Assessment of Seasonal Prairie Pothole Wetlands Using an Index of Biological Integrity

Edward S. DeKeyser, Don Kirby, Animal and Range Sciences Department, North Dakota State University
and Mike Ell, North Dakota Department of Health

Abstract:

An Index of Biological Integrity (IBI) was developed for quantitatively assessing the quality, or condition of seasonal wetlands. Between 1998 and 1999, vegetative composition was measured from 66 seasonal wetlands mainly concentrated on the Missouri Coteau Physiographic Region, within the Mixed Grass Prairie Vegetation Zone of central North Dakota. Wetlands were selected based on a range of disturbance and from well-managed native grasslands to heavily disturbed cropland. Vegetation data were delineated into metrics of characteristics of the data set (e.g. species richness, percentage of introduced and annual plants) and analyzed using principal components and cluster analyses. Five disturbance quality classes, very good, good, fair, poor, and very poor were determined. Based on these classes, ranges and scores were then assigned for each metric. By using this classification system, additional seasonal wetlands in the Missouri Coteau Region can now be assessed and placed in quality classes for mitigation or ecological purposes, such as tracking the improvement of restored or reclaimed wetlands, wildlife habitat evaluation, and evaluation of other ecological functions.

Introduction:

The Clean Water Act was passed by Congress in 1972 (Public Law 92-500) and stated as a goal "the restoration and maintenance of chemical, physical and biological integrity of Nation's waters." During the late 1980's and early 1990's the idea of a no net loss of wetlands policy was a top priority of the Environmental Protection Agency (EPA). The idea became policy with the Wetland Conservation provision (Swampbuster) of the 1985 and 1990 farm bills. The provision compels agricultural producers to preserve wetlands on the land they own or manage by restricting their eligibility for certain benefits awarded by the United States Department of Agriculture. However, a no net loss of wetlands policy did not mean that wetlands could not be drained. It meant that if a wetland is drained it must be replaced by a wetland of similar or greater quality, which would come from wetland restoration or wetland creation. Questions arising from the Clean Water Act's goal and the subsequent bills that followed are: How does one decide on the quality of a wetland? And How does one measure biological integrity?

The Index of Biological Integrity (IBI) or biological assessment of wetlands being developed by the EPA and several state agencies, tackles these questions by quantitatively measuring biological characteristics of wetlands and then comparing the results to a range of disturbances. Wetland vegetation exhibits attributes in response to disturbance that indicate wetland condition. Using these attributes, vegetative groupings can be delineated into reference categories, or quality classes, which could improve management and mitigation of wetlands.

The location of wetland community zones and their species composition are influenced mostly by hydrologic factors such as water regime and salinity (Dix and Smeins 1967, Walker and Coupland 1968, 1970, Stewart and Kantrud 1971, 1972). Another important element in determining the composition of wetland vegetation is disturbance. Often the magnitude of disturbance is more significant than the type of disturbance (Kantrud et al. 1989b). There is limited published material focusing upon a range of anthropogenic disturbances and the subsequent reaction of wetland vegetative communities in the Northern Great Plains. There are a number of disturbances recognized in the Northern Great Plains such as grazing, mowing, burning, siltation (Kantrud et al. 1989a), cultivation (Walker and Coupland 1968), excessive nutrient loads and anoxia, and pesticide and heavy metal contamination (Adamus 1996). Two other disturbance categories are restored wetlands and idle wetlands, which differ vegetatively when compared to native prairie wetlands. The disturbances listed will often occur simultaneously, such as cultivation and sedimentation, or cultivation and nutrient loading.

Objective:

1. Devise a classification system that will categorize wetlands by vegetative composition in response to disturbance type and degree.

Figure 1. High quality seasonal wetland BS9901.

Methods:

The quadrat method was utilized by evenly distributing fifteen 1 m quadrats in the middle of the emergent zone(s) to avoid overlapping of species from other zones, and evenly distributing fifteen 1 m[2] quadrats in a sprinkled fashion in the most interior zone of each wetland. Each species found within a quadrat was then assigned a Daubenmire cover class based on the basal cover of that particular species in the quadrat. The technique used to record 1 m[2] quadrats is similar to that used by the Northern Prairie Science Center in their study of restored wetlands in 1997 (Euliss and Gleason 1997). Litter thickness, water depth, percent bare bottom, percent standing dead, and secondary species not located within the quadrat but between quadrats were also recorded.

Data were then analyzed using a multimetric approach developed by Karr (1981), and described more recently by Karr and Chu (1997). Karr (1981) defined a metric as an "attribute" of the community in question. One example of a metric developed for plant species would be species richness of native perennials. An ideal metric has a notable linear change over a range of anthropogenic disturbances at different intensities of disturbance (Karr and Chu 1997).

Each of the metrics used for wetland assessment had a wide range of values spanning across the disturbance gradient. The values were separated into three groups initially set up from what would be anticipated in a high quality, primarily native, area. The value ranges were assigned a rating of 5 if the values in that range were close to what would be anticipated in a high quality area; a 3 if the values in that range varied somewhat from what would be anticipated; or a 1 if the values varied strongly from what would be anticipated (Miller et al. 1988). The vegetative data for a wetland is expected to occur within one of the three value ranges after the value ranges are assigned. Each metric is then assigned a 5, 3, or 1 depending upon which value range the data occurs.

The value ranges for the metric rankings as well as the value ranges for the quality classes were devised with the use of Ordination (PCA or ordination – mean of observation_1 mean observation_2, mean observation_3, denotes a specific metric data. The standardized data were then analyzed using PCA. Fisher's Proportionality Test was used to ascertain which PCs were significant (p > .1) (Fisher 1958).

The wetlands were then grouped using the significant PCs in the clustering factors in cluster analysis. The wetlands were grouped in a dendrogram and quality classes, or disturbance groups, categorized by subjectively setting the cluster distance of the dendrogram. The groups were tested to see if they were significantly different using MRPP. If the initial cluster analysis groups were significantly different, then the groups were subdivided into smaller groups and tested again. The procedure was repeated until a number of statistically different cluster analysis groups were found that were biologically similar.

Table 1. Metrics developed for use in an Index of Biological Integrity.

Metrics
Species Richness of Native Perennials
Number of Genera of Native Perennials
Assemblance: Native Grass and Grass-Like Species
Percentage of Annual, Biennial and Introduced Species or Entire Species List
Wet Meadow Zone – Number of Native Perennial Species
Number of Species with a C-Value > 5
Wet Meadow Zone – Number of Species with a C-Value > 4
Average C-Value
Floristic Quality Index

Results:

Nine metrics were selected as possible metrics that would work for the quadrat sampled method (Table 1). The metrics were chosen because of the notable linear change over the disturbance gradient, and because of their independence from one another. Value ranges assigned to the three ratings of the metrics for the seasonal wetland quadrat data set are listed in Table 2.

Two examples of the assignment of the ratings for the seasonal wetland quadrat data are listed in Table 3. The examples are of a high quality wetland (BS9901) (Figure 1) and a low quality wetland (Yipsilanti) (Figure 2). Using categories of native perennial species as an example, the value range for a 1 rating is 0-31 native perennial species, for a rating of 3 is 32-42 native perennial species, and for a rating of 5 is 43 or more native perennial species. The wetland BS9901 had 52 native perennial species so it was assigned a rating of 5 for this metric. The wetland Yipsilanti had 5 native perennial species so it was assigned a rating of 1 for this metric. After each metric is assigned a rating, the ratings are added together to get a total metric score for the wetland. The sum of these multiple metrics has been referred to as the IBI (Karr and Chu 1997).

After all wetlands were scored using the above procedure, score ranges for quality classes were subjectively determined (Table 4). In contrast to the wetlands in Table 3, wetland BS9901 would fall into the very good quality class with a total score of 41, and the wetland Yipsilanti would fall into the very poor quality class with a total score of 9.

Table 2. Metric value ranges for the metric scores of 1, 3, and 5 of the quadrat data set for the seasonal wetlands.

Metric	Value Range for 1	Value Range for 3	Value Range for 5
Sp. Rich.[1]	0-31	32-42	43+
# Genera[2]	0-26	27-38	39+
Grass-like[3]	0-8	9-17	18+
% of annuals[4]	56.00+	56.00-39.71	39.70-0
# Nat. in WMZ[5]	0-9	10-20	21+
# C > 5[6]	0-5	6-20	21+
# C > 4 in WMZ[7]	0-4	5-14	14+
Avg. C[8]	0-3.15	3.16-4.00	4.01+
FQI[9]	0-22.99	23.00-28.99	29.00+

[1] Species richness of native perennial plant species.
[2] Number of Genera of native perennial plant species.
[3] Number of grass and grass-like species (Poaceae, Juncaceae, Cyperaceae).
[4] Percentage of the total species list that are annual, biennial, and introduced.
[5] Number of native perennial plant species found in the wet meadow zone.
[6] Number of plant species with a C-Value > 5.
[7] Number of plant species with a C-Value > 4 found in the wet meadow zone.
[8] Average C-Value of all species present.
[9] Floristic Quality Index.

Table 3. Examples of assigning ratings to metric values for a high quality (BS9901) and a low quality wetland (Yipsilanti) for the seasonal wetlandquadrat data set.

Metrics	Observed Value	Range	Observed Value	Range
Sp. Rich.[1]	52	5	5	1
# Genera[2]	38	3	5	1
Grass-like[3]	17	3	1	1
% of annuals[4]	14.75	5	83.33	1
# Nat. in WMZ[5]	25	5	1	1
# C > 5[6]	27	5	0	1
# C > 4 in WMZ[7]	12	3	0	1
Avg. C[8]	4.04	5	1.50	1
FQI[9]	33.38	5	3.54	1
	Total Score	41	Total Score	9

Table 4. Quality classes and scoring for each class for the total metric scores of seasonal wetlands for the quadrat data set.

Quality Class	Score Range for the Quadrat Data Set
Very Good	38-45
Good	30-37
Fair	22-29
Poor	14-21
Very Poor	< 13

Figure 2. Low quality seasonal wetland Yipsilanti.

Discussion:

A successful classification system to assess wetlands must consist of attributes of the vegetative composition that furnish dependable signs of the wetlands' overall quality or condition (Karr and Chu 1997). The success of an individual attribute in determining wetland quality depends on the ability of the attribute to correlate with the level of disturbance. The best way to test an attribute's ability to give an indication of the level of disturbance is to observe a steady change over a disturbance gradient. The metrics (attributes) developed in this study had a notable change over a disturbance gradient that was constructed with a number of different disturbances occurring in and around seasonal wetlands in central North Dakota. The metrics were then combined to create a workable IBI for the assessment of seasonal wetlands.

Literature Cited:

Adamus, P.R. 1996. Bioindicators for assessing ecological integrity of prairie wetlands. EPA/600/R-96/082. U.S. Environmental Protection Agency, National Health and Environmental Effects Research laboratory, Western Ecology Division, Corvallis, OR.

Biondini, M.E., P.W. Mielke, and K.J. Berry. 1988. Data-dependent permutation techniques for the analysis of ecological data. Vegetatio 75:161-168.

Dix, R.L., and F.E. Smeins. 1967. The prairie, meadow, and marsh vegetation of Nelson county, North Dakota. Canadian Journal of Botany 45:21-58.

Euliss, Jr., N.H., and R.A. Gleason. 1997. Standard operating procedure: Extensive variables for study sites. Unpublished. Evaluation of restored wetlands in the Prairie Pothole Region of the United States (Draft). U.S. Geological Survey, Biological Resources Division, Northern Prairie Wildlife Research Center, Jamestown, N.D.

Fisher, R.A. 1958. Statistical method for research workers. 13th ed. Hafner, New York, N.Y. 175pp.

Kantrud, H.A., J.B. Millar, and A.G. van der Valk. 1989a. Vegetation of wetlands of the Prairie Pothole Region. Pages 132-187 in A.G. van der Valk, ed. Northern Prairie Wetlands. Iowa State University Press, Ames, Iowa.

Kantrud, H.A., G.L. Krapu, and G.A. Swanson. 1989b. Prairie basin wetlands of the Dakotas: A community profile. U.S. Fish and Wildlife Service Biological Report 85(7.28). 116 pp.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6(6):21-27.

Karr, J.R., and E.W. Chu. 1997. Biological monitoring and assessment: Using multimetric indexes effectively. EPA 235-R97-001. University of Washington, Seattle.

Krabbenhoft, K., D. Kirby, M. Biondini, G. Halvorson and D. Nilson. 1993. Topoedaphic unit analysis: A site classification system for reclaimed mined lands. Catena 20:289-308.

Ludwig, J.A., and J.F. Reynolds. 1988. Statistical ecology; a primer on methods and computing. John Wiley & Sons, Inc. New York, N.Y. 337 pp.

Miller, D.L., P.M. Leonard, R.M. Hughes, J.R. Karr, P.B. Moyle, L.H. Schrader, B.A. Thompson, R.A. Daniels, K.D. Fausch, G.A. Fitzhugh, J.R. Gammon, D.B. Halliwell, P.L. Angermeier, and D.J. Orth. 1988. Regional applications of an index of biotic integrity for use in water resource management. Fisheries 13(5):12-20.

Stewart, R.E., and H.A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated prairie region. U.S. Fish and Wildlife Service, Resource Publication 92. 57 pp.

Stewart, R.E., and H.A. Kantrud. 1972. Vegetation of prairie potholes, North Dakota, in relation to quality of water and other environmental factors. U.S. Geological Survey, Professional paper 585-D. 36 pp.

Walker, B.H., and R.T. Coupland. 1968. An analysis of vegetation-environment relationships in Saskatchewan sloughs. Canadian Journal of Botany 46:509-522.

Walker, B.H., and R.T. Coupland. 1970. Herbaceous wetland vegetation in the Aspen Grove and Grassland Regions of Saskatchewan. Canadian Journal of Botany 48:1861-1874.