ECOLOGICAL DYNAMICS OF A CREATED SEASONAL WETLAND IN NORTH DAKOTA[1]

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Abstract: The objective of the research was to compare created and natural seasonal wetlands in terms of (1) composition of vegetative communities, (2) net primary productivity, and (3) aboveground and belowground decomposition rates of plant tissues. The created seasonal wetland is located on the Falkirk Mine (North American Coal Corp.), which is on the western edge of the Prairie Pothole Region approximately 90 km north of Bismarck, ND. The natural seasonal wetland is located in the east-central portion of the Prairie Pothole Region approximately 150 km east of the Falkirk Mine. Permanent transects perpendicular to the wet meadow and shallow marsh vegetative zones were established between 1991 and 1992 for the created wetland and between 1990 and 1991 for the natural wetland. Aboveground live biomass was estimated by clipping random 0.1-m^2 or 0.25-m^2 quadrats in each vegetative zone. Decomposition rates were determined by incubating known amounts of fresh, dried plant tissue in mesh bags above and below ground over two growing seasons. Comparison of yield between the wetlands will be restricted to 1991. A total of 43 plant species were identified at the created wetland. Eighteen species are considered "weedy" pioneer types, while eight species are dominant wet meadow and shallow marsh plants identified with native seasonal wetlands. Aboveground live biomass in 1991 was 4,920 and 5,480 kg/ha for the wet meadow and shallow marsh zones of the created wetland. In comparison, the natural wetland in 1991 had aboveground live biomass of 11,886 and 8,521 kg/ha for the wet meadow and shallow marsh zones. Decomposition rates were slow in both created and natural seasonal wetlands. After 2 yr, 50% decomposition was never reached for aboveground and belowground zones in either wetland. Plant detritus remains in seasonal northern prairie wetland systems for extended time periods.

Additional Key Words: surface coal mining, prairie pothole region, net primary productivity, decomposition rate.

Introduction

The need for wetland protection and restoration is long overdue. Nearly 50% of the wetlands in the conterminous United States have been drained or altered (Office of Technology Assessment 1984). In North Dakota, approximately 60% of the original wetlands have been drained or altered with less than 1 million ha remaining (Tiner 1984, Mitsch and Gosselink 1986). Northern Great Plains wetlands are considered an important wetland region of the world, especially because of the numbers of waterfowl produced in the region (Ogaard et al. 1981, Weller 1981).

The concept of wetland creation has met various degrees of acceptance among environmental, regulatory, and development groups (Larson 1987). Wetland creation is accomplished by manipulating the hydrology, soil, and vegetation of a site. Previously, many restored wetlands considered successes were assessed solely on wetland plant establishment (Reimold and Cobler 1986, Blomberg 1987), while reports of the performance of other wetland functions in the literature are scant (Cooper 1987). Since Federal and State reclamation statutes regulate created wetlands as ecosystems, a better understanding of the basic functions in created wetlands is necessary to accurately assess the "success" of these restored wetlands.

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The objective of this research was to compare created with natural seasonal wetlands in the Prairie Pothole Region of west-central North Dakota. Specific objectives were to (1) identify plant species and communities, (2) determine aboveground net primary productivity of each plant community, and (3) examine aboveground and belowground decomposition rates of plant tissues in each community.

Study Area

The natural seasonal wetland was located on the Cottonwood Lake Research Area approximately 50 km northwest of Jamestown, ND. The created seasonal wetland was located on the Falkirk Mine, Underwood, ND, operated by the North American Coal Corp. Both research sites are in the Missouri Coteau Physiographic Region, a large glacial drift complex (LaBaugh et al. 1987).

The semiarid, continental climate of the region is characterized by cold winters and hot summers. Temperatures range from -12° C in January to 22° C in July. Average annual precipitation is 45 cm, of which 80% falls between April and September. However, dry conditions persisted over the study period, and annual precipitation between 1989 and 1991 averaged 40 cm.

The natural wetland was classified as seasonal using the Stewart and Kantrud (1971) system. Seasonal wetlands have wet meadow and shallow marsh vegetative zones formed in concentric rings from increasing water permanency. Wet meadow zones are dominated by grasses, rushes, sedges, and forbs. Some woody vegetation may also be present. Shallow marsh zones are dominated by coarse emergent grasses, sedges, and some forbs.

The created wetland was reclaimed by engineering a catchment basin, topsoiling with previously excavated wetland soil, and seeding with a grass species mixture. The catchment basin was modeled using the U.S. Department of Agriculture's Soil Conservation Service TR20 Model. The model engineers restored wetlands for both surface acreage of catchment basin and acre foot of water storage. The study site, one of numerous restored wetlands on the mine, received national recognition in 1986 from the Office of Surface Mining (Excellence in Surface Coal Mining Award) and in 1989 from the Take Pride in America National Award Program for wetland reclamation.

Methods

Three transects were established in both wetlands. The transects extended from the center outward, bisecting vegetational zones. Subsequent sampling took place at permanent points along the transects, 1 for each zone and transect in the natural wetland (6 total) and 2 in the shallow marsh and 3 in the wet meadow zones for each transect in the created wetland (15 total).

Aboveground Live Biomass

In the natural wetland, aboveground live biomass (ALB) was estimated by harvesting twice a year. The first sampling coincided with the full growth stage of cattail (*Typha latifolia*), which occurred in mid-June. The second harvest occurred in mid-August at the beginning of cattail senescence. If live biomass increased between harvests, the increase was added to the initial sampling estimates. Four 0.1-m^2 quadrats were randomly located and clipped to species at each point. Clippings were dried to a constant weight at 60° C and weighed.

Created wetland ALB was estimated in early August at full growth of cattail. Five 0.25-m^2 quadrats were randomly harvested at each point on shallow marsh transects. Ten quadrats total were harvested (4, 3, and 3) at the three permanent transect points in the wet meadow zone. Clippings were separated to species, dried to a constant weight at 60° C, and weighed.

Biomass Decomposition

Aboveground and belowground decomposition was determined for the dominant emergent species using the litter bag technique (Brinson et al. 1981). Bags were constructed of 2-mm nylon mesh screen and were approximately 10 by 15 cm. To account for losses or accumulation of material in bags, control bags filled with Styrofoam[3] packaging peanuts were placed alongside every plant litter bag.

Nine aboveground and nine belowground litter bags were placed at each sampling point of the natural wetland. Aboveground bags were filled with a dominant species from each vegetative zone. Slough sedge (*Carex atherodes*) was used for the wet meadow zone and marsh smartweed (*Polygonum coccineum*) for the shallow marsh zone. Plant material from these species was collected in the spring of 1990, dried, weighed, and placed in bags. Belowground litter bags were filled with washed, dried, and weighed roots collected from their respective zone. All litter bags were placed in or on the ground on June 25, 1990. Bags were retrieved after 2 days, and after 2, 4, 8, 16, 54, 60, 108, and 114 weeks. Upon retrieval, bags were gently washed, dried, and weighed.

For the created wetland, seven aboveground and seven belowground litter bags of each species were placed at sampling points along transects. Wooly sedge (*Carex lanuginosa*) and Mexican dock (*Rumex mexicanus*) were selected for the wet meadow zone, while slough sedge, creeping spikerush (*Eleocharis palustris*), and marsh smartweed were selected in the shallow marsh zone. Belowground litter bags were filled with washed, dried, and weighed roots and rhizomes collected from their respective vegetative zone. Dried and weighed materials from these species were placed in or on the ground June 12, 1991. Bags were retrieved at 2 days, and at 4, 8, 16, 52, 68, and 104 weeks. Upon retrieval, bags were gently washed, dried, and weighed.

Rate of decomposition for both wetlands was derived using the following equation:

$$\%\ \text{decomposition} = \frac{[OM_p x S_p - (S_r - (C_p - C_r)) x OM_r] x 100}{(OM_p x S_p)},$$

where OM_p = proportion of sample's organic matter when placed,
OM_r = proportion of sample's organic matter when retrieved,
C_p = weight of control when placed,
C_r = weight of control when retrieved,
S_p = weight of sample when placed, and
S_r = weight of sample when retrieved.

Statistical Analysis

Analyses were conducted using the Statistical Analysis System (SAS 1990). Treatments were the two wetlands, natural and created, while transects served as replication. Aboveground net primary production differences were tested using a t-test ($P<0.05$). Comparisons made were between years on each wetland and between wetlands in 1991. Least squares analysis ($P<0.05$) was conducted for aboveground and belowground decomposition in each vegetative zone. Differences were separated using Tukey's test ($P<0.05$). Comparisons between treatments and dates and within treatments across retrieval dates were made. Repeated-measures analysis ($P<0.05$) of the General Linear Models (SAS 1990) was conducted to test means and slopes of decomposition rates between wetlands for each zone.

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[3]Reference to specific products does not imply endorsement by the Bureau of Mines.

Results and Discussion

Species Composition

A total of 43 plant species were identified in the created wetland (table 1). Eighteen species are considered "weedy" pioneer types, while eight species are dominant wet meadow and shallow marsh plants identified with native wetlands. Owing to dry conditions, seven low prairie species were also found occupying the wet meadow zone.

Dominant species in the native wetland included quackgrass (*Agropyron repens*), smooth brome (*Bromus inermis*), northern reedgrass (*Calamagrostis inexpansa*), slough sedge (*Carex atherodes*), Canada thistle (*Cirsium arvense*), wild licorice (*Glycyrrhiza lepidota*), fowl bluegrass (*Poa palustris*), swamp knotweed (*Polygonum coccineum*), and western snowberry (*Symphoricarpos occidentalis*) in the wet meadow zone, and ovalleaf milkweed (*Asclepias ovalifolia*), slough sedge, Canada thistle, and swamp knotweed in the shallow marsh zone. Numerous "weedy" pioneer species and low prairie species also occupied the wet meadow and shallow marsh zones of the native seasonal wetland. A complete list of common dominant native wetland species by zone can be found in Stewart and Kantrud (1971), Fulton et al. (1986), and Kantrud et al. (1989).

Plant species in native, freshwater, and seasonal wetlands are distributed by the presence or absence of water and their tolerance to water permanence. Species and normal zonation patterns have been shown to be altered during extended wet or dry periods, which are common to northern prairie ecosystems (Smeins 1967, Stewart and Kantrud 1971, Fulton et al. 1986, Kantrud et al. 1989). Both wetlands in this study were subjected to an extended dry period from the fall of 1987 to 1992. The presence and relative abundance of low prairie and "weedy" pioneer species in both seasonal wetlands is indicative of these dry conditions. Despite the disturbances due to reclamation and extended drought, species composition of the created wetland appears promising for continued recolonization of the site.

Aboveground Live Biomass

Aboveground live biomass within zones was not different ($P<0.05$) between years for each wetland (table 2). Numerically, ALB was greater in 1991 for each zone of the natural seasonal wetland compared to the created wetland; however, owing to variability between transects and sampling sites, ALB within zones in 1991 was not different ($P<0.05$) between wetlands.

The range of ALB found in this study is similar to those of previous reports. Green (1987) and Mings et al. (1989) determined seasonal, freshwater wetland ALB for wet meadow zones ranging from 2,300 to 7,300 kg/ha. In a review, Fulton et al. (1986) reported typical wet meadow zone yields in freshwater wetlands to average approximately 4,000 kg/ha (2 st/acre). According to Fulton et al. (1986), aboveground production by shallow marsh species averages approximately 7,000 kg/ha (3.5 st/acre), or nearly twice that of wet meadow species. Rey et al. (1990) reported a range of 8,350 to 23,200 kg/ha for shallow marsh zones, while Brinson et al. (1981) found net primary production in cattail-dominated (*Typha*) ecosystems ranging from 3,300 to 24,500 kg/ha.

Fluctuating moisture regimes greatly affect vegetation zonation and ALB in northern plains seasonal wetlands (Smeins 1967, Millar 1973, Kantrud et al. 1989). Kantrud et al. (1989) stated that high water levels can kill up to 25% of the emergent vegetation in prairie wetlands. Green (1987) reported annual ALB in a seasonal wetland increased from 3,750 to 7,200 kg/ha owing to an improved moisture regime. Dry conditions were experienced throughout the present study. This is most evident in the ALB estimated for the created wetland, where community evolution was still taking place. Despite the dry conditions, ALB in the natural wetland was favorable when compared to other reported values.

Table 1. Species identified in a created wetland on the Falkirk Mine, Underwood, ND, 1991-92.

Scientific Name[1]	**Common Name**	**Zone**[2]
Agropyron caninum	Slender wheatgrass	LP, WM
*Agropyron repens**	Quackgrass	LP, WM
Agropyron smithii	Western wheatgrass	LP, WM
Amaranthus albus	Tumble pigweed	SM, WM
Ambrosia artemisifolia	Ragweed	SM, WM
*Aster ericoides**	White prairie aster	WM
Aster puniceus	Swamp aster	SM
*Bromus inermis**	Smooth brome	LP, WM
*Calamagrostis inexpansa**	Northern reedgrass	SM
*Carex atherodes**	Slough sedge	SM
*Carex lanuginosa**	Wooly sedge	SM
Chenopodium album	Lambsquarter	WM
*Cirsium arvense**	Canada thistle	SM, WM
Descurainia sophia	Flixweed	SM, WM
*Eleocharis palustris**	Creeping spikerush	SM
Helianthus annuus	Common sunflower	WM
Kochia scoparia	Fireweed summercypress	SM, WM
Lactuca pulchella	Blue wild lettuce	SM, WM
Lactuca serriola	Prickly lettuce	SM, WM
Malva rotundifolia	Running mallow	SM, WM
Melilotus officinalis	Yellow sweetclover	LP, WM
Mentha arvensis	Mint	WM
*Phalaris arundinacea**	Reed canarygrass	SM
Poa pratensis	Kentucky bluegrass	LP, WM
*Polygonum coccineum**	Swamp knotweed	SM
Populus deltoides	Cottonwood	SM, WM
Rumex mexicanus	Mexican dock	SM, WM
Rumex pseudonatronatus	Dock	SM, WM
Salix amygdaloides	Peachleaf willow	SM, WM
Salix exigua	Sandbar willow	SM, WM
Salsola kali	Russian thistle	SM, WM
*Scirpus fluviatilis**	River bulrush	SM
*Scirpus validus**	Softstem bulrush	SM
Sisymbrium altissimum	Tumbling mustard	SM, WM
*Sonchus arvensis**	Sow thistle	WM
*Sparganium eurycarpum**	Bur-reed	SM
Stipa viridula	Green needlegrass	LP, WM
Taraxacum officinale	Common dandelion	WM
*Teucrium occidentale**	Germander	WM
Thlaspi arvense	Field pennycress	SM, WM
Tragopogon dubius	Goatsbeard	WM
*Typha glauca**	Blue cattail	SM

[1]Starred species are native to northern prairie wetlands.
[2]LP = low prairie; WM = wet meadow; SM = shallow marsh.

Biomass Decomposition

Decomposition rates for both zones and wetlands were slow (fig. 1). Decomposition of incubated plant materials never reached 50% even after 104 or 114 weeks. Plant detritus remains in northern prairie wetlands for extended time periods, which agrees with previous studies (Mason and Bryant 1975, Brinson et al. 1981, Polunin 1984, Murkin et al. 1989).

Aboveground decomposition rates for both vegetative zones were similar ($P<0.05$) between wetlands (fig. 1). However, belowground decomposition rates were greater ($P<0.05$) at and following 16 weeks incubation in both vegetative zones of the created wetland compared to the natural wetland.

Over time, aboveground and belowground decomposition rates increased ($P<0.05$) in both zones of the created wetland and in the aboveground environment of the natural wetland (fig. 1). Belowground decomposition rates of the natural wetland were similar ($P<0.05$) over the 114-week incubation period. Mean decomposition and rate of decomposition (slope) were greater ($P<0.05$) in the created seasonal wetland except aboveground in the shallow marsh zone, where mean and rate were similar.

The decomposition rates experienced can be explained by the continued dry conditions throughout the study. Absence of surface or subsurface water and warmer temperatures in the absence of water would lead to aerobic conditions, which would increase decomposition rates (Godshalk and Wetzel 1977, 1978, Polunin 1984, Ohlson 1987). Aerobic conditions existed throughout the study for aboveground and belowground incubated materials for the created wetland and for aboveground incubation bags for the natural wetland. Decomposition rates for these zones and wetlands followed similar patterns. Decomposition rates for belowground incubated materials in the natural wetland were lower and did not increase over the study period. This level and pattern of decomposition would be typical of anaerobic environments that may be exhibited in belowground shallow marsh vegetative zones.

Table 2. Aboveground net primary production (x + standard error) for a natural and a created seasonal wetland in central North Dakota kg/ha.

Wetland[1]	Zone	
	Wet meadow	Shallow marsh
Natural:		
1990	11,536 (792)	4,781 (3,028)
1991	11,886 (1,516)	8,521 (1,574)
Created:		
1991	4,920 (2,334)	5,480 (1,682)
1992	2,111 (875)	2,451 (1,311)

[1]No differences ($P<0.05$) were found between years within wetlands for each zone; No differences ($P<0.05$) were found in 1991 between wetlands for each zone.

Conclusions

The extended dry conditions experienced throughout the study significantly influenced the development of the created seasonal wetland. Numerous "weedy" pioneer species dominated the composition of vegetation zones in this wetland. However, common dominant native wetland species were present and hold promise for future recolonization of the site. Annual ALB was strongly influenced in the created wetland by the lack of moisture. Aboveground and belowground decomposition patterns in the created wetland were similar to aboveground decomposition in the natural wetland. This pattern would be indicative of dry, warm aerobic soil conditions in contrast to expected wet, cool anaerobic soil environments of natural seasonal wetlands. Overall, decomposition rates of plant materials are very slow in northern prairie wetlands, which is supported by the results of this study.

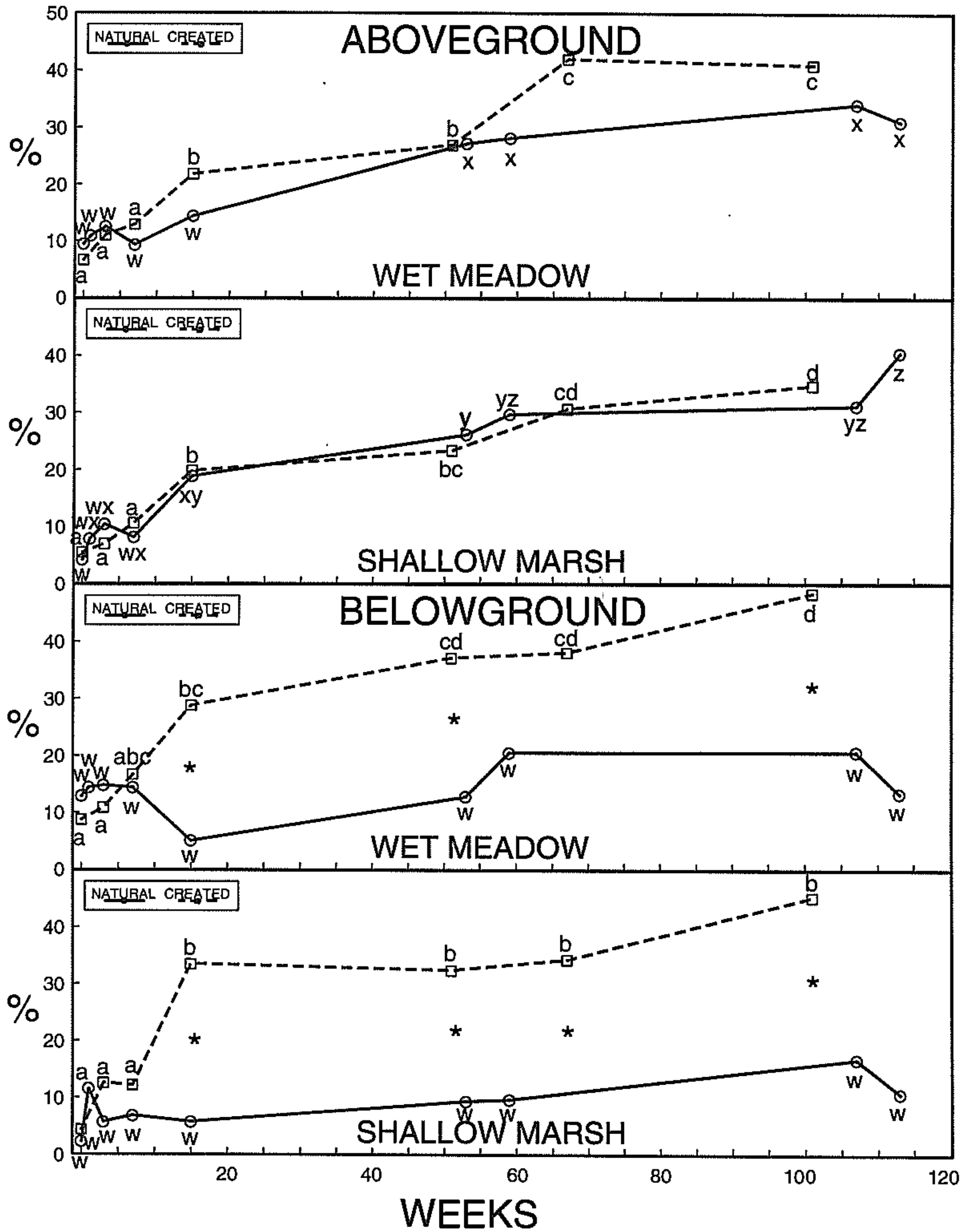

Figure 1. Decomposition rates for aboveground and belowground plant material incubated in wet meadow and shallow marsh vegetative zones of a natural and a created seasonal wetland.

* Difference ($P<0.05$) between natural and created wetland decomposition rate for an incubation stage.

[abcd] Difference ($P<0.05$) in decomposition rate over time for the created wetland.

[wxyz] Difference ($P<0.05$) in decomposition rate over time for the natural wetland.

Literature Cited

Blomberg, G. 1987. Development and mitigation of wetlands in the Pacific northwest. Northwest Environ. J. 3:63-91.

Brinson, M. M., A. E. Lugo and S. Brown. 1981. Primary productivity, decomposition and consumer activity in freshwater wetlands. Ann. Rev. Ecological Systems 12:123-161.
http://dx.doi.org/10.1146/annurev.es.12.110181.001011

Cooper, J. W. 1987. An overview of estuarine habitat mitigation projects in Washington State. Northwest Environ. J. 3:112-127.

Fulton, G. W., J. L. Richardson and W. T. Barker. 1986. Wetland soils and vegetation. ND Res. Rep. No. 106.

Godshalk, G. L. and R. G. Wetzel. 1977. Decomposition of macrophytes and the metabolism of organic matter in sediments. p. 258-264. *In:* J. L. Folterman (ed.), *Interactions between sediments and fresh water*. Junk, The Hague.

Godshalk, G. L. and R. G. Wetzel. 1978. Decomposition in the littoral zone of lakes. p. 131-143. *In:* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.), *Freshwater wetlands: Ecological processes and management potential.* Academic Press, New York.

Green, D. M. 1987. Composition, production, disappearance and nutritive content of wetland vegetation on the Missouri Coteau. M.S. thesis, ND State University, Fargo.

Kantrud, N. A., G. L. Krapu and G. A. Swanson. 1989. Prairie basin wetlands of the Dakotas: A community profile. Biol. Rep. 85. U.S. Dept. Interior, Fish & Wildlife Serv., Washington, DC.

LaBaugh, J. W., T. C. Winter, B. A. Adomaitis and G. A. Swanson. 1987. Hydrology and chemistry of selected wetlands in the Cottonwood Lake area, Stutsman County, North Dakota, 1979-82. U.S. Geol. Surv. Pro. Paper 1431.

Larson, J. S. 1987. Wetland creation and restoration: An outline of the scientific perspective. p. 73-79. *In:* Proceedings of a conference: Increasing our wetland resources. Washington, DC.

Mason, D. F. and J. J. Bryant. 1975. Production, nutrient content and decomposition of *Phragmites communis* (Trin.) and *Typha angustifolia* (L). J. Ecol. 63:71-95.
http://dx.doi.org/10.2307/2258843

Millar, J. B. 1973. Vegetation changes in shallow marsh wetlands under improving moisture regime. Can. J. Bot. 51:1443-1457. http://dx.doi.org/10.1139/b73-184

Mings, T. S., D. R. Kirby and D. M. Green. 1989. Seasonal wetlands and livestock grazing on the Missouri Coteau: Above ground biomass. ND Acad. Sci. Proc. Grand Forks.

Mitsch, W. J. and J. G. Gosselink. 1986. Wetlands. Van Nostrand Reinhold Co., New York. 539 p.

Murkin, H. R., A. G. van der Valk and S. B. Davis. 1989. Decomposition of four dominant macrophytes in the Delta Marsh, Manitoba. Wildl. Soc. Bull. 17:215-221.

Office of Technology Assessment. 1984. Wetlands: Their use and regulation. OTA-0-206, U.S. Congress, Washington, DC.

Ogaard, L. A., J. A. Leitch, D. F. Scott and W. C. Nelson. 1981. The fauna of the prairie wetlands: Research methods and annotated bibliography. ND Exp. Sta. Res. Rep. 86.

Ohlson, M. 1987. Spatial variation in decomposition rate of *Carex rostrata* leaves on a Swedish mire. J. Ecol. 75:1191-1197. http://dx.doi.org/10.2307/2260322

Polunin, N. V. C. 1984. The decomposition of emergent macrophytes in fresh water. Adv. Ecol. Res. 14:115-166. http://dx.doi.org/10.1016/S0065-2504(08)60170-1

Reimold, R. J. and S. A. Cobler. 1986. Wetlands mitigation effectiveness. Contract 68-04-0015. U.S. Environ. Protection Agency, Region 1, Boston, MA. 75 p.

Rey, J. R., F. Shaffer, R. Crossman and D. Tremain. 1990. Above-ground primary production in impounded, ditched, and natural *Batis-salicornia* marshes along the Indian River Lagoon, Florida, U.S.A. Wetlands 10(2):151-171. http://dx.doi.org/10.1007/BF03160830

SAS. 1990. SAS/STAT User's Guide, Version 6, Fourth Edition, Vol. 2, Cary, NC.

Smeins, F. E. 1967. The wetland vegetation of the Red River Valley and drift prairie regions of Minnesota, North Dakota and Manitoba. Ph.D. Diss., U. Saskatchewan, Saskatoon.

Stewart, R. E. and H. A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated prairie region. U.S. Fish Wildl. Serv. Resource Publ. 92.

Tiner, R. W. 1984. Wetlands of the United States: Current status and recent trends. U.S. Fish Wildl. Serv., Washington, DC.

Weller, M. W. 1981. *Freshwater marshes*. Univ. MN Press, Minneapolis. 146 p.