to early September.

Titus and Stephens (1983) reported the following changes in proportional distribution of biomass within *V. americana* beds in Chenango Lake, New York: In late May, stems elongated from winter buds to produce small, leafy rosettes, at which time winter buds constituted the largest plant fraction by dry weight. Leaves dominated the plant biomass from mid-June through early August. Winter buds again rose to importance by late August just before the senescence of other plant parts. By mid-June, roots composed 13% of total plant biomass and continued to do so until the end of August. During the same period, stolons constituted 12–15% of total plant biomass. Flowers and fruits that developed in late summer usually did not exceed 0.6% of total plant biomass.

During the 1978 growing season in Chenango Lake, New York, *V. americana* winter buds accounted for 11% of total dry weight (Titus and Stephens 1983). Asexual reproduction was at least an order of magnitude greater than sexual reproduction in Chenango Lake.

## Ecology

### *Water Depth and Turbidity*

In plotting the depths of *V. americana* against secchi disk transparencies (Fig. 4), Davis and Brinson (1980)

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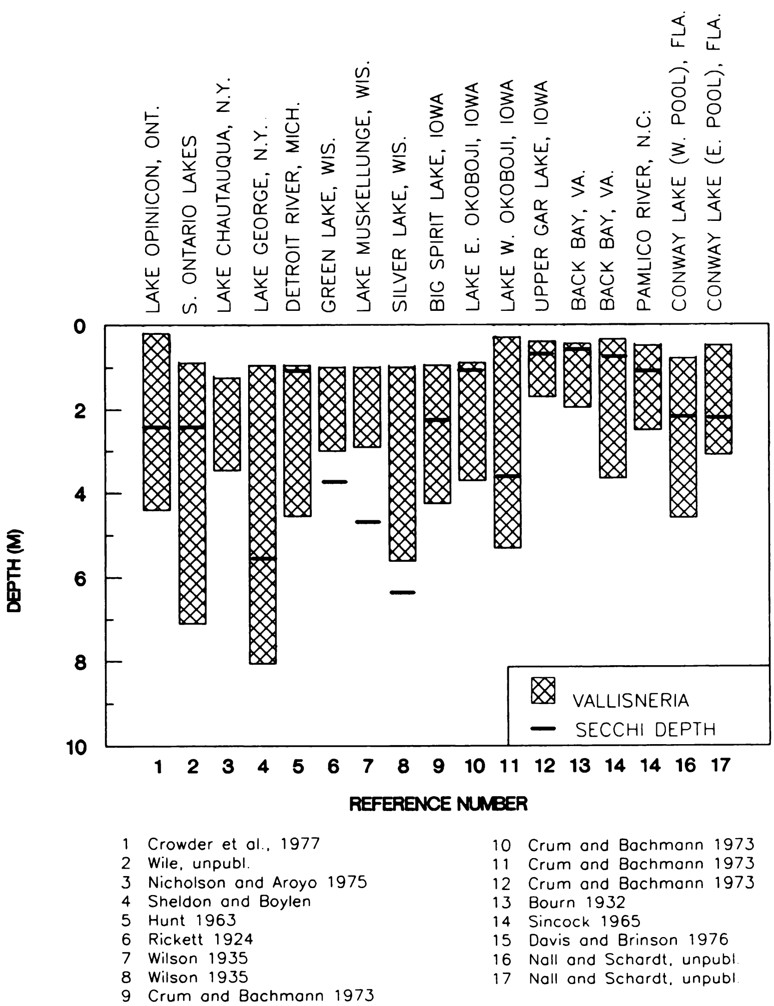


**Fig. 4.** Secchi disk depth and range of greatest abundance of *Vallisneria americana* in selected lakes (after Davis and Brinson 1980). The jagged end of a bar represents an approximate measurement.

found it has the capacity to maintain a relatively high biomass in turbid systems. Davis and Carey (1981) suggested that this species may even spread with perturbations that increase turbulence. *Vallisneria americana* increased in lower Currituck Sound, North Carolina, in 1978 during conditions of increased turbidity (Davis and Brinson 1980). In contrast, tropical storm Agnes, which struck the East Coast in 1972, was cited as a factor in the decrease of *V. americana* in different portions of Chesapeake Bay (Bayley et al. 1978; Kerwin et al. 1976). The main effects were increased turbidity and uprooting of plants. Bourn (1932) also believed that the turbidity levels existing in Back Bay and Currituck Sound during the late 1920's and early 1930's prohibited growth of submerged macrophytes.

*Vallisneria americana* may be disadvantaged in deep turbid water because of its limited elongation potential resulting in inability to concentrate photoreceptive biomass at or near the water surface in low light environments (Barko et al. 1984). *Vallisneria americana* compensates for possibly disadvantageous morphological features (in comparison with a plant such as *Myriophyllum*) by a greater physiological adaptability to low light regimes (Titus and Adams 1979b). This species was the most shade-adapted of five macrophytes studied by Meyer et al. (1943). In Trout Lake, Wisconsin, *V. americana* was found growing in 4.5 m of water where the light intensity was 4.5% of that at the surface (Spence and Chrystal 1970a, 1970b). *Vallisneria americana* is light adaptable; it acclimates rapidly to increasing light and efficiently uses low light (Titus and Adams 1979b). Plants emerging from winter buds under laboratory conditions have the ability to elongate to a mean length of 44.0 cm in total darkness (C. E. Korschgen, unpublished data).

Hunt (1963) found 30–150 cm to be the optimum depth for growth of *V. americana* in the Detroit River,

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Michigan, although the plant occurred as deep as 335 cm. *Vallisneria americana* exhibited a constant decrease in the rate of apparent photosynthesis with an increase in depth of immersion, but it maintained an appreciable rate of photosynthesis (25% of that at the surface) to a depth of 10 m, where light intensity was 0.5% of that at the surface (Meyer et al. 1943). Carter and Rybicki (1985) observed that the water depth in which most *V. americana* was growing was above or slightly below the 10% photic zone as determined from spring measurements. The deepest spring biomass occurred where the photic zone was about 5% of the surface measurements.

### *Hydrostatic Pressure*

Hydrostatic pressure, rather than light availability, probably controls maximum depth distribution of aquatic macrophytes, according to Davis and Brinson (1980). They concluded that 6 to 7 m is the maximum depth for *V. americana*. The plant is commonly found at depths of 1–5 m and densities of 100–1,000 rosettes/$m^2$ in Lake George, New York; densities at maximum depth (7 m) were 16–400 rosettes/$m^2$ (Sheldon and Boylen 1977).

### *Substrate*

*Vallisneria americana* grows in substrates ranging from gravel to hard clay, but grows best in silty sand (Hunt 1963). The plant seemed to grow as well in mud as in sand in Lake Mendota, Wisconsin (Denniston 1921); however, *V. americana* was restricted to sandy-textured sediment of University Bay, Lake Mendota in 1966 (Lind and Cottam 1969). Hunt (1963) believed that only an impervious substrate or a soft, shifting one prevented establishment of *V. americana*. In Lake Onalaska, Wisconsin, Navigation Pool 7 of the Upper Mississippi River, *V. americana* beds are distributed over substrates of all textures and degrees of organic matter (G. A. Jackson and C. E. Korschgen, unpublished data). *Vallisneria americana* grows in organic, peatlike substrates at Rice Lake National Wildlife Refuge in central Minnesota (C. E. Korschgen, unpublished data). In the tidal Potomac River, the majority of winter buds were between 10 and 20 cm deep in silty clay and between 5 and 15 cm in sand (Rybicki and Carter 1986). Laboratory experiments by Carter et al. (1985) showed that emergence of winter buds was affected by the depth of the substrate. Most winter buds emerged from the substrate when buried by 15 cm of sediment. Only 25% emerged when covered with 20 cm of sediment, and none emerged when covered with 25 to 55 cm of sediment.

### *Temperature*

Barko et al. (1982, 1984) found that the growth of *V. americana* was severely restricted at water temperatures less than 20° C. *Vallisneria americana* grew at water temperatures of 19 to 31.5° C in the Detroit River (Hunt 1963) and 22.7 to 26.3° C in Lake Erie (Meyer et al. 1943). In laboratory tests (Wilkinson 1963) *V. americana* grew best within a water temperature range of 33 to 36° C; below 19° C arrested growth occurred and above 50° C plants became limp and disintegrated. *Vallisneria americana* has not been found to overwinter in green form in Lake Mendota, Wisconsin (Lind and Cottam 1969).

Water temperature effected a greater range of response in *V. americana* leaf length than did light. However, at water temperatures of 20° C or more, overall *V. americana* biomass production and shoot density generally increased with increasing light, particularly between low and middle light levels (Barko et al. 1982). Total chlorophyll in *V. americana* increased with decreasing irradiance irrespective of temperature, but total chlorophyll content increased with rising temperature (from 12 to 32° C at 4 Celsius degree increments) at all light levels (Barko and Filbin 1983).

### *Flow*

*Vallisneria americana* is common in both lotic and lentic water bodies. Rooted plants that occur in moving water have tough, flexible stems or leaves, a creeping growth habit, frequent adventitious roots, and vegetative reproduction (Hynes 1970). The plant's greater allocation of biomass to below-sediment parts may allow the species to maintain itself in shallow water having relatively great wave action (Titus and Adams 1979a). McAtee (1939) recommended planting *V. americana* in quiet to slight-current waters. Some current is usually necessary for *V. americana* growth (Moyle and Hotchkiss 1945).

### *Water Chemistry*

Aquatic macrophytes have wide tolerances to water chemistry regimes (Pip 1979; Hellquist 1980), and *V. americana* is no exception. The plant may tolerate a broader range of water chemistry characteristics than those discussed here; the published information is influenced by the lakes available for study. Only a few field and laboratory studies have been conducted to determine the exact tolerance limits of *V. americana*.

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Table 2. *Literature references to alkalinity and pH of aquatic habitat for American wildcelery* (Vallisneria americana).

| | Alkalinity (mg/L) | | pH | | |
|---|---|---|---|---|---|
| Location (no. of sites) | Mean | Min.-max. | Mean | Min.-max. | Source |
| New England (38) | | | 7.4 | 5.8–10.2 | Crow and Hellquist 1982 |
| Lake Erie | | | | 6.8–8.9 | Meyer et al. 1943 |
| Lake Erie | | 71–94 | | | Hunt 1963 |
| Detroit River, Michigan | | | | 6.5–9.0 | Hunt 1963 |
| Back Bay, Virginia | | | | 6.8–8.9 | Chamberlain 1948 |
| Wisconsin (2) | | | | 5.7–7.8 | Wilson 1935 |
| Northeastern Wisconsin (3) | | 18–34 | | 7.3–9.0 | Fassett 1930 |
| Pool 7, Upper Mississippi River | 133 | 87–175 | 8.0 | 8.0–9.2 | Dawson et al. 1984 |
| Minnesota (55) | | | 8.2 | 7.0–8.9 | Moyle 1945 |
| Minnesota | | 19–277 | | | Moyle 1945 |
| Minnesota | | <40–200 | | 6.8–8.8 | Moyle and Hotchkiss 1945 |
| Lake Opinicon, Ontario | | 80–93 | | 7.7–8.5 | Crowder et al. 1977 |
| Central Canada (141) | 80 | 10–200 | | | Pip 1979 |
| Ontario lakes (5) | | | | 5.5–7.0 | Harvey et al. 1981 |

### Alkalinity

Bourn (1934), citing studies conducted in North Dakota and Nebraska, concluded that *V. americana* does not grow in saline or alkaline lakes typical of western watersheds. Other reports list alkalinity (mg/L) in water bodies where *V. americana* is found (Table 2).

### pH

Titus and Stone (1982) found that the dissolved inorganic carbon (used in photosynthesis) uptake rates by *V. americana* declined with increasing pH. The uptake rate declined by 61% from pH 7 to 8, but changed only slightly from pH 8 to 9. *Vallisneria* plant weight, number of rosettes per plant, and number of buds per plant were found to decrease with declining pH (Hoover 1984; Grise 1983). *Vallisneria americana* is rarely reported growing in lakes with pH values below 6. Grise et al. (1986) found that at pH 5 iron and aluminum toxicity may limit plant growth. In laboratory experiments in which plants were grown at pH 5 the leaf tips browned and senesced prematurely and winter buds were small and less able to support growth the following spring. Other references to pH in water bodies where *V. americana* are found are in Table 2.

### Salinity

Although *V. americana* is considered a freshwater plant, it will grow in water that has elevated salt concentrations (Hunt 1963). Salt content of water consists principally of chloride, sulfate, sodium, magnesium, and calcium (Todd 1970). *Vallisneria americana* has survived in salt concentrations as great as 20% (7,000 ppm) of seawater and thrived at 12% (4,200 ppm; Bourn 1934). Distribution of submerged aquatic vegetation in Chesapeake Bay tends to be determined by a salinity regime. The plant is found in areas where salinity is 3,000 to 5,000 ppm (Steenis 1970). Haller et al. (1974) determined that water with more than 6,660 ppm salinity is toxic to *V. americana*. Haramis and Carter (1983) found *V. americana* to be the only plant to persist in the transition zone of the Potomac River where the salinity was 500 to 10,000 ppm; it grew at 10,000 ppm but died and decayed at 13,500 ppm (Carter et al. 1985). *Vallisneria americana* did not grow in Potomac River water, which had a chlorine content equivalent to 6,000 to 8,000 ppm of sodium chloride (Martin and Uhler 1939).

Sincock (unpublished report) concluded that *V. americana* plants in Currituck Sound were capable of tolerating higher salinities when grown in a silt substrate rather than sand. This difference is possibly due to high cation exchange in silt soils that protect the root structure. Sand substrates are not found to have the same buffering capacity.

### Other

Water samples were analyzed monthly from Pools 7 and 8 navigation channel area of the Upper Mississippi River for 10 years (1972–81; Dawson et al. 1984). These data (Table 3) illustrate a water chemistry regime in which

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Table 3. *Mean and monthly variation of water chemistry parameters of Pool 7 (navigation channel) of the Upper Mississippi River, May to September, 1972–81 (Dawson et al. 1984).*

| Parameter | Mean<br>Min.–max. | Parameter | Mean<br>Min.–max. |
|---|---|---|---|
| Nitrite nitrogen (mg/L) | 0.03<br><0.008–0.040 | BOD[a] (mg/L) | 2.8<br>2.3–4.0 |
| Nitrate nitrogen (mg/L) | 0.49<br><0.37–0.68 | Total hardness (mg/L as $CaCO_3$) | 157<br>152–164 |
| Ammonia nitrogen (mg/L) | 0.13<br><0.07–0.15 | Dissolved oxygen (mg/L) | 8.5<br>6.0–11.5 |
| Total phosphate (mg/L as $PO_4$) | 0.63<br><0.42–1.00 | Suspended matter (mg/L) | 27.3<br>16.0–57.3 |

[a]Biological oxygen demand.

*V. americana* has been very prolific for more than 25 years (C. E. Korschgen, unpublished data). In water chemistry analyses (Crowder et al. 1977) of Lake Opinicon, Ontario (Table 4), *V. americana* showed the highest percent frequency and second highest total abundance of all aquatic macrophytes sampled in the lake.

## Chemical Control

The toxicity of most chemical compounds to specific aquatic macrophytes under different environmental conditions has yet to be thoroughly investigated, but chlorine, chromates, cyanides, heavy metals, phenols, and aromatic solvents are probably toxic to all macrophytes, even in low concentrations (Sculthorpe 1967). Stevenson and Confer (1978) discussed the uptake of heavy metals and effects of petrochemicals.

Forney and Davis (1981) concluded that the concentrations of atrazine and glyphosate normally found in farm field runoff water will not pose any threat to *V. americana*. However, they did not state the concentrations found in runoff water. Correll and Wu (1982) determined that 650 g/L dissolved atrazine significantly inhibited photosynthesis in *V. americana*, and 120 g/L caused 100% mortality within 30 days. After 47 days *V. americana* had a 50% mortality at 12 g/L; the production of new plants at the end of runners and the leaf surface area increase of survivors was significantly reduced.

A 100-ppm concentration of 2,4-D killed *V. americana* and 10-ppm concentrations inhibited its growth (Gerking 1948). Lakes containing 0.5 and 0.25 ppm simazine suppressed *V. americana* growth but did not eliminate it (Norton and Ellis 1976). Other herbicides varied in their effects on *V. americana* (Table 5).

*Vallisneria americana* experienced retarded growth, loss of chlorophyll, and collapse when exposed to total available chlorine levels of 0.5 to 0.125 ppm in laboratory studies by Webster and Rawles (1976). They suggested that chlorine pollution may have been a cause for the loss of submersed aquatic plants in Chesapeake Bay in the 1970's.

Table 4. *Chemical properties of water in Lake Opinicon, Ontario, Canada (from Crowder et al. 1977).*

| Parameter | Range | Parameter | Range |
|---|---|---|---|
| Dissolved oxygen (mg/L) | 10.7–15.2 | Potassium (mg/L) | 11.7 |
| | | Sodium (mg/L) | 2.5 |
| Free $CO_2$ (mg/L) | 0–2.4 | Calcium (mg/L) | 192 |
| Total Kjeldahl nitrogen (mg/L) | 0.39–0.43 | Magnesium (mg/L) | 24.3 |
| Total phosphorus (mg/L) | 0.014–0.026 | Chloride (mg/L) | 4–8.2 |

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Table 5. *Control of* Vallisneria americana *by selected herbicides (Lawrence and Hollingsworth 1969).*

| Herbicide | Concentrations | Degree of control |
|---|---|---|
| Silvex | 0.5 to 2 ppm | None |
| | 5 to 30 ppm | 70 to 100% |
| | 2 ppm | Satisfactory |
| Diquat dibromide | 0.25 ppm | 30 to 90% |
| Diquat dichloride | 0.25 to 0.5 ppm | 30 to 100% |
| Paraquat dichloride | 0.25 to 0.5 ppm | 67 to 93% |
| 2,4,-D IOE granules | 16.5 to 27.5 kg/ha | Unsatisfactory |
| 2,4-D D, E granules | 44 kg/ha | None |
| Acrolein | 2.55 ppm | Killed |
| Endothall, DDS | 2 to 3 ppm | Seasonal |

## *Biological Control*

### Influence of Other Plants

Rapid increases of Eurasian milfoil, *Myriophyllum spicatum* (such as those that occurred in the late 1950's and early 1960's in Chesapeake Bay) probably reduced native species, including *V. americana* (Orth and Moore 1981). But when Eurasian milfoil declined in the late 1970's, native species returned to approximately their former abundances. The ability of Eurasian milfoil to extend its growing season in relation to that of *V. americana* (by photosynthesizing at low temperatures) may have been a factor in its replacement of *V. americana* in Lake Wingra, Wisconsin (Titus and Adams 1979b). Also, because *V. americana* distributes the major portion of its shoot biomass near the sediment surface (hence lower light regime) it was apparently incapable of successfully competing with canopy-forming species such as *Hydrilla verticillata* in Florida (Barko et al. 1984) and *M. spicatum* in Lake Wingra in Wisconsin (Titus and Adams 1979b).

However, Titus and Adams (1979a) have given two possible reasons for why *M. spicatum* has not completely replaced *V. americana* in University Bay of Lake Mendota or in Lake Wingra, Wisconsin. First, *V. americana* has an inherently higher productivity during summer months. Second, it has a better rooting system that allows it to exist in shallow water subject to wave wash.

Titus and Stephens (1983) studied the neighbor influences of *Chara vulgaris* and *Potamogeton amplifolius* on seasonal growth patterns of *V. americana* in Chenango Lake, New York. They determined that plant dry weight was consistently, but not significantly, lower for plants with neighbors than those without neighbors; leaf numbers, stolon length, and winter bud production did not differ significantly. *Vallisneria americana* allocated more biomass to vertical extension in the presence of neighbors and to horizontal extension in the absence of neighbors. Titus and Stephens (1983) speculated that neighbor influences may have greater importance in more productive macrophyte communities, whereas dense macrophyte growth may have a more profound effect on the physicochemical environment.

By reducing photosynthetic light, epiphytic algae may sufficiently light-stress submerged macrophytes enough to jeopardize growth the next year (Phillips et al. 1978).

### Influence of Animals

Carter and Rybicki (1985) studied transplanted *V. americana* in the Potomac River and observed that grazers such as waterfowl, muskrats (*Ondatra zibethicus*) and red-bellied turtles (*Pseudemys rubriventris*) influenced the establishment of plant beds. Plants grown in full exclosures during their first year became established and were evident the following year.

Common carp (*Cyprinus carpio*) are implicated in the loss of submersed macrophyte beds, either by uprooting plants or by increasing turbidity or sedimentation. Carp do not seem to feed directly off the bottom; instead they uproot the vegetation and then feed on the shoots and roots that settle to the bottom. When the fish have stirred up a cloud of mud, debris, and plants, they swim through the cloud sucking up whatever is edible (Eddy and Underhill 1974). Carp introduced into Lake Wingra in the late 1800's probably caused *V. americana* to disappear from the lake by 1929 (Davis and Brinson 1980). One year after carp removal by rotenone in the Middle Harbor of Lake Erie, Ohio, *V. americana* was found in areas where it had not been present before treatment (Anderson 1950).

Grass carp (*Ctenopharyngodon idella*) feed on *Chara*, *Najas*, *Hydrilla*, *Myriophyllum*, and *V. americana* in decreasing order (Sutton and Blackburn 1973).

A great variety of invertebrates are known to attack waterfowl food plants and occasionally become highly destructive. Leaves of *V. americana* in Potomac River beds are occasionally riddled by certain fly larvae (Martin and Uhler 1939). Plant beds in Pool 7 have many invertebrates on and in the leaves (E. Chilton, personal communication). The effect of these invertebrates on the productivity of, or disease introductions to, *V. americana* plants is unknown.

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Table 6. Vallisneria americana *biomass from various locations in Wisconsin (from Donnermeyer 1982).*

| Site | Average biomass dry weight (g/m$^2$) | Source |
|---|---|---|
| Trout Lake, N.E. Wisconsin | 0.001 | Wilson (1941) |
| Silver Lake, N.E. Wisconsin | 0.02 | Wilson (1935) |
| Sweeny Lake, N.E. Wisconsin | 0.04 | Wilson (1937) |
| Green Lake, S.E. Wisconsin | 0.5 | Rickett (1924) |
| Green Lake, S.E. Wisconsin | 3.9 | Bumby (1977) |
| Lake Mendota, S.E. Wisconsin | 67.0 | Rickett (1922) |
| Navigation Pool 8, Upper Mississippi River | 93.4 | Sefton (1976) |
| Navigation Pool 7, Upper Mississippi River | 170.3[a] (1980)<br>149.5[a] (1981) | C. E. Korschgen (unpublished data) |
| Navigation Pool 9, Upper Mississippi River | 171.1[a] (1980)<br>176.0[a] (1981) | C. E. Korschgen (unpublished data) |
| Navigation Pool 9, Upper Mississippi River | 154.6[a] (1980)<br>109.7[a] (1981) | C. E. Korschgen (unpublished data) |
| Navigation Pool 9, Upper Mississippi River | 176.6[b]<br>144.5[c] | Donnermeyer (1982) |
| Navigation Pool 9, Upper Mississippi River | 217.3[d]<br>173.6[e] | Donnermeyer (1982) |
| Lake Mendota, S.E. Wisconsin | 344 | Titus and Adams (1979a) |

[a]Shoot biomass only, measured in August 1980.
[b]Shoot biomass only, measured on 1 September 1980.
[c]Shoot biomass only, measured on 14 August 1980.
[d]Total biomass, measured on 1 September 1980.
[e]Total biomass, measured on 14 August 1980.

# Productivity

## *Rosettes*

Zamuda (1976) reported a maximum *V. americana* density of 280 rosettes/m$^2$ in August and a seasonal mean of 200 rosettes/m$^2$ for the Pamlico River Estuary, North Carolina. Donnermeyer (1982) measured a maximum density of 214 rosettes/m$^2$ in Navigation Pool 9 of the Upper Mississippi River. After sampling rosette densities along six transects within *V. americana* beds in Navigation Pool 7 of the Upper Mississippi River in 1980–83, C. E. Korschgen (unpublished data) determined densities of 50–253 rosettes/m$^2$. Table 6 shows the variability of *V. americana* biomass in various Wisconsin locations.

## *Winter Buds*

A maximum winter bud density of 233/m$^2$ and a mean of 55/m$^2$ were reported for the lower Detroit River; the maximum and mean winter bud (wet weight) biomass was 68.7 g/m$^2$ and 16.6 g/m$^2$, respectively (Hunt 1963). When Hunt's biomass data was converted to dry weight by using a conversion factor of 30.2% dry matter (C. E. Korschgen, unpublished data), the Detroit River had a maximum and mean winter bud (dry weight) biomass of 20.8 g/m$^2$ and 5.0 g/m$^2$, respectively. Donnermeyer and Smart (1985) reported a maximum winter bud density of 158/m$^2$ and a maximum and mean (dry weight) biomass of 30.1 g/m$^2$ and 20 g/m$^2$, respectively. Variation of winter bud biomass for the years 1980, 1983, and 1984, of 36 g/m$^2$, 32 g/m$^2$, and 47 g/m$^2$ (oven dry weight), respectively, was found (C. E. Korschgen, unpublished data) in Lake Onalaska, Wisconsin (Navigation Pool 7, Upper Mississippi River). The variations may be attributable to annual changes in density of *V. americana* or sampling error.

# Value

## *General*

Roots, rhizomes, and stolons of most aquatic plants help to reduce erosion and facilitate colonization by benthic algae and invertebrates; their foliage offers shelter, support and, at least during daylight, a locally enriched

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oxygen supply (Sculthorpe 1967). Macrophytes also provide a direct or indirect source of food for an immense variety of aquatic invertebrates and fishes, and for birds and mammals that frequent aquatic habitats (Sculthorpe 1967).

## *Wildlife Food*

All parts of *V. americana* are important food items for many species of waterbirds (Sculthorpe 1967). McAtee (1939) reported that *V. americana* was eaten by 19 species of wild ducks. Martin and Uhler (1939) examined 7,998 stomachs of 18 species of ducks; *V. americana* accounted for about 2% of the food eaten, making it the seventh most popular plant food. The plant was the most important food used by ducks in the Lower Detroit River (Hunt 1963). *Vallisneria americana* and *Potamogeton* spp. were the most important plant foods as measured by percent volume and the collection of 47 greater scaup (*Aythya marila*), 44 lesser scaup (*A. affinis*), and 39 common goldeneye (*Bucephala clangula*) in the Detroit River during the winters of 1980 and 1981 (Jones and Drobney 1986).

Foods consumed by canvasbacks and food availability were studied on Navigation Pool 7 of the Upper Mississippi River in 1978, 1979, and 1980 (Korschgen et al. 1988). Canvasbacks fed primarily on winter buds of *V. americana* and consumed 40% of the standing crop of 380,000±44,350 SD kg (dry weight) in Lake Onalaska in 1980. Traditionally, canvasbacks have been primarily obligated to two foods during fall migration—sago pondweed (*Potamogeton pectinatus*) and *V. americana* (Cottam 1939; Perry 1982). The proliferation of *V. americana* in Navigation Pools 7, 8, and 9 of the Upper Mississippi River (C. E. Korschgen, unpublished data) occurred at the same time that historically important migrational habitats deteriorated elsewhere. During the 1960's and 1970's, canvasbacks shifted their migration routes to respond to the food supplies produced by *V. americana* on the Upper Mississippi River. An estimated 75% of the canvasback population in the three eastern flyways use this food resource each fall (Korschgen et al. 1988).

## *Nutritive Value*

### Shoot Material

The nutritive value of aquatic macrophytes is dependent on the fertility of their water medium. Protein content is usually considered the most valuable constituent of foodstuffs (Boyd and Blackburn 1970). Crude protein (dry weight) has been measured for *V. americana* from several locations. Proximate analysis of entire shoots collected near Fort Lauderdale, Florida, revealed a crude protein range of 17.6–27.0% of dry weight (Boyd and Blackburn 1970). Plants collected from Lake Mendota, Wisconsin, had 12.4–24.1% crude protein (Schuette and Alder 1927; Gerloff and Krombholz 1966); plants from Lake Chemung, Ontario, had 18.1–19.8% (Muztar et al. 1978a). Donnermeyer (1982) determined the crude protein content of various parts of *V. americana* over the growing season (Table 7). Levels of various amino acids showed a similar pattern in 12 species of aquatic macrophytes collected from Lake Chemung, Ontario; of the essential amino acids, *V. americana* had moderate amounts of leucine, arginine, and valine, but was relatively low in lysine (Muztar et al. 1978b).

Mineral and nutrient content of *V. americana* leaves is similar to that of land forages in the United States (Hentges et al. 1973; Easley and Shirley 1974). Although the nutritive value of dried *V. americana* was similar to alfalfa hay according to Linn et al. (1975), Muztar et al. (1977) fed dried pelleted *V. americana* leaves to tame roosters and ducks and determined that it had a true metabolizable energy value of about half that of dehydrated alfalfa. However, the *V. americana* in the study by Muztar et al. (1977) was not washed before it was dried and surface contamination may have caused excessive amounts of surface ash, therefore a lower true metabolizable energy value. If *V. americana* is grown in soft water and washed, ash might decrease; *V. americana* should then have metabolizable energy values comparable to alfalfa and other forage plants (Muztar et al. 1977).

### Winter Buds

Winter buds are high in dry matter and low in ash and fiber content, consequently giving them high nutritional potential (Donnermeyer and Smart 1985). Winter buds harvested from September 1980 through April 1981 from Navigation Pool 9 of the Upper Mississippi River contained 10.4% crude protein and averaged 3,978 cal/g dry weight (Donnermeyer and Smart 1985). *Vallisneria americana* winter buds collected in 1980 from Lake Onalaska Navigation Pool 7 of the Upper Mississippi River had mean caloric contents of 4,075 cal/g dry weight (Korschgen et al. 1988). Winter buds collected from Lake Onalaska in fall 1980 had a mean crude protein value of 11.0%; ash, 4.6%; crude fiber, 2.8%; crude fat, 0.8%; and nitrogen-free extract, 80.8% (C. E. Korschgen, unpublished data).

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Table 7. *Crude protein content (dry weight) of* Vallisneria americana *organs, Navigation Pool 9, Upper Mississippi River, 1980*[a] *(from Donnermeyer 1982).*

| | Date | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Crude protein content | 5-28 | 6-27 | 7-13 | 7-29 | 8-14 | 9-1 | 9-16 | 10-6 | Mean |
| **Leaves** | | | | | | | | | |
| Crude protein (%) | 21.4 | 16.4 | 16.0 | 14.4 | 16.5 | 15.8 | 14.0 | 13.5 | 16.0 |
| Crude protein (% ash-free) | 28.1 | 25.8 | 26.1 | 29.7 | 22.8 | 20.4 | 18.5 | 18.8 | 22.7 |
| **Rootstocks** | | | | | | | | | |
| Crude protein (%) | —[b] | 12.8 | 10.4 | 12.8 | 14.1 | 11.3 | 8.0 | 14.0 | 11.9 |
| Crude protein (% ash-free) | | 17.4 | 15.3 | 18.2 | 17.6 | 14.0 | 10.5 | 19.1 | 16.0 |
| **Stolons** | | | | | | | | | |
| Crude protein (%) | 17.1 | 16.0 | 13.2 | 9.4 | 10.6 | 6.9 | 6.3 | 9.4 | 11.1 |
| Crude protein (% ash-free) | 19.5 | 19.3 | 16.9 | 11.7 | 12.8 | 8.2 | 8.1 | 12.5 | 13.6 |
| **Fruits** | | | | | | | | | |
| Crude protein (%) | — | — | — | 12.2[c] | | 11.8 | 12.1 | 10.9 | 11.7 |
| Crude protein (% ash-free) | — | — | — | 13.4 | | 12.8 | 13.2 | 11.9 | 12.8 |
| **Pedicels** | | | | | | | | | |
| Crude protein (%) | — | — | — | 11.5[c] | | 7.4[d] | | 9.2 | 9.4 |
| Crude protein (% ash-free) | — | — | — | 14.4 | | 9.4 | | 12.1 | 12.0 |

[a]All values are means of triplicate analyses.
[b]Specific organs were not present in biomass.
[c]Samples from 7-29 and 8-14 were combined for analyses.
[d]Samples from 9-1 and 9-16 were combined for analyses.

## *Invertebrate Cover*

A mixed stand of *Chara* and *V. americana* in Anchor Bay, Lake St. Clair, Michigan, contained high numbers of amphipods, midge larvae, and other important yellow perch (*Perca flavescens*) food items (Heberger 1978). When comparing introduced *Myriophyllum spicatum* beds and mixed native *Potamogeton–V. americana* communities as habitat for fish and their invertebrate prey in Lake Opinicon, Ontario, five major zoobenthos taxa were found to be 3 to 7 times more abundant in the mixed native communities than in the introduced *M. spicatum* beds (Keast 1984); significantly more Isopoda, Chironomidae larvae, Ephemeroptera nymphs, Trichoptera larvae, and small gastropods were found in the *Potamogeton–V. americana* communities in May and July. Densities of foliage invertebrates in May were 4 times as great on combined samples of *Potamogeton robbinsii* and *V. americana* than on *M. spicatum* foliage, twice as great in June, 3 times as great in July, and twice as great in August (Keast 1984). *Vallisneria americana* had a greater quantity of benthic organisms beneath it than did *Elodea canadensis* and *Najas flexilis*; *V. americana*, with its more extensive root system, may have provided a more stable substrate for the benthos (Gerking 1957).

In a study of Lake Mendota, Wisconsin, Andrews and Hasler (1942) found that *V. americana* had a smaller standing crop of invertebrates (number/kg dry weight of plant) than did *Ceratophyllum demersum*, *Myriophyllum exalbescens*, and *Potamogeton pectinatus*.

## *Fish Cover*

Eight times as many bluegills (*Lepomis macrochirus*) and twice as many pumpkinseeds (*Lepomis gibbosus*) were netted by day in *Potamogeton–V. americana* mixed communities than in *M. spicatum* beds (Keast 1984). For bluegills, the ratio was maintained in night collections. Numbers of yellow perch were also higher at night in the mixed native plant communities. In July, 3 to 6 times as many bluegills, pumpkinseeds, and yellow perch were netted, day or night, in the mixed communities. In several Florida lakes, 35 species of juvenile fish inhabited dense aquatic plant communities that included *V. americana* (Barnett and Schneider 1974).

## *Other*

Submersed aquatic macrophytes serve as important primary producers, using $CO_2$ and inorganic nutrients as

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raw materials for carbohydrate and protein production. Submerged macrophytes, including *V. americana*, act as nutrient buffers by using dissolved nitrogen and phosphorus for growth (Stevenson et al. 1979). When these nutrients are removed from the water, they become unavailable for use by algae. Submerged macrophytes also act as nutrient cyclers. Most shoot nutrients are obtained from the sediments through the roots; the nutrients and organic matter leak into the water from living shoots and are liberated during decomposition of dead plant material. Dissolved nutrients and organic matter released to the water may then be transported by currents throughout the water body. In this way, littoral vegetation is a potential source of materials for pelagic production (Carpenter 1981).

# Propagation

When poor light penetration of aquatic habitat makes environmental conditions marginally suitable for vegetation growth, a minimum bed size or a critical population density per unit area may be required to establish populations of plants. Plants alter their environment in ways that may increase the long-term survival of the population by reducing turbidity locally and anchoring the sediments (Carter and Rybicki 1985).

Considerable work has been conducted to develop propagation techniques for some of the subtropical seagrass species such as eelgrass (*Zostera marina*), shoalgrass (*Halodule wrightii*), and manatee grass (*Syringodium filiforme*; Fonseca et al. 1982; Kenworthy et al. 1984). We have summarized methods of harvest, storage, planting, and the labor required for this work.

## *Methods of Planting*

Depending on the water quality regime, *V. americana* can probably be best established by transplanting winter buds. Techniques for planting both seeds and winter buds follow.

When establishing *V. americana*, one must first determine if the planting area is suitable for *V. americana* growth. For instance, did the area historically have *V. americana*, and do areas of similar water quality, depth, turbidity, and bottom substrate have *V. americana* growing in them, or do they support plants with similar habitat requirements such as *Potamogeton pectinatus*, *Heteranthera dubia*, *Myriophyllum spicatum*, or *M. exalbescens*? Unless conditions appear to be favorable for *V. americana*, small test plantings should be made the first year.

The area to be planted should have a water depth of 0.7 to 1.8 m with 0.9 to 1.2 m preferred. The most important requirement for sprouting winter buds or seeds is light energy, which is a function of water transparency. Secchi disk readings multiplied by a constant (2.7–3.0) will give the approximate depth of the photic zone required by plants (Cole 1979). Winter buds should be planted so that they will be well within this photic zone. The substrate should be of firm silt or a sand–silt mixture. Hard clay or silty soft mud should be avoided. A slow current is better than stagnant or rapidly flowing water.

Consideration should be given to enclosing the experimental planting area with a fence (wood-slatted snow fence, chicken wire, or welded wire) that will persist in water for several months. Fencing serves several purposes: it protects the young plants from rough fish, acts as a wave break, delimits the planting area, and holds plants that float to the surface at the end of the growing season. A marked but open plot, adjacent to the fenced plot, should be set up as a control planting to see if fencing is needed. Whether fencing is used or not, the planting area should be permanently marked so it can be relocated.

### Planting Seeds

Most studies recommend mixing seeds with wet, sticky mud or clay soil before planting. Pieces of this mixture are then scattered in the planting area, ideally in spring. Muenscher (1936) recommended spring planting over fall planting because seeds planted in fall may be removed from the planting area by water currents, waves, or ice movement during spring breakup; buried by sediment; or eaten by migrating waterfowl. Moyle and Hotchkiss (1945) suggested making balls out of the mud and seed mixture, or placing pieces of it in a single thickness of cheese cloth.

*Vallisneria americana* fruiting structures containing the seeds can be gathered in late summer with a rake or net (Moyle and Hotchkiss 1945). The harvested fruits can be allowed to decompose in a water-filled container (Muenscher 1936) or broken into pieces (Moyle and Hotchkiss 1945). If planting in the next spring is desired, the seeds or pieces of fruit should be stored in cold water (1–3° C) under dark conditions (Muenscher 1936). Hoover (1984) found that *V. americana* seeds germinated 2–5 weeks later on the more organic sediments of his study areas. This could be ecologically important because such plants might have competition from other species that are phenologically advanced.

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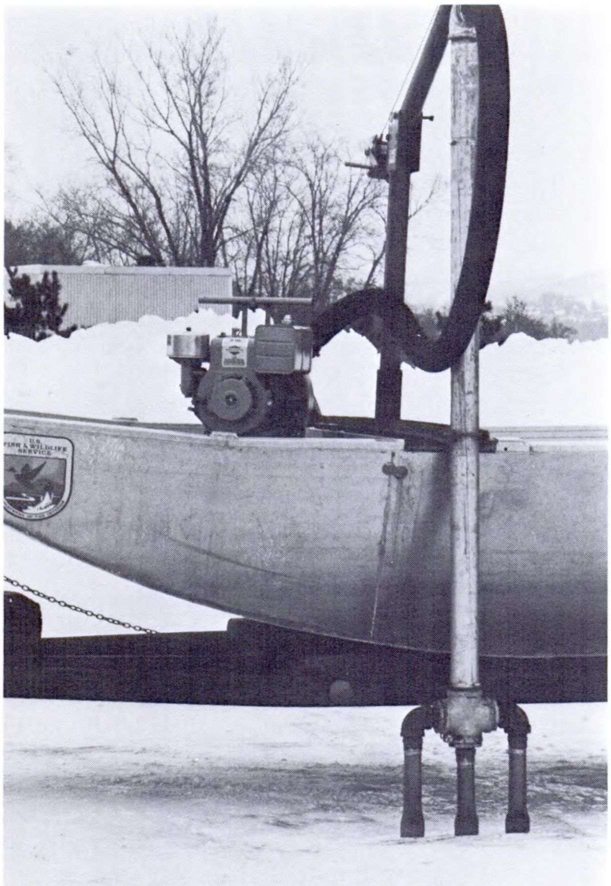

**Fig. 5.** Hydraulic dredge used to harvest winter buds of American wildcelery.

## Transplanting Winter Buds

If winter buds are going to be harvested for transplanting, a *V. americana* bed should be found in the same locale. The size of winter buds is influenced by the pH (acidic conditions produce smaller buds) and the type of substrate (Hoover 1984). Small winter buds produce smaller plants than large buds (Hoover 1984); therefore, more desirable results will be obtained by planting large buds.

Winter buds can be collected by sieving substrate collected from an existing *V. americana* bed by shovel or with a hydraulic dredge. Winter buds normally float to the water surface when loosened from the sediments. They can then be collected in great numbers with little effort by moving the substrate with a high pressure and volume water pump. We constructed a dredge (pump, dredge, davit) for collecting winter buds (Fig. 5). The gasoline pump had specifications of 8 horsepower and 7.62-cm (3 inches) suction and discharge hoses and an output volume of 83,270 L per hour. The long dredge pipe was 7.62-cm (3 inches) galvanized iron pipe reduced to three 5.08-cm (2 inches) copper nozzles about 15 cm (6 inches) apart. The nozzles (shaped by heating copper tubes with a torch) terminated with 1.27-cm × 7.62-cm openings. The dredge was suspended from the davit by 0.95-cm (3/8 inch) cable. In this way the dredge could easily be moved to any position above the substrate to ensure adequate water pressure for excavating a trench 45 cm wide and about 15 cm deep. The depth of the trench could also be regulated through movement of the boat.

When ready to start excavating, we searched areas that were about 1 m deep (so that persons in chest waders could be in the water). We used a long metal fence post as an anchor for the boat and ran a nylon line from the post through a C-clamp on the bow of the boat. The boat was then moved in an arc with the rope restricting backward but not lateral movement. At the end of the arc a small length of rope was released so that the dredge would excavate a trench parallel to the one made on the previous pass. This technique permitted efficient harvest of an area with the least amount of effort to maneuver the boat.

Two or more persons waded around the boat (or downstream if in a current) and swept up the winter buds with dip nets. In some situations the buds rose to the water surface 30 m or more from the boat so it was best to initially determine the pattern of the water current.

Because winter buds do not store well for extended periods (C. E. Korschgen, unpublished data), they should be collected just before transplanting, and stored in water in a refrigerator (at less than 10° C) to prevent the shoots from elongating.

Muenscher (1936) recommended that winter buds be transplanted in spring for the reasons previously described for seeds. At northern latitudes, the winter buds should be planted from mid-April to early May, when the water temperature is 10–14° C.

An efficient method for planting winter buds is to place one or more winter buds in a reinforced paper envelope in which holes have been punched, or in a cotton–polyester, nylon, or plastic mesh bag (0.64 cm holes) filled with a gravel mixture for weight (Fig. 6). Paper and cotton–polyester bags should be tested in the field to ensure that they will not deteriorate before the winter buds sprout and root. The bags can be prefilled with gravel to avoid delays in the transplanting process. After the winter buds are placed in the bags, the bags should be closed with a twist tie and kept wet until they are deposited at the transplant site.

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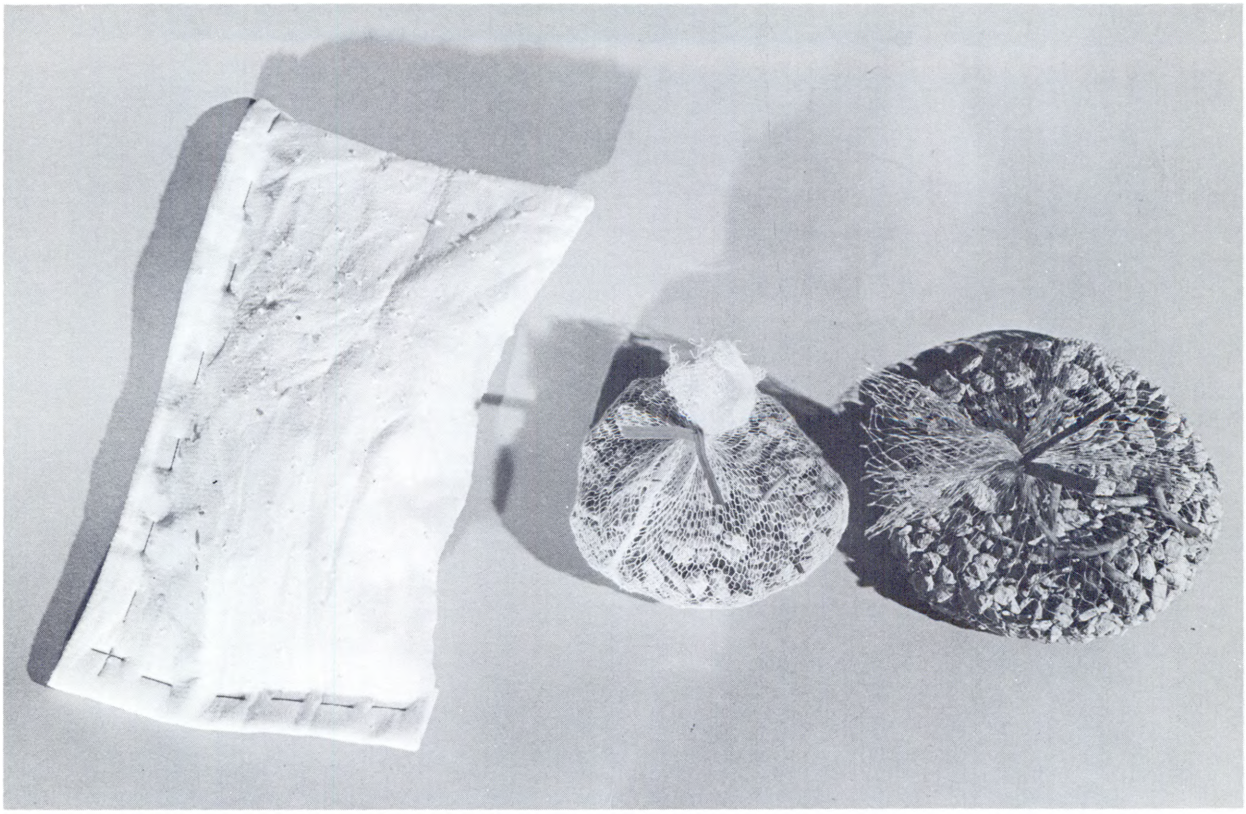

**Fig. 6.** Examples of three packaging techniques for American wildcelery winter buds.

Trial plantings are recommended for new areas. Success can be determined at minimal cost by establishing two or three paired plots (fenced vs. open) of about 7.5 m on a side. Initially, about 250 to 300 winter buds per exclosure should be planted to determine if the location is suitable. A high-density planting compensates for injured or inferior winter buds that do not grow.

The ideal method for planting *V. americana* winter buds is to bury them 5 to 10 cm in the sediment. Divers may plant the winter buds by hand, or if water drawdown is possible, the water may be lowered to a level where the winter buds may be planted by hand. Because contracting SCUBA divers is expensive and water drawdown may not be possible, we generally recommend placing the buds in weighted mesh sacks. A planting density of 1,000 per 0.4 ha is recommended.

## *Evaluation of Transplants*

Records should be kept of how many winter buds were transplanted at each site. The planting should be evaluated during and at the end of the growing season. The simplest way to determine if the winter buds have sprouted and are growing well is to place a couple of the transplant bags that contain winter buds in a sunken container filled with substrate from the site. A float attached to the container helps to locate the plants for periodic inspection. A five-gallon plastic bucket works well if a hole is cut in the side of the bucket to permit water to drain when the bucket is lifted.

Leaves will grow rapidly in a favorable environment and, within a few weeks, new rhizomes should irrupt from the primary plant, giving rise to additional plants (Fig. 7). At northern latitudes (Wisconsin) the plants will flower around 1 August, produce winter buds around 1 September, and senesce around 1 October. If the transplant is successful, the plot should contain a dense stand of plants by September (Fig. 8).

In a favorable environment, each winter bud should produce at least three or more new plants. The net gain of plants can be quickly estimated by counting the number of floating rosettes within the fenced area as the plants senesce. Careful examination of these rosettes for the descending rhizome, which terminated in a winter bud,

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**Fig. 7.** American wildcelery plants growing from nylon mesh bag.

will indicate whether or not the plants produced buds. The density and size of the winter buds can be determined by searching for them in the substrate with a post-hole digger, corer, or long-handled shovel; the number of winter buds per unit area may then be estimated and the size measured.

The planting should be monitored for a second growing season.

## *Materials*

Transplanting
- Fencing
- Posts
- Mesh bags
- Gravel scoops
- Twist ties
- Winter buds, coolers for transport of winter buds
- Carrying tray (plastic bread loaf carriers as used by bakeries)
- Boat, chest waders, hip boots
- Marking buoys

Harvesting
- Pump, gasoline
- Dredge
- Boat with davit
- Ice chests
- Dip nets
- Chest waders
- Anchor post
- Nylon line

## *Costs*

Winter buds are available from commercial supply companies that raise and harvest their own stock and cost about 10¢ each. If a trial program or a small-scale operational program is going to be initiated, purchasing winter buds is probably more cost effective than buying the equipment to harvest them (except for long-handled shovels and a sieving box).

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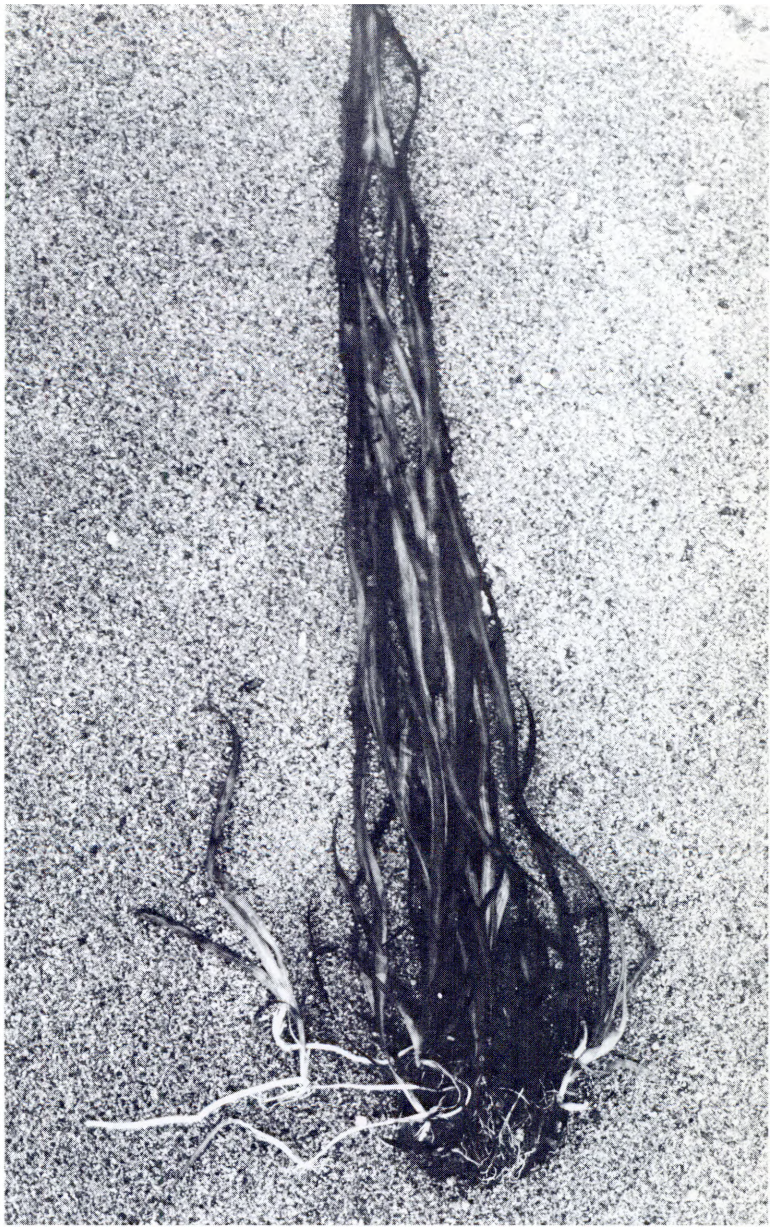

**Fig. 8.** Three-month-old transplanted American wildcelery plants growing in an enclosure on Lake Puckaway, Wisconsin.

## *Sources*

In the event that winter buds or seeds are not available from a nearby water body, they can be purchased from wild game food nurseries. Many suppliers sell American wildcelery parts adapted to a northern environment. It is unknown how well these winter buds would tolerate the climate of southern areas or brackish water conditions.

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Korschgen, Carl E., and William L. Green. 1988. **American wildcelery (*Vallisneria americana*): Ecological considerations for restoration.** U.S. Fish Wildl. Serv., *Fish Wildl. Tech. Rep.* 19. 24 pp.

The success of vegetation management programs for waterfowl is dependent on knowing the physical and physiological requirements of target species. Lakes and riverine impoundments that contain an abundance of the American wildcelery (*Vallisneria americana*) have traditionally been favored by canvasbacks (*Aythya valisineria*) and other waterfowl as feeding areas during migration. Information on the ecology of American wildcelery is summarized to serve as a guide for potential wetland restoration projects. Techniques are described for transplanting winter buds. Management programs that employ these techniques should define objectives clearly and evaluate the water regime carefully before initiating major restoration.

**Key words:** *Vallisneria americana*, American wildcelery, aquatic vegetation, plant ecology, restoration, natural history, waterfowl habitat.

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