American Wild Celery (*Vallisneria americana*) Population Dynamics Within Lake Onalaska from 1980 – 2003

Amy M Seitz [1,2]

[1]*Department of Resource Analysis, Saint Mary's University of Minnesota, Winona, MN* 55987; [2]*United States Fish and Wildlife Service, Upper Mississippi River National Wildlife and Fish Refuge – La Crosse District, Onalaska, WI 54650*

Keywords: Vallisneria americana, American wild celery, submersed aquatic vegetation, Upper Mississippi River National Wildlife and Fish Refuge, Analysis of Variance (ANOVA), Spearman rank correlation, Tukey's test, Geographical Information Systems (GIS), *Aythya valisineria*, canvasback duck

Abstract

The United States Fish and Wildlife Service surveys submersed aquatic vegetation annually to measure American wild celery (*Vallisneria americana)* population density and frequency of occurrence, in Lake Onalaska, Navigation Pool 7 of the Upper Mississippi River National Wildlife and Fish Refuge. Since 1980, sampling continues to be conducted in August during peak vegetation growth along fixed transects. There has been significant change in density and frequency of occurrence since 1980. Statistically significant correlations have been found between American wild celery density and water depth. After a population decline in the late 1980's American wild celery continues to recover.

Introduction

American wild celery is a critical and increasingly important component of quality waterfowl staging areas (Korschgen *et al.* 1988). Temporal change in American wild celery populations of Lake Onalaska is an important consideration for resource management. As these populations are extensively dynamic, extreme fluctuations in density and frequency of occurrence take place.

Natural History

Vallisneria americana is a submersed, aquatic macrophyte with long, ribbon-like leaves approximately 3-11 millimeters wide and 2 meters or more long (Muenscher 1944). It is a dioecious, vascular perennial typically found in shallow lakes and streams throughout eastern North America, ranging from Nova Scotia west to South Dakota and then south to the Gulf of Mexico (Fassett 1957). It is a common species in Mississippi River backwaters. American wild celery occurs in water depths of 0.3-5.0 meters; totally submersed or with the upper portion of leaves floating (Korschgen and Green 1988). These plants predominately reproduce via tuberous tipped rhizomes, which like the fruit and other parts of the plant, are relished by canvasbacks (*Aythya valisneria)*.

Healthy stands of submersed aquatic vegetation, particularly American wild celery, have historically attracted fall migrating waterfowl to Lake Onalaska (Korschgen *et al.* 1988). Food of canvasbacks during fall migration generally is comprised of vegetative matter. A major component of this food is American wild celery and it is an excellent source of carbohydrates. Bellrose (1980) affirms canvasbacks' preference of American wild celery. Approximately 75 percent, of North American canvasbacks use the Upper Mississippi River during fall migration (Korschgen and Green 1988).

Staging areas are locations along waterfowl migration routes where birds refuel and rest. In the 1950s, Lake Onalaska became an important waterfowl staging area for diving ducks, particularly canvasbacks. This is due in large part to the excellent food source available and the disappearance of many smaller traditional wetland staging areas outside the river corridor. With the increase in importance to preserve these areas, the majority of Lake Onalaska was designated a closed area to waterfowl hunting in 1957. This designation means that the area is off limits to migratory bird hunting and trapping. Closed Areas provide migrating waterfowl with refueling and resting locations.

American wild celery improves water quality by stabilizing sediments and filtering suspended materials (Korschgen *et al.* 1988). It also absorbs nutrients such as phosphorus and makes them unavailable for algal absorption (Korschgen *et al*. 1987; Barko *et al*. 1991). The roots, rhizomes, and stolons reduce erosion and facilitate colonization of aquatic invertebrates. American wild celery foliage offers shelter, support, and locally enriched oxygen supply for a variety of aquatic invertebrate populations. American wild celery provides nursery areas for young fish and serves as spawning habitat (Engel 1990). Food resource management on canvasback staging areas must emphasize American wild celery and other tuber producing plants e.g. arrowhead (*Sagittaria* spp.) and pondweeds (*Potamogeton* spp.) (Korschgen *et al.* 1988).

Flooding, lock and dam construction and sedimentation have resulted in dramatic effects to the river ecosystem. First, flooding has had dramatic effects on aquatic macrophytes. Complex interactions of date, duration and magnitude of floodwater inundation all collaborate to stress plants (Spink and Rogers 1996). Second, American wild celery distribution and density has been impacted by the development of the Upper Mississippi River Navigation System. The navigation system implemented a complex of Lock and Dam structures designed to maintain a 9-foot navigation channel. Because of this, much of the original floodplain forest, marsh and agricultural lands adjacent to the Mississippi River were inundated with permanent water (Korschgen *et al.* 1987). The dams that control water levels created 90,000 acres of marshland in the Upper Mississippi River National Wildlife and Fish Refuge. Soon after inundation, water levels stabilized and submersed aquatic vegetation thrived. This magnificent waterfowl habitat was only temporary. The lack of seasonal water level fluctuations eventually transformed this superb waterfowl marshland habitat into open water. Third, the trapping efficiency of fine sediments in off-channel areas has greatly increased (Peck and Smart 1986). The resultant accumulation of fine sediments has led to a wide range of problems for aquatic macrophytes (Sparks *et al*. 1990).

Materials and Methods

Lake Onalaska is a ~7,700-acre impounded lake like area immediately above Lock and Dam 7 within the Upper Mississippi River National Wildlife and Fish Refuge. Lock and Dam 7, constructed by the United States Army Corps of Engineers, was completed in 1937.

In 1980, twelve 800 meter transects (Figure 1) were established in areas of historically dense vegetative cover to measure American wild celery population density. Monitoring was employed to increase understanding of observed population fluctuations. Biologists surveyed submersed aquatic vegetation in Lake Onalaska annually through 1984 and stopped the survey. It was restarted in 1989 following a crash in submersed aquatics (Kenow 2004).

The annual sample size consisted of 120 quadrats (0.33 meter^2) per year. These 120 data points are distributed 10 per each of the 12 transects. In 1989, transect 11 was cut short with the construction of a dredge spoil island. Twelve samples were taken at shorter intervals. These twelve transects were sampled in 1980, 1983 and 1989-2003. Transect end points were entered into a PLGR+96 (Rockwell Precise Lightweight GPS Receiver) which utilizes the Precise Positioning Service (PPS) of the Department of Defense Global Positioning System. Using the Navigation feature of the PLGR, buoys were placed to mark these end points. PLGRs were not used prior to the mid-1990s to lay out transects; the technology used from 1980 thru 1995 was LORAN. Each three-person boat crew was given a map to locate their assigned transects. Quadrat frame spacing of 70 to 80 meters along any

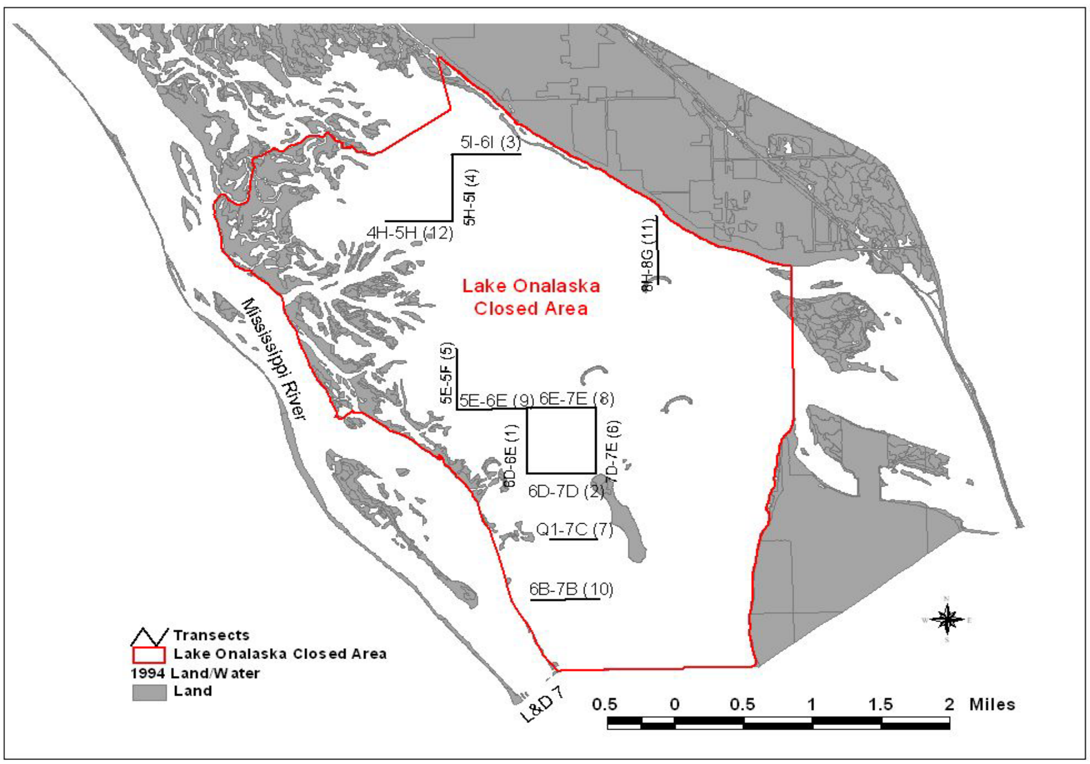

Figure 1. American wild celery sampling transects, the characters not in parenthesis were the original name for transects. The numbers within parenthesis were assigned to simplify the transects' identity.

given transect varies due to uncontrolled factors such as boat drivers' spatial judgment and accessibility issues relating to sedimentation and dense vegetation. A buoy was attached to each quadrat frame. This buoy facilitated ease of location on the lake bottom by a diver. At each quadrat drop point all American wild celery plants found within the quadrat frame were collected and counted. Depth readings were recorded at each quadrat drop point using a three-meter pole numbered with 0.1-meter increments. Depth data were not collected in 1980 and 1983.

Statistical Analyses

Four null hypotheses were tested. The first two null hypotheses were discounted based on graphical illustration. The remaining two null hypotheses were rejected statistically. These data were analyzed with SPSS™ Statistical Software and hypotheses were statistically tested. Spearman Rank Correlation was used as a nonparametric test of correlations between American wild celery density and depth. The Spearman correlation coefficient (r_s) uses the ranks of the X and Y observations rather than the observations themselves (Devore and Peck 1986) to test for correlation. According to Zar (1999), the critical value of the Spearman correlation coefficient is $(r_t)_{0.05|1\ (120)} = 0.150$. If the absolute value of r_s is greater than or equal to r_t then there is a correlation.

The Analysis of Variance was used as a parametric statistical test of differences between transect means of American wild celery density for ~120 samples annually. Those years that had a P-value< 0.05 were further tested with the Tukey test. The Tukey test is a multiple comparison test used to determine if there are differences between transect means within individual years sampled. According to Zar (1999), the critical value used for the Tukey test is $q_{0.05(60,12)} = 4.808$. With a sample size of 120 points, the error degree of freedom (DF) for the analysis of variance is 108. In the table of critical values for the q distribution, v (error DF for the analysis of variance) jumps from 60 to 120. Since the sample error DF falls within this range the lower v value was used. Twelve represents the number of groups (transects) annually sampled. When the calculated q value was greater than the critical q the null hypothesis was rejected. Statistically significant correlations do not necessarily imply cause and effect but serve to illustrate possible factors (Ambrose and Ambrose 1995) effecting American wild celery density.

Results

Overall, four null hypotheses were tested. They are as follows. First, there is no temporal change in American wild celery frequency of occurrence. Second, there is no temporal change in American wild celery plant density. Third, American wild celery plant densities are not correlated to depth. Fourth, all transects have equal mean plant densities. The first and second null hypotheses were discounted based on drastic temporal changes in plant density and frequency of occurrence identified in graphical illustrations. There is temporal change in American wild celery frequency of occurrence and plant density. The remaining two null hypotheses were statistically rejected. The alternate hypotheses are as follows. First, there is a correlation between

American wild celery plant density and depth. Second, the mean values of plant densities according to transect are not equal.

Temporal Change in Frequency of Occurrence and Density

The first null hypothesis, no temporal change in American wild celery annual frequency of occurrence, was discounted based on graphical illustration. Figure 2 illustrates temporal change in annual frequency of occurrence of American wild celery plants found in ~120 quadrats sampled yearly. The second null hypothesis, no temporal change in American wild celery plant density, was discounted based on graphical illustration. Figure 3 depicts American wild celery mean annual plant density (MAPD). MAPD is a measure of American wild celery plants counted within ~120 discrete 0.33m^2 quadrat frames collected in any given year.

According to all years sampled, 1980 was the best year for American wild celery production. The frequency of occurrence was 100 percent and MAPD was 90.5 plants/0.33m^2. In 1983 American wild celery production decreased from that of 1980. The frequency of occurrence was 100 percent but the MAPD decreased to 49.4 plants/0.33m^2. Between 1983 and 1990 there was a precipitous decline. By 1990 a drastic reduction in American wild celery was obvious. The frequency of occurrence decreased to 31.0 percent and MAPD was only 2.7 plants/0.33m^2.

Relative to other years sampled, 1991-1997 represents the lowest levels of production. Specifically, the frequency of occurrence for each of these years was less than 17 percent. The MAPD remained below 5 plants/0.33m^2.

The start of American wild celery recovery began in 1994 when the frequency of occurrence rose by 2.5

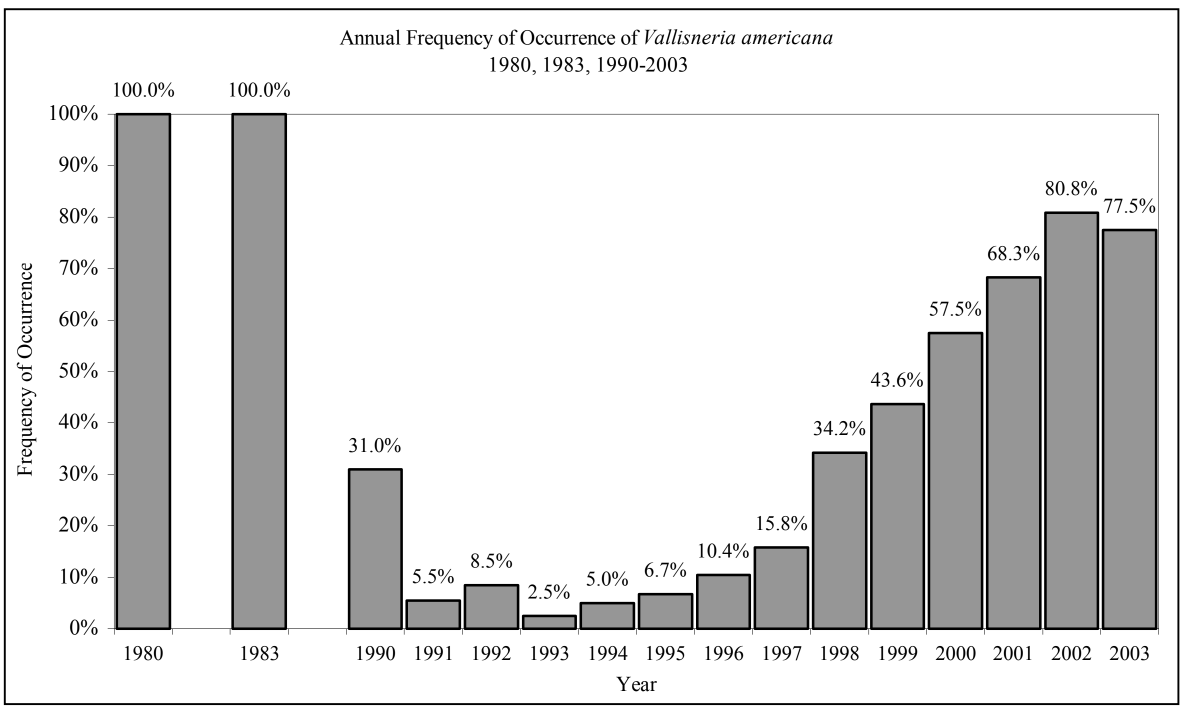

Figure 2. The annual frequency of occurrence of *V. americana* is a percentage of ~120 quadrat frames containing at least one plant in any given year.

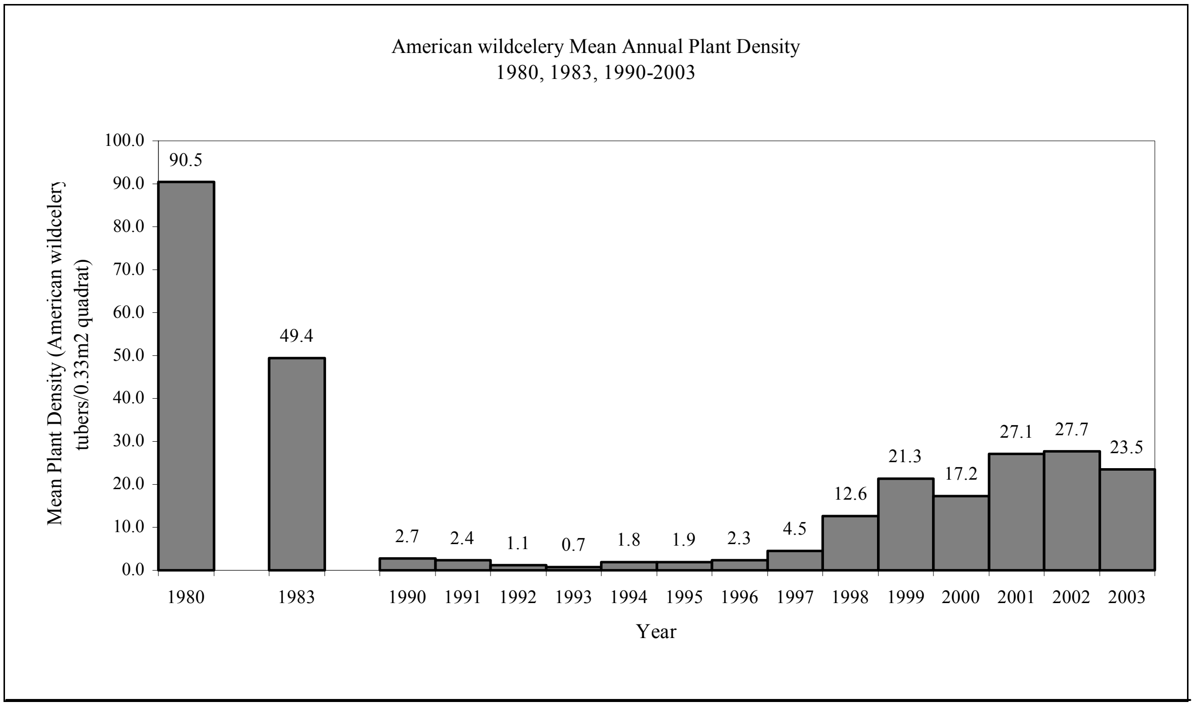

Figure 3. American wild celery mean annual plant density.

percent and the MAPD increased by 1.1 plants/0.33m^2 between 1993 and 1994. By 2002, the frequency of occurrence was 80.8 percent and MAPD was 27.7 plants/0.33m^2. In 2000, there was a consistent increase in plant abundance since 1994. In 2000, the frequency of occurrence increased by 15 percent from 1999 but the MAPD declined. By 2003, the APP was 77.5 percent and MAPD was 23.5 plants/0.33m^2.

Density vs. Depth

The third null hypothesis, depth has no effect on American wild celery plant densities, was discounted based on Figure 4 and rejected based on Spearman rank correlations (Table 1).

Figure 4 demonstrates the temporal fluctuations of MAPD in conjunction with mean annual measured depths. The first year analyzed, 1990, exhibited anomalous MAPD compared to other years with a corresponding mean annual depth of 1.3 meters. Plant density for 1990 was low relative to other years with a depth close to 1.3 meters. From 1991 - 1997, the mean annual depth measured stayed ~1.2 meters while the MAPD remained less than 4.5 plants/0.33m^2. This shows that the vegetation can grow in shallow water, 1.17 – 1.24 meters, but did not prosper. In 1998, MAPD began to recover while the mean annual depth decreased. Some other factors unknown to this study may have positively affected the population. From 1999 - 2002, MAPD changes closely corresponded to fluctuations in depth. For these years, depth was more closely related to density than previously demonstrated. In 2003, MAPD decreased without a corresponding decrease in mean annual depth. Some other factors unknown to this study may have negatively effected the population. Spearman rank correlations (Table 1) statistically reject the third null

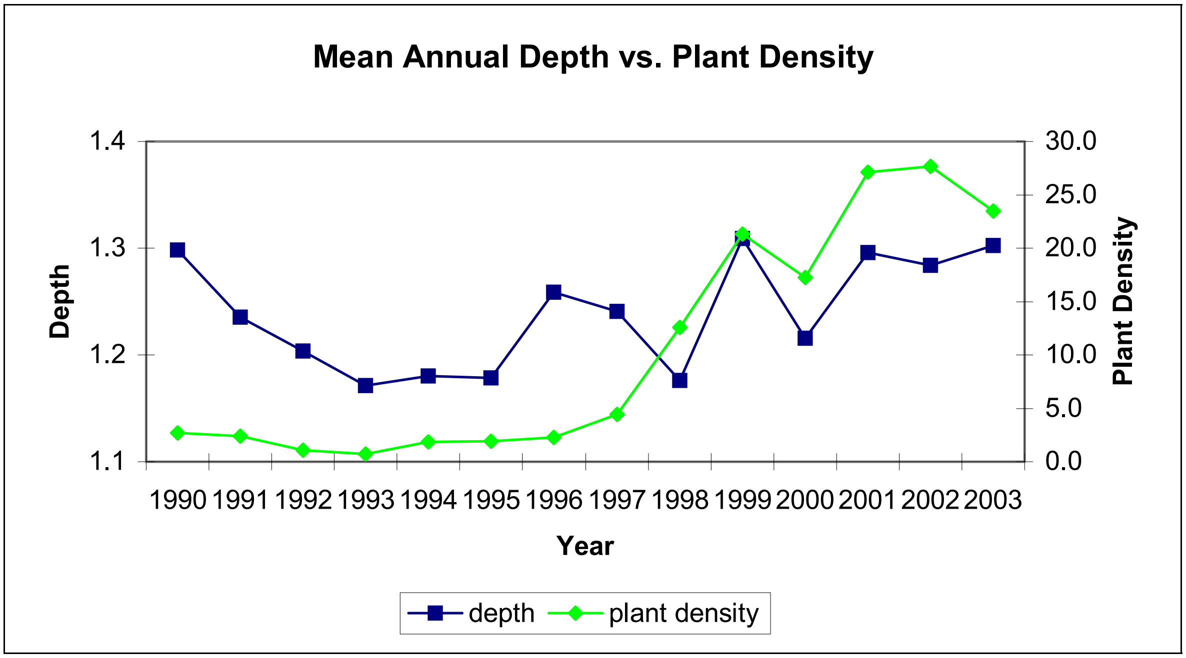

Figure 4. Mean Annual Plant Density in comparison with Mean Annual Depth.

hypothesis which was depth has no effect on American wild celery plant density and corroborate the pattern represented in Figure 4. All years, except 2003, had a significant correlation. From 1990-1995, 1997-1999, and 2001-2002 there was a highly significant correlation between water depth and American wild celery density.

Table 1. Spearman Rank Correlation Coefficient of Depth vs. Plant Density.

Year	r_s
1990	-0.396**
1991	-0.315**
1992	-0.398**
1993	-0.243**
1994	-0.224**
1995	-0.343**
1996	-0.156*
1997	-0.255**
1998	-0.331**
1999	-0.308**
2000	-0.189*
2001	-0.272**
2002	-0.309**
2003	-0.015

** Highly significant (0.01 > P > 0.005)
* Significant (0.05 > P > 0.01)

Spatial Illustration of Temporal Change

The fourth hypothesis, spatial distribution of transects has no effect on American wild celery plant density, was rejected based on Analysis of Variance (ANOVA) and Tukey multiple comparisons testing of transect densities. ANOVA was conducted on American wild celery plant density for each year by transect. The twelve transects were defined in ANOVA as groups. Within these groups most have ten density measurements or sample points. Five of these groups contain less than ten sample points.

According to ANOVA, a significant ($P < 0.05$) difference existed for mean transect plant densities in 1990, 1991, 1996 and 1999 - 2003. For the aforementioned years, the null hypothesis was rejected because there is significant variability in annual mean transect plant densities. Here, spatial distribution of transects may have predisposed American wild celery to different environmental factors. No significant difference was found in American wild celery densities from 1992 – 1995, 1997 and 1998. Other variables may have negated location as the primary factor influencing American wild celery in these years.

A Tukey test was employed for years that ANOVA reported a significant difference between mean transect plant densities. This test attempts to differentiate the differences proposed by ANOVA. Unfortunately, for 1996 and 1999 the Tukey test failed to reject a false null hypothesis. These Type II errors limit discussion of results.

For 1990 and 1991, mean transect plant density (MTPD) values for transect 12 (see Figure 1 for transect number locations) were significantly greater than all other transects. This location predisposed American wild celery to factors that allowed it to thrive. By 2000, transects 12 and 4 had become the least dense, while transect 6 was the greatest. Over the course of ten years, some combination of factors have adversely affected the American wild celery densities on transects 12 and 4 more so than any other. During 2001, the MTPD of transect 2 had the greatest density, while transects 4 and 12 remained the least dense. In 2002 and 2003 the MTPD of transect 6 was the greatest and only transect 4 remained significantly lower in density.

The Tukey test has shown great change in transect 12 from 1990 to 2000. This transect has plummeted from the most dense in 1990 to the least in 2000. Also, from 2000 through 2003, transect 4 has remained the least dense while other transects are recovering. Transect location demonstrates differing population changes. The environmental factors effecting American wild celery may differ throughout Lake Onalaska.

Discussion

Density and depth correlations suggest a critical depth value of 1.26 meters. This value separates decreasing and increasing populations. The temporal change in American wild celery frequency of occurrence and density indicates population change. The most important element of this change is the degree of population recovery. The degree of population recovery can be further analyzed by comparing the difference between current transect levels and those of the maximum and minimum values.

Correlation of Density and Depth

There is a strong correlation between American wild celery plant density and depth. American wild celery production is a function of environmental factors, where depth is a variable. Specifically, when mean annual depth values are at or below 1.26 meters the population decreased (Figure 5). When mean annual depth values are above 1.26 meters the American wild celery population increased. From 1999 – 2002, MAPD changes closely correlate to fluctuations in depth. However, in 1990, 1998, and 2003 density and depth were not as strongly correlated. In 1990, the population was low regardless of a mean annual depth greater than 1.26 meters. Conversely, in 1998 the population increased despite a mean annual depth less than 1.26 meters. In 2003, mean annual depth was greater than 1.26 meters but the MAPD declined. There may be additional variables more greatly correlated to density in these years. Those variables could be water clarity, turbidity and/or ecological succession. In 1990, 1998, and 2003 depth did not affect the function of environmental factors as greatly as in 1999 – 2002. A critical depth value of 1.26 meters identifies specific density and depth correlations.

Frequency of Occurrence and Density Indicators of Population Change

The year 1983 represents a decline in American wild celery plant density. The annual frequency of occurrence failed to indicate American wild celery population decline. In 1983, the frequency of occurrence remained at 100 percent, while the plant density dropped 45 percent. The extent of American wild celery beds may be very high, at the same time density may be significantly declining or recovering. Frequency of occurrence alone is not sensitive enough to detect significant changes in American wild celery populations. However, the frequency of occurrence may identify a critical value needed to support high densities. During 1998 the frequency of occurrence rose to 34.2 percent while the accompanying density increased to 12.6 plants/0.33m^2. Populations may increase during years in which the frequency of occurrence remains above 34.2 percent. In 1990, the frequency of occurrence was below 34.2 percent and remained so through 1997. These years the MATD was at or below 4.5 plants/0.33m^2.

Plants alter their environment by anchoring sediments and reducing local turbidity (Carter and Rybicki 1985). A minimum APP of 34.2 percent may signify where the American wild celery is able to alter the environment in ways that increase the long-term propagation and vigor of the population.

Currently, in 2003, the American wild celery population is reestablishing. Since 1998 the frequency of occurrence values have increased significantly above 34.2 percent. To date, there remains an overall 22.5 percent deficit in frequency of occurrence values compared to the maximum in 1980.

Since 1998 the MAPD values have been increasing. Presently, there remains an overall 73.4 percent deficit in MAPD values according to the maximum in 1980. The elevated frequency of occurrence and rising MAPD implies the population is reestablishing. If the frequency of occurrence rises to 100 percent the MAPD may increase at a faster rate.

Spatial Aspect of Recovery

A varying degree of recovery is depicted by individual transects. The spatial aspect of recovery is best illustrated by the following four figures. Figures 5 and 6 illustrate the present degree of recovery relative to past maximum and minimum mean transect density levels. To expand on transect mean density results of Tukey testing, the greatest negative percent change from 1980 to 2003 occurred on transect 4 and the least on transect 6. Not only has transect 4 drastically declined but has also not begun to recover. The function of environmental variables at this location is negatively affecting density.

Conversely, transect 6 has recovered to near 1980 levels of density. The function of environmental variables at this location is positively affecting density. Transects 4 and 6 represent different functions of American wild celery production. Transect frequency of occurrence reaffirms the distinctness of transects 4 and 6. In figure 7, transect 6 is shown to be reestablished but not recovered. While frequency of occurrence is 100 percent and

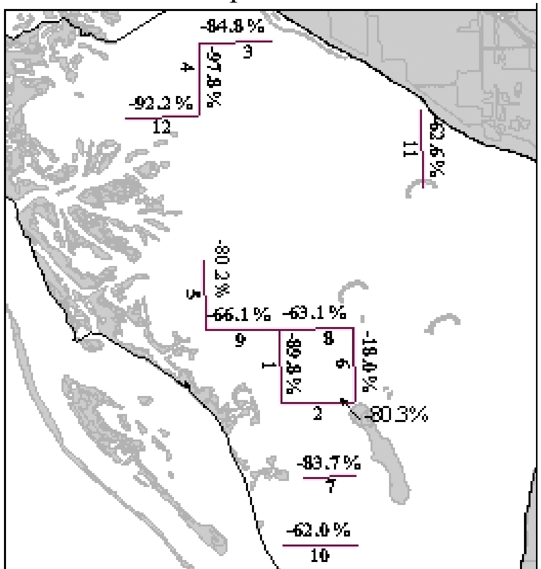

Figure 5. Transect mean density (plants/$0.33m^2$) percent change from 1980 to 2003.

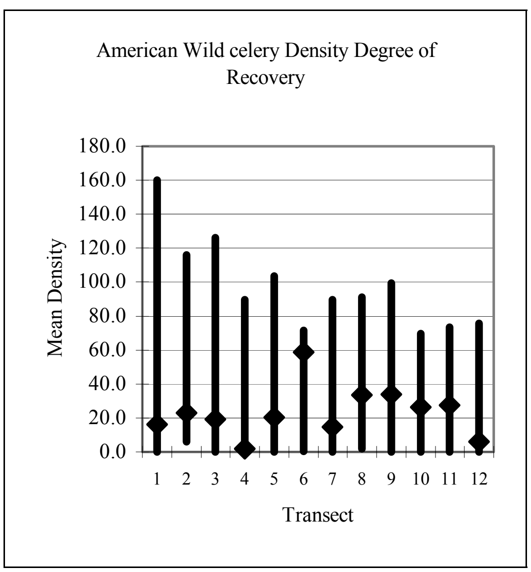

Figure 6. Current transect mean density (plants/$0.33m^2$) relative to the maximum (1980) and minimum (1993). The diamond represents current (2003) transect mean densities.

reestablished, the density has yet to recover. Alternately, transect 4 has not reestablished and has not recovered. The frequency of occurrence is down 80 percent from 1980 (Figure 8) and the

transect mean density is near minimum reported in 1993 and not recovering. With few exceptions, transect means (density and frequency of occurrence)

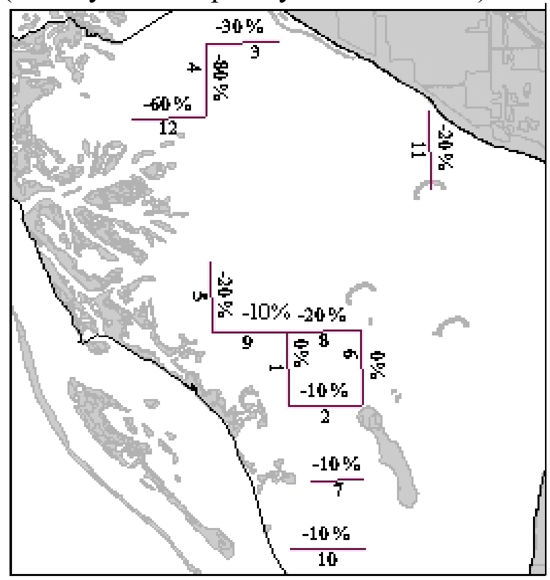

Figure 7. Transect presence (percent of quadrat frames containing American wild celery plants) change from 1980 to 2003.

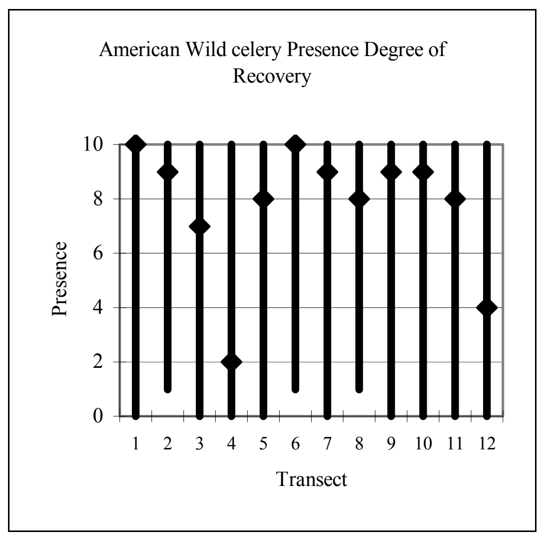

Figure 8. Current transect frequency of occurrence (percent of quadrat frames containing American wild celery plants) relative to the maximum (1980) and minimum (1993). The diamond represents current (2003) transect frequency of occurrence level.

demonstrate reestablishing American wild celery populations. Exceptions include transects 4,12 and 6. Transects 4 and 12 are not reestablishing. In contrast, transect 6 has nearly recovered. Transect means demonstrate a varying degree of recovery.

Conclusion

American wild celery is a critical component of waterfowl staging areas. As the disappearance of many smaller traditional staging areas continues, the quality of those that remain in the River corridor become increasingly important. The temporal change in American wild celery reflects critical population dynamics. These dynamics are correlated to water depth but are dependent on a number of factors. Statistical analyses confirm that American wild celery has increased annually since 1993. The statistically significant correlation between American wild celery density and water depth does not imply cause and effect. The degree of population recovery is best analyzed with a spatial context.

Recommendations

It is recommended that in the future a more comprehensive approach to American wild celery population sampling be instituted. Specifically, ancillary data must be collected. Currently, depth is known to be a major correlative factor in density and frequency of occurrence. But it is not the sole factor effecting change. Ancillary data pertinent to American wild celery population dynamics includes: turbidity, sedimentation and ecological succession. The current transect sampling technique presents a limited view of American wild celery density and growth patterns in Lake Onalaska. Suggestions include, but are not limited to, one direction of travel along each transect, sampling all the submersed vegetation within the quadrat frame, recording the substrate type and dropping secchi discs to determine turbidity. This ancillary data will help resource managers get a clearer picture of American wild celery population dynamics in Lake Onalaska.

Acknowledgements

I thank Dr. McConville, Saint Mary's University, Department of Resource Analysis and Jim Nissen, U.S. Fish and Wildlife Service, for investing the time to guide and support me. Also, all the time and effort of the FWS, USGS staff and volunteers collecting the American wild celery data.

References

Ambrose, Harrison W. III and Katharine Peckham Ambrose. 1995. A Handbook of Biological Investigations. Fifth edition. Hunter Textbooks Inc.: Winston-Salem, N.C. 194pp.

Barko, J. W., Gunnison, D., and Carpenter, S. R. 1991. Sediment interactions with submersed macrophyte growth and community dynamics. Aquatic Botany. 41: 41-65.

Bellrose, Frank C., 1980. Ducks, geese and swans of North America. Third Edition. Harrisburg, PA: Stackpole Books. 540pp.

Carter, V., and N. B. Rybicki. 1985. The effects of grazers and light penetration on the survival of transplants of *Vallisneria americana* Michx. in the tidal Potomac River, Maryland. Aquat. Bot. 23: 197-213.

Devore, Jay and Roxy Peck. 1986. Statistics The Exploration and Analysis of Data. West Publishing Company: St. Paul. 699pp.

Engel, S. 1990. Ecosystem responses to growth and control of submersed macrophytes- a literature review. Technical Bulletin No. 170. Department of Natural Resources, Madison, WI.

Fassett, N. C. 1957. A manual of aquatic plants. University of Wisconsin Press, Madison. 405pp.

Kenow. K. 2004. Pers. Comm. Upper Midwest Environmental Sciences Center, Onalaska, WI.

Korschgen, C. E., G. A. Jackson, L. F. Muessig, and D. C. Southworth. 1987. Sedimentation in Lake Onalaska, Navigation Pool 7, Upper Mississippi River, Since Impoundment. Water Resources Bulletin. 23(2): 221-226

Korschgen, C. E., L. S. George, and W. L. Green. 1988. Feeding ecology of Canvasbacks staging on Pool 7 of the Upper Mississippi River. Pages 237-250 in M. W. Weller, editor. *Waterfowl in winter*. University of Minnesota Press, Minneapolis.

Korschgen, C. E. and W. L. Green. 1988. American wild celery (*V. americana*): Ecological Considerations for Restoration. U.S. Fish and Wildlife Service. Fish and Wildlife Technical Report 19. 24pp.

Muenscher, W. C. 1944. Aquatic Plants of the United States. Comstock Publishing Company, Inc. Cornell University: Ithaca, New York.

Peck, J. H. and M. M. Smart. 1986. An assessment of the aquatic wetland vegetation of the Upper Mississippi River. *Hydrobiologia* 136: 57-76.

Sparks, R. E., P. B. Bayley, S. L. Kohler and L. L. Osborne. 1990. Disturbance and recovery of large floodplain rivers. Environmental Management 14: 699-709.

Spike, Andrew and S. Rogers. 1996. The effects of a record flood on the aquatic vegetation of the Upper Mississippi River System: Some preliminary findings. *Hydrobiologia* 340: 51-57.

Zar, Jerrold A. 1999. Biostatistical Analysis. Fourth Edition. Prentice Hall: New Jersey. 663pp.