*Aquatic Botany*, 22 (1985) 33—44
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands 

# THE BIOMASS AND NUTRITIVE POTENTIAL OF *VALLISNERIA AMERICANA* MICHX IN NAVIGATION POOL 9 OF THE UPPER MISSISSIPPI RIVER

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(Accepted 14 February 1985)

ABSTRACT

Donnermeyer, G.N. and Smart, M.M., 1985. The biomass and nutritive potential of *Vallisneria americana* Michx in Navigation Pool 9 of the Upper Mississippi River. *Aquat. Bot.*, 22: 33—44.

*Vallisneria americana* Michx (wild celery) was studied to determine the biomass and nutritive potential of all morphological structures. A 2.6-ha stand of uniform *V. americana* was sampled during the summer and autumn of 1980, and the spring and summer of 1981 in the southern portion of Navigation Pool 9 of the Upper Mississippi River.

The maximum production rate of 3.2 g $m^{-2}$ $day^{-1}$ was coincident with rapid rosette production and flowering, and occurred mid- to late-July 1980. The maximum biomass of 217.3 g dry wt. $m^{-2}$ was on 1 September 1980, when fruit development was also at a maximum. Leaves composed 60—70% of the summer biomass; winter buds constituted all of the winter biomass.

Winter buds and fruits had the greatest nutritive potentials. Both organs contained relatively high dry matter concentrations and were low in ash (less than 10%) and fiber content. The potentially-digestible ash-free non-cell-wall fraction (NCF) was composed of an average of 75.7 and 82.2% of the dry weight of fruits and winter buds, respectively. In contrast, the nutritive potential of leaves, rootstocks, peduncles and stolons was reduced because of high moisture (less than 8% dry matter), ash and fiber concentrations. Staminate inflorescences and pistillate flowers were high in crude protein (averaged 21.8% and 16.1% of the dry-weight, respectively) and ash-free non-cell-wall fractions, but they accounted for only 2.7% of the plant biomass. The maximum calorific content of *V. americana* was approximately 3200 kJ $m^{-2}$ at peak biomass on 1 September 1980.

## INTRODUCTION

The submergent aquatic macrophyte *Vallisneria americana* Michx (wild celery) is an important food for waterfowl (Martin et al., 1951). In Navigation Pools 7, 8 and 9 of the Upper Mississippi River there were about 3672

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ha of *V. americana* during 1980—1981 (C.E. Korschgen, personal communication, Northern Prairie Wildlife Research Center, La Crosse, WI, 1982). Approximately 75% of the North American canvas back ducks (*Aythya valisineria* (Wilson)) temporarily utilize this area during their migratory flight in autumn. During this time they feed primarily on winter buds of *V. americana* (C.E. Korschgen, personal communication, 1982).

This investigation was conducted to determine the quantity and nutritive potential of *V. americana* in Navigation Pool 9. The specific objectives were to determine the biomass of the plant and the biomass and nutritive potential of each *V. americana* organ over a 1-year period.

## DESCRIPTION OF STUDY AREA

The study was conducted in the southern portion of Navigation Pool 9 between river miles 653 and 654 of the Upper Mississippi River. Pool 9 is a hard (130—258 mg $l^{-1}$ $CaCO_3$), slightly alkaline (pH: 7.7—8.3), nitrogen- and phosphorus-enriched body of water. The study area contained approximately 2.6 ha of a monospecific, continuous stand of *V. americana.* The plant bed was not enclosed or otherwise restricted in its use by consumers. The mean water depths of the study area ranged from 95 to 120 cm; the minimum was 30 cm and the maximum was 170 cm. Sandy sediments (at least 75% sand) prevailed in areas less than a meter deep; silt and clay sediments were common in the deeper portions of the study area.

## MATERIALS AND METHODS

*Vallisneria americana* was collected on 10 different sampling dates from 28 May 1980 to 6 June 1981. From May to October, 20—40 samples were collected per 8 transects. During late autumn and early spring 16 samples were collected along the transects. Each sample covered 0.17 $m^2$ and consisted of 10 grabs taken with an extended post hole digger. Underground plant material was separated from sediments by sieving with a 6.4-mm mesh screen. All plant material was rinsed, placed in polyethylene bags, and transported to the laboratory. Additional rosettes were collected during the summer of 1981 and were analysed for nutritive quality, fruit and flower development and organ biomass.

Samples were washed, wet weights were determined and rosettes were separated by morphological structures (Fig. 1). Organs were enumerated and samples were frozen. Samples were later thawed and placed in a force draft oven at 60—80°C for approximately 48 h or until a constant dry weight was obtained. Biomass was calculated and productivity was determined as the change in biomass over a period of time (Donnermeyer, 1982). Biomass is defined as the dry weight of living material and includes both above and below sediment plant parts. All organs except fruits were ground in a Wiley mill to pass a 0.4-mm mesh screen. Fruits were triturated with a mortar and pestle because they obstructed the mill. Organ samples were then frozen. Prior to further analyses they were redried at 60°C for 24 h.

Nutritive analyses were conducted on plant organs from each sampling date. The percentage of crude protein was calculated as the percentage of total nitrogen × 6.25 (Boyd and Goodyear, 1971). Nitrogen from samples collected in 1980 was digested by the total Kjeldahl process and was analyzed electrometrically with an ammonia electrode (Environmental Protection Agency, 1979). All samples were done in triplicate and the mean relative standard deviation (RSD) was 8.4%. Nitrogen in samples harvested in 1981 was digested and analyzed according to the total persulfate nitrogen (TPN) procedure (Smart et al., 1983). Ninety-two percent of the samples were done in triplicate and the mean RSD was 4.8%.

The cell-wall fraction (neutral-detergent fiber, NDF) and the non-cell-wall fraction (NCF) were determined according to Van Soest and Wine (1967). This process was modified for winter buds, stolons, staminate inflorescences and pistillate flowers in the following manner: after the reflux step, the organs were cooled at 32°C, and a 0.2% diastase of malt solution was added for 30 min. The enzyme digested the starch that would otherwise have persisted and would have contaminated the extracted fiber (Donnermeyer, 1982). Fifty percent of the samples were done in triplicate and the mean RSD was 3.2%.

Ash values were obtained by heating samples at 500—550°C for 6 h (Wood, 1975). The ash content was subtracted from the non-cell wall

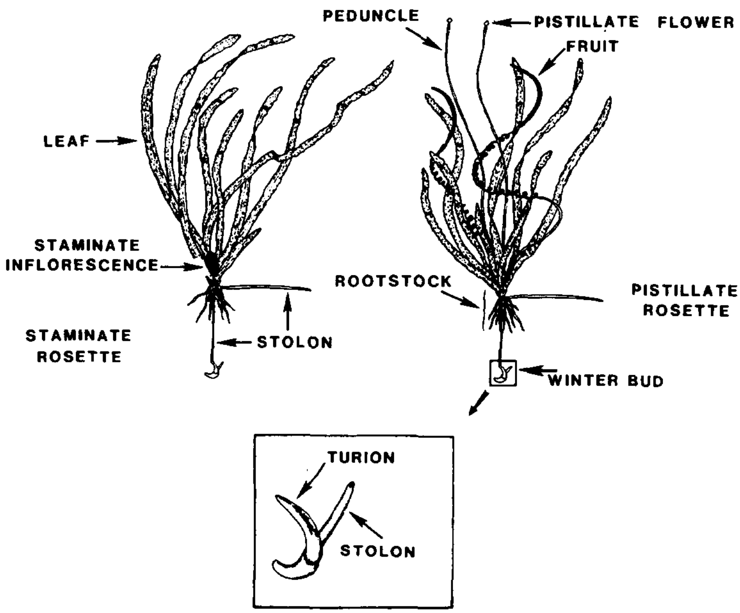



Fig. 1. Morphological structures of *Vallisneria americana* that were analyzed for nutritive potential.

raction (NCF) after fiber and ash concentrations were determined. This rovided a more refined estimate of the digestive portion of each organ ish free-NCF). Sixty-five percent of the samples were done in triplicate nd the mean RSD was 2.8%. Calorific content was determined with an diabatic bomb calorimeter. Whole, unground organs were compressed in pellet for analyses. Thirty-five percent of the samples were done in triplicate and the mean RSD was 0.6%.

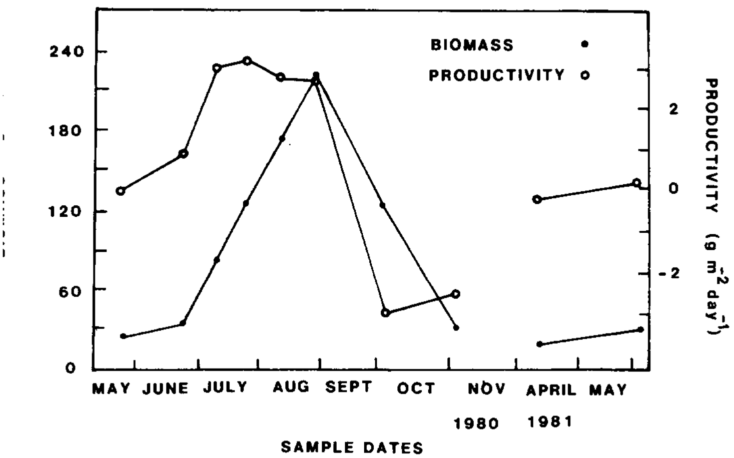
ESULTS AND DISCUSSION

*iomass*

*Vallisneria americana* production was low early in the growing season. y mid-summer, net primary productivity had increased, and reached a aximum of 3.2 g $m^{-2}$ $day^{-1}$ during the latter half of July (Fig. 2). Growth ontinued and the maximum seasonal biomass of 217.3 g dry wt. $m^{-2}$ (SE = .0) was observed on 1 September. This is among the highest cited for *V. nericana*. Senescence and death were evident from 1 September until November. Biomass was approximately 20 g dry wt. $m^{-2}$, as winter buds verwintered in the sediment.

Leaves constituted 60—70% of the biomass from late June to early October Table I). By 9 November, leaves could only be collected from sheltered reas that were adjacent to islands. At that time only 1.9 g dry wt. $m^{-2}$ were bserved.

Maximum winter bud production occurred from 14 August to 6 October Fig. 3). Maximum bud biomass (30.1 g dry wt. $m^{-2}$) was on 6 October 1980, nd the maximum of 158 buds $m^{-2}$ were collected at that time. Winter




g. 2. Biomass and productivity of *Vallisneria americana*, Navigation Pool 9, Upper ssissippi River, 1980—1981.

TABLE I

The approximate percentage contribution of each organ to the total *Vallisneria americana* biomass, Navigation Pool 9, Upper Mississippi River, 1980—1981

| Plant organs | Sampling dates | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1980 | | | | | | 1981 | |
| | 28 May | 27 June | 29 July | 1 Sept | 6 Oct | 9 Nov | 12 Apr | 6 June |
| Leaves | 19.5 | 67.6 | 70.8 | 67.5 | 61.6 | 6.3 | —[a] | 26.2 |
| Winter buds | 65.5 | 15.5 | 2.2 | 5.9 | 26.5 | 91.4 | 100 | 55.5 |
| Rootstocks | — | 14.4 | 11.4 | 7.3 | 3.8 | 2.3[b] | — | — |
| Stolons | 15.0[c] | 2.6 | 2.7 | 4.1 | 5.2 | | — | 18.3[c] |
| Fruits | — | — | 5.3 | 10.9 | 2.5 | — | — | — |
| Peduncles | — | — | 4.9 | 4.2 | 0.4 | — | — | — |
| Staminate inflorescences | — | — | 2.1 | 0.1 | — | — | — | — |
| Pistillate flowers | — | — | 0.6 | — | — | — | — | — |

[a]Specific organ not present in biomass.
[b]Percentage represents the summation of rootstocks and stolons.
[c]Represents stolons growing directly from winter buds.

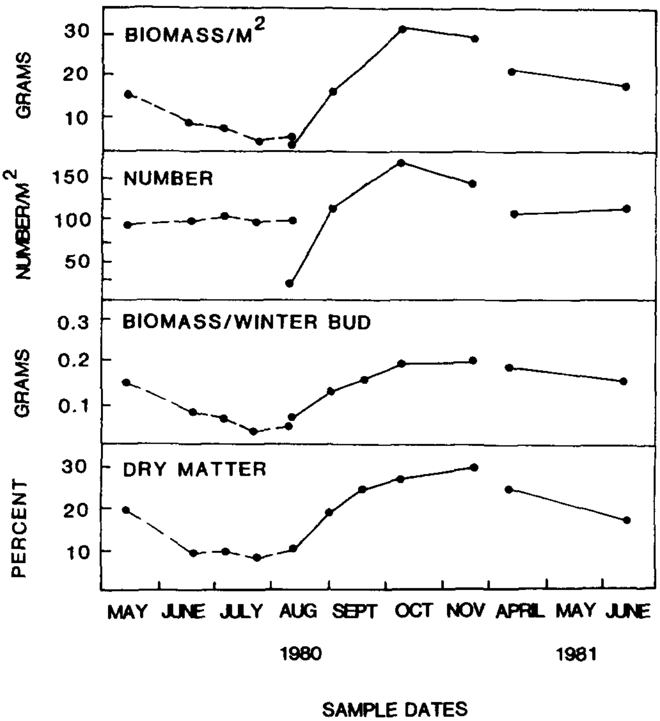



Fig. 3. Biomass, density and percentage dry matter for winter buds of *Vallisneria americana*, Navigation Pool 9, Upper Mississippi River, 1980—1981. (Dashed line indicates winter buds from the previous year and solid line indicates the current year's winter buds.)

ıd density and biomass declined by approximately 30% from 6 October )80 to 12 April 1981; the largest decrease occurred after 9 November (Fig. . These decreases in winter buds may be attributable to waterfowl cropping was observed in Navigation Pool 7 (C.E. Korschgen, personal communica- ɔn, 1982). The maximum dry matter concentration of the new winter buds 9.5%) occurred on 9 November. The mean biomass of individual winter ıds increased from 0.06 g in mid-August to 0.20 g in November. After eaking dormancy in May and producing plants, the spent buds decom- ɔsed and accounted for only 2.2% of the total biomass at the end of July 'able I).

Maximum fruit biomass was on 1 September and composed 10.9% (23.7 $m^{-2}$) of the total plant biomass at that time (Table I). During fruit develop- ent, the dry matter of fruits increased from 9.5 to 14.3%. The biomass each fruit increased from 0.04 to 0.30 g during the same period. Other gans associated with flowering (peduncles, staminate inflorescences and stillate flowers) did not exceed a biomass of 10 g dry wt. $m^{-2}$, when each ıs analyzed. Collectively, these organs rarely accounted for over 7% of the tal plant biomass Pistillate plants contained an average of 4.3 peduncles ith attached flowers. Approximately one-half of the pistillate flowers had veloped into fruits by late summer. By the end of August, pistillate ɔwers were no longer observed; only peduncles with mature fruits were ident. Staminate plants averaged 5.7 inflorescences. All inflorescences d opened and released their flowers by the end of August.

The maximum rootstock biomass was coincident with peak biomass ı 1 September and only a trace remained by 9 November. Rootstocks mposed a maximum of 14.4% of the plant material on 27 June. A steady cline in the relative contribution of rootstocks to the total biomass was served during the remainder of the growing season (Table I).

The stolons of *V. americana* that were formed from winter buds com- sed 15% of the biomass in late May. In contrast, stolons that were pro- ıced during vegetative reproduction later in the summer rarely constituted er 5% of the total crop, and they never exceeded a biomass of 9 g $m^{-2}$. ıch rosette averaged 2.5 stolons at the end of August.

*ıtritive quality*

Submersed aquatic macrophytes are nutritionally characterized by low y matter and high ash concentrations; both negatively affect nutritive ality. Low dry matter concentrations reduce nutritive quality because rbivores consume large quantities of water when the plant is ingested. ıcrophytes typically contain between 5—15% dry matter (National Acad- y of Sciences, 1976); *V. americana* averaged 9% during the growing season. aves, rootstocks, stolons, peduncles, pistillate flowers and staminate florescences averaged less than 8% dry matter. In contrast, the average y matter of winter buds and fruits was 24.8 and 12%, respectively (Table .

TABLE II

Nutritive potential of *Vallisneria americana* organs, Navigation Pool 9, Upper Mississippi River, 1980—1981

| Plant organs | Ash[a] | | | Fiber[a] | | | Ash-free NCF | | | Crude protein[a] | | | Calorific content[a] | | | Dry matter | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean (%) | S.E.[b] | *N* | Mean (%) | S.E. | *N* | Mean (%) | S.E. | *N* | Mean (%) | S.E. | *N* | Mean (kJ $g^{-1}$) | S.E. | *N* | Mean (%) | S.E. | *N* |
| Leaves | 29.1 | 2.1 | 8 | 34.0 | 1.9 | 8 | 39.5 | 2.4 | 8 | 16.0 | 0.9 | 8 | 14.2 | 0.32 | 7 | 6.2 | 0.6 | 8 |
| Rootstocks | 25.4 | 1.8 | 7 | 39.5 | 1.6 | 7 | 37.4 | 1.6 | 7 | 11.9 | 0.8 | 7 | 14.3 | 0.35 | 4 | 7.3 | 0.6 | 7 |
| Stolons | 19.0 | 1.4 | 8 | 36.7 | 2.1 | 8 | 49.5 | 3.0 | 8 | 11.1 | 1.4 | 8 | 14.2 | 0.49 | 6 | 5.9 | 0.4 | 8 |
| Fruits | 8.6 | 0.2 | 4 | 16.4 | 1.3 | 4 | 75.7 | 1.2 | 4 | 11.8 | 0.3 | 4 | 17.7 | 0.37 | 3 | 12.0 | 0.5 | 4 |
| Peduncles | 21.6 | 1.2 | 3 | 36.0 | 0.7 | 3 | 43.8 | 1.8 | 3 | 9.4 | 1.2 | 3 | 13.7 | 0.47 | 3 | 6.6 | 0.6 | 3 |
| Staminate inflorescences | 17.1 | — | 1 | 22.3 | — | 2 | 62.0 | — | 2 | 21.9 | — | 2 | 18.0 | — | 1 | 6.4 | 0.1 | 5 |
| Pistillate flowers | 11.8 | — | 2 | 21.0 | — | 2 | 69.0 | — | 2 | 16.1 | — | 2 | 16.6 | — | 1 | 7.8 | 0.5 | 3 |
| Winter buds | 4.7 | 0.4 | 5 | 13.9 | 1.2 | 5 | 82.2 | 1.4 | 5 | 9.9 | 0.7 | 5 | 17.5 | 0.05 | 5 | 24.8 | 1.8 | 5 |

[a]Data are expressed on a dry weight basis.
[b]Abbreviation for standard error.

TABLE III

Nutritive variables of *Vallisneria americana* from various sources

| Site | Part of plant | Dry matter (%) | Crude protein[a] (%) | Ash[a] (%) | NDF[a] fiber (%) | Calories (kJ g$^{-1}$) | Source |
|---|---|---|---|---|---|---|---|
| Lake Mendota, WI | —[b] | — | 17.5 | 20.7 | — | — | Birge and Juday, 1922 |
| Lake Mendota, WI | — | — | 11.8 | 25.2 | — | — | Schuette and Alder, 1927 |
| Minnesota Lakes, MN | — | — | 15.0 | 28.6 | — | — | Gortner, 1934 |
| Lake Owasso, St. Paul, MN | Photosynthetic biomass | 5.2 | 15.2 | 15.6 | — | — | Nelson and Palmer, 1939 |
| Lake Mendota, WI | Entire plant | — | 12.4—24.1[c] (17.2) | — | — | — | Gerloff and Krombholz, 1966 |
| Fort Lauderdale, FL | Shoot biomass | 8.0—12.0 | 17.6—27.0 (21.1) | — | — | — | Boyd and Blackburn, 1970 |
| New York, NY | Above ground parts | — | 8.0—12.4 (10.0) | 21.8—40.3 (31.0) | — | — | Lathwell, 1973 |
| Minnesota Lakes, MN | Aerial parts | — | 15.2 | 3.1 | 41.0 | — | Linn et al., 1975 |
| Lake Chemung, Ont. | — | 4.1—9.8 (7.0) | 18.1—19.8 (19.1) | 23.3—43.1 (33.2) | 34.4 | 13.0—15.9 (14.2) | Muztar et al., 1978 |
| Navigation Pool 9, Upper Mississippi River, WI | Entire plant | 7.4—12.9 (9.0) | 12.2—15.2 (13.9) | 11.4—32.0 (22.3) | 15.5—36.2 (29.3) | 14.6[d] | Present study |
| | Leaves | 3.2—9.5 (6.2) | 13.5—21.4 (16.0) | 22.9—38.7 (29.1) | 23.9—39.5 (34.0) | 14.2[e] | Present study |

[a]Data are expressed on a dry weight basis.
[b]Data not available.
[c]The range is indicated and numbers in parentheses are mean values.
[d]Mean calorific content on 1 September 1980.
[e]Mean calorific content from 1980—1981 ($N$=7).

The high ash content of aquatic plants effectively lowers the concentration of organic matter and may interfere with digestion and absorption of energy contributing nutrients (Muztar et al., 1977). The mean ash content of *V. americana* in Pool 9 was 22.3% of the biomass during the growing season. The maximum concentration was during mid-July, when approximately 35% of the biomass was inorganic residue. Maximum and minimum mean ash concentrations for plant organs were in leaves (29.1%) and winter buds (4.7%). Most organs averaged 17—25% ash; however, fruits and pistillate flowers averaged less than 12% (Table II). These values are similar to other records of ash concentrations of *V. americana* (Table III).

The non-cell-wall fraction (NCF) contains proteins, lipids, sugars and starches that are readily digested by herbivores (Van Soest, 1967). In this study, approximately 92% of the ash content of *V. americana* was in the potentially-digestible NCF, therefore lowering the digestibility of this fraction. Muztan et al. (1978) reported similar results for several macrophytes. However, winter buds and fruits have high digestive potentials because they contain mean concentrations of ash-free NCF of 82.2 and 75.7%, respectively (Table II). Leaf and rootstock biomass averaged less than 40% ash-free NCF; therefore, these organs had low digestive potential when compared to other organs. The greatest concentrations of ash-free NCF in leaves and stolons (54.5 and 64.5%, respectively) occurred early in the growing season. At maximum biomass on 1 September, approximately 47% of the crop was ash-free NCF. A large amount of energy (approximately 53%) was not available to the non-ruminant herbivores, because only energy in the form of digestible biomass can be utilized.

The cell-wall fraction (neutral detergent fiber, NDF) constituted 15.5—36.2% of the biomass. The greatest concentrations were in late summer and early autumn. The NDF fraction includes the structural components of the plant (cellulose, hemicellulose and lignin). Neutral-detergent fiber is not digestible by non-ruminant animals, whereas ruminants can partially digest the cellulose and hemicellulose components. When neutral-detergent fiber concentrations constitute 55—60% of the dry weight of a plant, ingestion of vegetation by herbivores may decrease (Van Soest, 1966). Winter buds and fruits had minimal fiber concentrations of 13.9 and 16.4% of their dry weight, respectively. Fibre content of most organs ranges from 33 to 40% of the dry weight (Table II).

Crude protein concentrations ranged from 12.2% of the biomass on 6 October to 15.2% in early June. The maximum crude protein biomass (30.3 g $m^{-2}$, 13.9%) was coincident with maximum biomass on 1 September. Individual plant organs had values that ranged from 6.3% crude protein in stolons to 24.5% in male inflorescences; annual means ranged from 9.4% crude protein in peduncles to 21.9% in male inflorescences (Table II). The digestible NCF contains approximately 90% of the crude protein in plants (Van Soest, 1966); therefore, most of the plant protein should be available to herbivores.

*Vallisneria americana* leaves were high in nitrogen and they constituted proximately 70% of the summer biomass. Based on this information and e crude protein content, we calculated that the leaves contained approxi-ıtely 72% of the summer crude protein content. Young leaves sampled ring the spring of 1980 and 1981 contained high crude protein con-ntrations of 21.4 and 21.9% of the dry weight, respectively. In contrast, e crude protein values for leaves sampled during the autumn were 13.5%. nilar decreases in leaf crude protein content were reported for *V. ameri-na* from Lake Mendota, Wisconsin (Gerloff and Krombholz, 1966). How-er, crude protein of submergent plants can decrease, increase or remain nstant with age (Boyd and Blackburn, 1970).

When compared to forage crops, submergent macrophytes, including *americana*, are lower in fiber, but similar in crude protein. In this study *americana* ranged from 12.2 to 15.2% crude protein and from 15.5 36.2% fiber during the growing season (Table III). Alfalfa contained nilar crude protein levels (16.9%) and higher fiber concentrations (40.2%; ın et al., 1975). Other studies reported crude protein concentrations r *V. americana* that ranged from 8 to 27% of the dry weight (Table III). aves were included in all analyses, but the time of harvest and the kind plant parts varied with each investigation.

The calorific content of *V. americana* was approximately 14.6 kJ $g^{-1}$, ıen the maximum biomass was observed (Table III). A similar calorific ue of 14.2 kJ $g^{-1}$ was determined for *V. americana* in Chemung Lake, ıtario (Muztar et al., 1978). Greater calorific values were found in young ves, stolons and peduncles when compared with older organs. Approxi-ıtely 3200 kJ $m^{-2}$ were present when maximum biomass was sampled 1 September. However, only about 47% of this energy was available the non-ruminant herbivores, because 53% of the biomass was in the form the non-digestible cell-wall fraction.

In *V. americana*, fruits and winter buds possessed the greatest nutritional tential. They were high in dry matter and were low in ash and fiber ntent (Table II). The digestible ash-free non-cell-wall fraction (NCF) nstituted an average of 75.7 and 82.2% of the biomass of fruits and winter ds, respectively. On a dry weight basis, fruits and winter buds also had ater calorific values than most other organs, 17.7 and 17.5 kJ $g^{-1}$, respec-ely. Significant amounts of energy in fruits and winter buds are available herbivores because of the high proportion of the digestible NCF. The ›tein content of winter buds and fruits may be available to herbivores cause of the low ash content. In addition, winter buds and fruits contributed nificant biomass to the total *V. americana* crop.

Organs other than fruits and winter buds contributed little to the nu-ive quality of *V. americana*. These organs were characterized by at least e of the following: high moisture content (usually over 90%), high ash fiber, or the organs composed a small percentage of the total biomass. wever, all organs contained neutral-detergent fiber concentrations below els that may decrease intake by herbivores.

ACKNOWLEDGMENTS

We wish to thank R.G. Rada for assistance with this manuscript and the many people who helped harvest *Vallisneria americana*. This study was funded by the River Studies Center, University of Wisconsin at La Crosse.

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