VEGETATIONAL CHANGE IN UNIVERSITY BAY FROM 1966 TO 1980

WILLIAM J. VANDER ZOUWEN
Department of Wildlife Ecology
University of Wisconsin-Madison

Abstract

The aquatic macrophytes of University Bay, Lake Mendota, Dane Co., Wisconsin, were sampled using the line transect method. Twenty-one lines were sampled, and all plants intercepting every 5th meter segment of each line were recorded. Data were used to construct a contour map of the vegetated zone of the bay, delimit plant communities, and determine species composition. Marked vegetative changes have occurred since Lind and Cottam studied the bay in 1966. The most pronounced changes were, (1) the decline of an exotic, *Myriophyllum spicatum,* which had become the dominant species, (2) the decline of *Vallisneria americana* and *Ceratophyllum demersum,* (3) the increase in importance of *Potamogeton pectinatus,* (4) a 30% reduction in littoral zone area, and (5) reduction of large continuous stands to scattered plants. The vegetative decline in University Bay paralleled similar declines in other Dane Co. lakes.

INTRODUCTION

Many investigators have documented aquatic macrophyte change over the last century, accompanying eutrophication of lakes in North America (e.g. Lind and Cottam 1969, Harman and Doane 1970, Nichols and Mori 1971, Stuckey 1971, Crum and Bachmann 1973, Bumby 1977). An exotic, *Myriophyllum spicatum,* has invaded many eutrophic waters in the eastern U.S., including the Madison, Wisconsin lakes (Nichols 1975). In the Madison lakes, *M. spicatum* replaced *Vallisneria americana* and several *Potamogeton* species as the dominant species (Lind and Cottam 1969, Nichols and Mori 1971). Lind and Cottam (1969) reported dominance of *Myriophyllum exalbescens,* but they evidently misidentified *M. spicatum* (Nichols 1971). *M. spicatum* has since declined in the Madison lakes (Carpenter 1979). The purpose of this study was to provide a current description of the aquatic vegetation of University Bay, Lake Mendota, extending the vegetation record for this bay to a 70 year period. Results of this study will be useful in a concurrent study of changes in value of University Bay as a waterfowl refuge. This paper describes changes in the drainage basin with consequent nutrient and sediment input, changes in distribution of rooted vegetation, species composition changes, community change, and apparent changes in aquatic macrophyte density.

STUDY AREA

The study area was located within the Yahara River basin system of lakes in south-central Wisconsin. The 106 ha University Bay is a small bay on the south side of Lake Mendota, bounded by the University of Wisconsin-Madison campus to the south and the Picnic Point peninsula to the north (Fig. 1). The hydrography is characterized by a sand bar extending from Willow Point to Picnic Point. A large shallow flat (<1.5 m) occurs west of the bar and depth reaches 16 m to the east. A more complete description of the study area was provided by Dillon (1956).

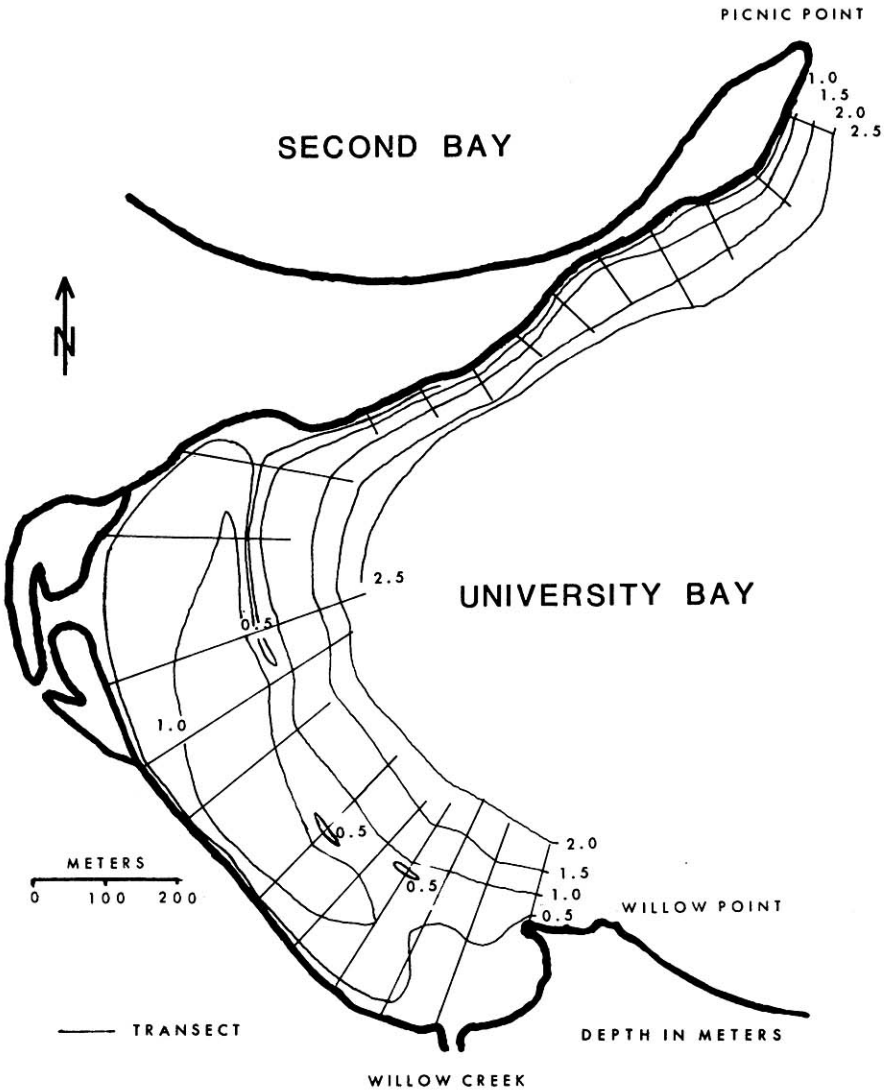

Fig. 1. Map of University Bay showing depth contours to the limit of growth of submerged aquatic plants. Transects ended where vegetation ended.

Methods

Sampling

Sampling of vegetation in University Bay in 1980 was designed to be directly comparable with that of Lind and Cottam (1969), i.e. 21 transects were positioned in the same locations as those of Lind and Cottam. I sampled vegetation between 28 July and 11 August, 1980, using a length of polypropylene rope, held at each end by an anchored buoy, as a transect line. Vegetation below every 5th meter segment of this line was sampled with a garden rake modified with ¼ inch wire mesh attached to the teeth. Each quadrat was, in essence, 1 m by 1 rake width (i.e. 36 cm). Depth at each quadrat was measured with a weighted line marked at 0.5 m intervals. The density of vegetation

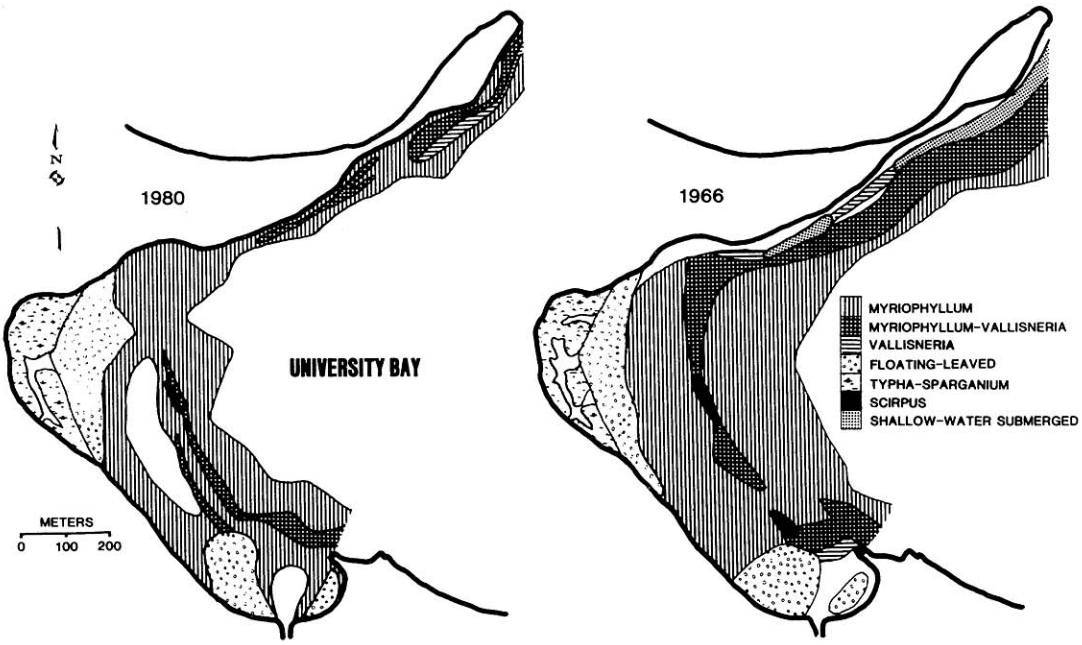

Fig. 2. Map of communities of University Bay in 1980 and 1966 (adapted from Lind and Cottam, 1969).

in each quadrat was recorded as present (1 plant), scattered (discontinuous), or continuous (solid stand). Each transect was terminated at the point beyond which no vegetation was found in five consecutive quadrats. Nomenclature of plant species follows that of Fassett (1960) as revised by Ogden.

Analysis of Data

Quadrat data from all transects in this study were combined to determine frequency and relative frequency based on the percentage of quadrats containing each species. The depth and species occurring at each quadrat were used to develop hydrographic and plant community maps of the vegetated area of University Bay (Figs. 1 and 2). Communities were delimited in the same manner as those of Lind and Cottam (1969). The floating-leaved and emergent communities were delimited on the basis of physiognomy. The remaining three communities consisted entirely of submerged plant species. These aggregations were a *Myriophyllum* community, a *Vallisneria* community and a joint *Myriophyllum-Vallisneria* community. The demarcation of community boundaries was made at the point where the distribution of the dominant species became discontinuous as recorded from transect quadrat data, not at the point where the species ceased to exist.

Total transect length in 1966 was approximately 40% longer than in 1980 due to the presence of vegetation in deeper water. In order that percent presence (frequency) be directly comparable with that in 1966, 1980 frequency data were corrected by dividing by 1.4. With this correction, actual change in area of presence can easily be ascertained. Without the correction, a species with the same distribution in each study would have a higher frequency in 1980 than in 1966.

Results

Vegetation grew to a greater depth along Picnic Point than in the southwest section of the bay (Fig. 1 and 2). Very little vege-

TABLE 1. Comparison of depths at which growth of submerged aquatics ceased in 1966 (Lind and Cottam 1969) and the present study. Depth at end of transect marks depth at which no more plants were found.

Depth limit interval (m)	*No. transects ending* 1966	1980
1.0–1.4	0	2
1.5–1.9	0	10
2.0–2.4	0	7
2.5–2.9	6	2
3.0–3.4	6	0
3.5–3.9	7	0
4.0–4.4	2	0

tation was found in water depths greater than 2.5 m (Table 1).

Submergent vegetation was generally sparse over most of the bay. Solid, continuous stands were found only in a narrow band along the eastern edge of the gravel bar, in a narrow band along Picnic Point, and in small scattered beds west of the bar. Vegetation was absent in 25% of the quadrats.

University Bay contained 14 submerged and floating-leaved plant species in 1980; only *Myriophyllum spicatum, Potamogeton pectinatus* and *Vallisneria americana* were common (Table 2). The other species present each had a relative frequency less than 4%.

Myriophyllum spicatum occurred in nearly all of the eulittoral zone of the bay, except on the delta at the mouth of Willow Creek and an area nearly devoid of vegetation west of the bar (Fig. 2). *M. spicatum* grew on organic and silt bottoms primarily. It was the only species commonly occurring in water deeper than 1.5 m. It occurred in greatest density along Picnic Point in water 1.0-1.5 m deep and along the eastern slope of the bar in water 0.8-1.5 m deep. Dense mats of filamentous algae (*Mougeotia* sp. and *Rhizoclonium* sp.) were present on these dense stands of *M. spicatum*.

Potamogeton pectinatus, the second most frequent species, was found in scattered

TABLE 2. Changes in aquatic macrophyte species composition in University Bay.

Species	*1966 Frequency (%)*	*1980 Frequency (%)*	*1966 Relative Frequency (%)*	*1980 Relative Frequency (%)*
Ceratophyllum demersum	18.1	4.2(3.0)[b]	13.6	3.7
Chara sp.	0.0[c]	0.0	0.0[c]	0.0
Elodea canadensis	0.4	2.8(2.0)	0.3	2.5
Heteranthera dubia	1.6	1.1(0.8)	1.2	1.0
Myriophyllum spicatum[a]	74.2	52.0(37.1)	55.6	45.4
Najas flexilis	0.1	1.1(0.8)	0.1	1.0
Nelumbo lutea	0.5	1.4(1.0)	0.4	1.2
Nymphaea tuberosa	9.4	6.0(4.3)	7.1	5.3
Potamogeton crispus	0.0[c]	1.7(1.2)	0.0[c]	1.5
Potamogeton foliosus	0.5	2.4(1.7)	0.0[c]	2.0
Potamogeton nodosus	0.8	0.3(0.2)	0.6	0.2
Potamogeton pectinatus	1.4	22.5(16.1)	1.1	19.6
Potamogeton richardsonii	2.2	1.0(0.7)	1.7	0.9
Potamogeton zosteriformis	0.2	0.0	0.1	0.0
Ranunculus trichophyllus	2.0	0.0	1.5	0.0
Vallisneria americana	21.0	16.3(11.6)	15.7	14.2
Zannichellia palustris	0.0[c]	1.4(1.0)	0.0[c]	1.2

[a] Reported as *Myriophyllum exalbescens* by Lind and Cottam (1969).

[b] Numbers in parentheses are percent frequencies corrected for a 40% greater total transect length in 1966 than 1980, for comparison with 1966 frequency data.

[c] Less than 0.05.

solid stands just north of the delta, at the north end of the bar, and near Willow Point, in addition to scattered plants elsewhere. This species was primarily located on or west of the bar. There was no pattern to distribution with respect to depth or bottom type, and few fruiting plants were found. It was not as continuous as *Myriophyllum spicatum,* but grew with it in all water less than 1.5 m deep except near the tip of Picnic Point.

Vallisneria americana was limited to sandy bottom areas near Willow Point, along both sides of the bar and along Picnic Point (Fig. 2). As with the vegetation in general, *V. americana* was present in greater depths along Picnic Point than near the Willow Creek delta. The depth to which *V. americana* grew ranged from 1.5-1.9 m. It was in poorest condition west of the bar where it was silt-covered and rotting. Healthy, flowering stands were present along Picnic Point where relatively little silt was found on the plants.

The *Myriophyllum* community was most prominent in the bay (Fig. 2) and was nearly monotypic in the deeper areas. *M. spicatum* became codominant with *V. americana* forming *Myriophyllum-Vallisneria* communities on sandy bottom along the bar and Picnic Point (Fig. 2). The community dominated by *V. americana* alone was found only in a narrow strip at the distal end of Picnic Point in water depths of 1.6-1.8 m.

Two emergent communities were recorded, a large *Typha-Sparganium* marsh on the mudflats in the northwest corner of the bay and a small bed of *Scirpus validus* on the bar (Fig. 2). The former was very dense whereas the latter was sparse.

Floating-leaved communities consisting of *Nymphaea tuberosa* and *Nelumbo lutea* were situated at the northwest and southwest corners of the bay (Fig. 2). *Myriophyllum spicatum* and *Ceratophyllum demersum* were the predominant submerged species below the floating-leaved plants. Silt and marl bottoms were characteristic of these communities.

The continually forming sand delta at the mouth of Willow Creek and a large portion of the deeper water west of the bar (Fig. 2) were nearly devoid of vegetation.

Discussion

Bay Area Changes and Nutrient and Sediment Input

In order to understand the vegetational changes in University Bay, changes in nutrient and particulate matter input should be known. Until 1910, University Bay was bounded to the west by a 53 ha marsh which undoubtedly trapped large amounts of nutrients and silt that would otherwise have entered the bay. In 1910, the marsh was drained and planted to corn. Thereafter, fertilizer-enriched water was pumped into the bay. From 1940 to 1980, the Madison population increased from 67,000 to 171,000, increasing the input of urban pollution, especially with the onset of the "detergent era." In addition, the rapidly growing communities upriver from Lake Mendota dumped treated sewage into the Yahara River until 1971. Probably the major contributor of nutrient and particulate matter to University Bay during the last 30 years has been Willow Creek (also known as University Creek), which wound through a marsh until the early 1950's. This creek was channelized, and the storm sewer outfall of the Hilldale area was placed at the head of the creek. This rapidly growing residential and commercial area increased in size from less than 8 km^2 to greater than 15 km^2 during the 1950's and early 1960's (Sterrett, 1975). This, together with increased building density and pavement surface, greatly increased runoff and thus nutrient and particulate loading to University Bay.

Ahern (1976) estimated that 922 kg of total phosphorous and 353,000 kg of particulate matter entered University Bay via

Willow Creek in 1972 alone. High sedimentation is evidenced by the delta forming at the mouth of the creek including an expanding, willow covered, island. Further evidence that nutrient loading has been most prominent since the early 1940's was provided by Bortleson and Lee (1972) when they found drastically increased phosphorous and nitrogen concentrations in the top 15 cm of the marl, representing the period of 1940 on.

Maximum Depth of Rooted Vegetation

Denniston (1921) and Andrews (1946) found rooted vegetation common to water depths of 5-7 m in University Bay. Indeed, some of the long-stem pondweeds grew profusely east of the bar to these depths. However, in 1966, most of the 21 transects ended in depths of 2.5-4.0 m, and by 1980, vegetation depth was further restricted, most of the transects ending between 1.5 and 2.5 m (Table 1). This change from 1966 to 1980 resulted in a littoral zone reduction of approximately 30%.

West of the bar, a large area of water where dense growths had occurred in 1966 was largely devoid of vegetation in 1980. This area coincides with water depths between 1.0 and 1.5 m (Figs. 1 and 2). On days when a high particulate load was carried by Willow Creek, it was evident that the current carried and deposited silt and sand primarily west of the bar. Wave action and carp activity in this shallow area further increased turbidity, preventing plants from growing in water as shallow as 1.0 m. Turbidity and silt resulting from Willow Creek also explains the shallower maximum depth of rooted vegetation found in 1966 (Lind and Cottam) and 1980 on this side of the bay (Fig. 1). It appears that factors causing major changes in maximum depth of vegetation have occurred since the early 1940s and continue to affect vegetation. Similar reductions in deep zone vegetation following eutrophication and siltation with related turbidity, have been reported elsewhere (Harman and Doane 1970, Morgan 1970, Felstehausen and Rabl 1973, Bumby 1977). Turbidity reduces light penetration and thus the depth at which plants can grow.

Cover Changes

Rickett (1921:509) stated, "In University Bay, almost all of the species found in the lake are present in a dense tangled growth." Andrews (1946:8) observed that "at each end of the bay aquatics with floating leaves become so abundant that large mats of floating algae and plant fragments are held in place permitting growths of duckweed in open water." Lind and Cottam (1969) suggested that the vegetation was dense enough to impede human use. Upon casual observation, it became obvious that such dense growths of vegetation did not occur in 1980. As mentioned earlier, the area of solid, continuous stands of vegetation was very limited. Moreover, the fact that in 25% of the quadrats not even 1 plant was found implies discontinuity.

There were also indications that the floating-leaved communities have thinned. *Myriophyllum spicatum* was infrequently found in the floating-leaved communities by Lind and Cottam in 1966. Further, in Lake Wingra, *M. spicatum* occurred in the floating-leaved communities only where *Nymphaea tuberosa* leaves were widely scattered. In 1980, the corrected frequency for *N. tuberosa* was half that in 1966 (Table 2), and *M. spicatum* was the dominant submerged species in this community.

Species Composition

Extensive beds of *Vallisneria americana, Potamogeton* species, and *Chara* sp. found in 1921 and 1946 were replaced by *Myriophyllum spicatum* by 1966 (Lind and Cottam 1969). Whether *M. spicatum* caused the decline of these species or invaded following the decline is not known. However, other lakes, having become eutrophic yet

lacking exotic species, also have experienced a decline in native species (Stuckey 1971, Crum and Bachmann 1973). Moreover, weedy species usually require disturbance or reduction in vigor of native species before explosive growth occurs.

The greatest change in vegetation of University Bay between 1966 and 1980 has been the decline of *M. spicatum*. Corrected frequency data show a decline from 74.2 to 36.1% in 1980. *M. spicatum* was still the most abundant species with a relative frequency of 45.4% in 1980. The deep water zone of *M. spicatum* has disappeared as well as a large area west of the bar (Fig. 2). This decline was most noticeable in Lake Mendota between 1974 and 1975, and it had occurred in the other 4 Madison area lakes by 1978 (Carpenter 1979). This pattern of invasion, abundance, and decline has been typical of most *M. spicatum* invasions (Carpenter 1979).

Phillips et al. (1978) presented a mechanism for vegetative decline, whereby increasing nutrient levels result in increasing growth of filamentous algae and other epiphytes. These epiphytes shade and, consequently, reduce the growth of macrophytes. Reduction in competition and in secretion of phytoplanktonic suppressants from macrophytes then results in increased phytoplankton biomass, further shading the macrophytes. Although filamentous algae were very abundant in 1966 and 1980, they could not, alone, account for the reduction in *M. spicatum* in University Bay; the disparity in loss between different parts of the bay would not be explained.

Carpenter (1979) discounted toxic metals, harvesting, herbicides, climatic variables, and nutrient levels as the cause of decline. Carpenter (1979:57) suggested that the decline ". . . was a result of synergistically interacting factors, perhaps including nutrients, epiphytes, competitors, and parasites or pathogens." Competition was not likely a factor in University Bay, because all of the common species except *Potamageton pectinatus* also declined (Table 2); *P. pectinatus* was not dense enough to cause competition with *M. spicatum* over most of the bay. It is likely that seston and epiphytes contributed to the decline; however, something more was involved since the decline occurs with most invasions of *M. spicatum*. Bayley et al. (1978) described a disease which could be spread from one plant to another under low light conditions, such as occurs with turbidity. Perhaps this is occurring in the Madison area.

The frequency of *Ceratophyllum demersum* increased 8-fold with the first year of decline of *Myriophyllum spicatum* in Lake Wingra; it is rated highly tolerant of turbidity (Davis and Brinson 1980). *C. demersum* was described as being very abundant everywhere west of the bar in University Bay in 1970 (Gillette unpubl. rept.). However, in 1980 *C. demersum* abundance was much reduced (Table 2). I searched for this species in 1981, finding few plants; these were in the most protected areas of the bay.

Carpenter (1979) suggested the reduction in density of *M. spicatum* in 1977 reduced competition with *C. demersum*. Perhaps this was occurring in University Bay in 1970. The reduction in density of *M. spicatum* from solid stands to scattered plants since 1970, together with decreased distribution, has likely led to increased wave action and turbulence in University Bay. This would adversely affect *C. demersum* (non-rooted) and may explain its current distribution and low abundance.

Vallisneria americana frequency decreased by almost one-half from 1966 to 1980 (Table 2). It was restricted to the coarsest bottoms. Perhaps siltation or resuspension of sediments was less there. Healthy plants were most abundant east of the bar, along Picnic Point, far from the silt source, Willow Creek. Perhaps, also, *Myriophyllum spicatum* could not have competed with *V. americana* on this substrate as it has

an affinity for fine organic substrates (Patten 1956).

Most other species remained in low abundance. By 1980, *Potamageton zosteriformis, Chara* sp., and *Ranunculus trichophyllus* had disappeared.

The one species that has significantly increased in importance since 1966 (Table 2), *Potamogeton pectinatus,* has survived high levels of urban pollution elsewhere (Butcher 1933, Haslam 1978, Ozimek 1978). It also doubled in frequency in L. Wingra (Carpenter 1979). The linear leaves of *P. pectinatus* remain relatively free of settling particles (Sculthorpe 1967, Sheimer and Prosser 1976). Moreover, the filamentous algae so abundant on *Myriophyllum spicatum* in University Bay were negligible on *P. pectinatus. P. pectinatus* is, however, very susceptible to shading in its early period of growth (Anderson 1978). These properties may have allowed *P. pectinatus* to persist and increase while other species have declined.

Community Changes

The northern pondweed communities have disappeared. The *Scirpus validus* bed has been reduced from a strip across the bar (Rickett 1921) to 3 separate beds in 1966 and to 1 bed by 1980 (Fig. 2). A delta of sand now lies where a diverse community occurred in 1950 at the mouth of the creek (White unpubl. rept.). Furthermore, there are no longer beds of shallow water communities dominated by *Elodea canadensis, Najas flexilis, Chara sp.* and *Zannichellia palustris* (Fig. 2). Now, the *Myriophyllum* community of 1966 could be better called the *Myriophyllum-P. pectinatus* community, and *Myriophyllum spicatum* has replaced *Ceratophyllum demersum* as the dominant submerged species in the floating-leaved community. Finally, the *Vallisneria* community has been reduced from near uniform distribution (Andrews 1946) to a few strips on sandy substrates by 1966 and reduced even further by 1980 (Fig. 2).

Conclusions

There has been an obvious decline in the macrophyte vegetation of University Bay between 1966 and 1980. The maximum depth of rooted vegetation has been reduced; a 30% reduction in littoral zone area has resulted. The continuity or density of vegetation has been reduced considerably. The pattern of abundance and decline of *Myriophyllum spicatum* followed that of invasions of this species elsewhere in North America and invasions of *Elodea canadensis* in Europe (Sculthorpe 1967). However, the vegetative decline in University Bay was not limited to *M. spicatum.* Other species, common in 1966, have decreased considerably; some species have vanished. Only one native species, known to be relatively tolerant of urban pollution, increased significantly in importance from 1966 to 1980. Whether the factors which affected the abundance of native species also led to the decline of *M. spicatum* is not known. However, it was obvious that turbidity and siltation from Willow Creek effluent did have an effect on *M. spicatum,* because the condition of these beds differed between areas near and far from the creek mouth. As Carpenter (1979) suggested, it is likely that many factors led to its decline in the Madison lakes.

The future of the vegetation in University Bay is, of course, uncertain. The decline of *M. spicatum* has been apparent for 6 years, and only 1 native species has increased. There is considerable space where macrophytes could grow without competition from other macrophytes; however they will not likely increase in abundance if nutrients and particulate matter continue to enter Lake Mendota from its watershed. Experiments in British lakes revealed that isolation of areas from nutrients and silt resulted in a positive response from native vegetation (Phillips et al. 1978). Although the state of

Wisconsin has been addressing watershed management, it is not likely that growth of macrophytes will be actively encouraged; the state is also responsible for macrophyte control.

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