A comparison of natural and constructed wetlands using the floristic quality assessment index

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Introduction

One of the important current issues about wetlands is their inclusion in state and federal water quality standards. "Applying water quality standards to wetlands is part of an overall effort to protect the Nation's wetland resources and provides a regulatory basis for a variety of programs for managing wetlands to meet this goal" (USEPA, 1990). States are required by the USEPA to develop biological criteria for wetlands, and Ohio is one of the few states that are actively working toward that goal. "In the past, regulatory agencies have used simple chemical criteria that served as surrogates for the biological integrity goal of the Clean Water Act, but controlling chemical water quality alone does not assure the integrity of water resources. Biological criteria offer a way to measure the end result of water quality management efforts and successfully protect surface water resources" (Yoder, 1991).

The quality of a wetland depends not only on the chemical and physical quality of the water, but also other variables such as wildlife habitat, species diversity, connectivity to other surface waters or habitats, and its ability to retain flood waters and recharge groundwater reservoirs (Mitsch and Gosselink, 1993). Biological criteria are necessary as tools for assessing wetland quality because they can be used to characterize various chemical, physical, and biological impacts and detect cumulative impacts.

The Ohio EPA Wetlands Program is currently working to develop biological criteria that may be used to aid in decision making about wetland issues in the state. They are testing the use of the Floristic Quality Assessment Index (FQAI) for possible development as a metric for wetland biocriteria (Fennessy, 1995). The FQAI is a vegetative metric tailored specifically to the flora of Ohio (Andreas and Lichvar, 1995), and is based on the method developed by Wilhelm and Ladd (1988). The FQAI can be used to assess the nativeness or naturalness of an area based on the presence of ecologically conservative species. The ability to evaluate floristically and assign a repeatable quantitative value has use in assessing wetland restoration projects and in designing and monitoring mitigation wetlands (Andreas and Lichvar, 1995).

Restoration and mitigation wetlands are designed with the goal of achieving a "natural" system, but sometimes fail to meet this goal. For example, Erwin (1991) found that of 40 mitigation projects in south Florida involving wetland creation and restoration, 60 percent were judged to be incomplete or failures. The most significant problems identified with the constructed wetlands were improper water levels and hydroperiods: "If the proper hydrologic conditions are developed, the chemical and biological conditions will respond accordingly. To develop a wetland that will be a low maintenance one, natural successional processes need to be allowed to proceed" (Mitsch and Gosselink, 1993). Andreas and Lichvar (1995) suggested that the FQAI can be used to assess restoration and mitigation projects. This metric would allow one to see if restored and constructed wetlands are similar in quality to natural wetlands or are progressing ecologically toward natural systems.

This study focuses on comparing four natural wetlands with a pair of constructed wetlands in Ohio by using the FQAI. It also compares annual vegetation surveys of the constructed wetlands using the FQAI to monitor the quality of the wetlands as they mature. It is important to know how the quality of constructed wetlands compares with that of natural wetlands and how the quality changes annually to determine if the constructed wetlands are providing adequate ecosystem functions. Also, it is important to determine the quality of the wetland for regulatory purposes.

The FQAI can be converted to a score used by the Ohio EPA Ohio Wetland Assessment Method (OWAM) to determine the category of the wetland (Fennessy et al., 1998). These categories (1=low quality; 2=intermediate; 3=high) are used for determining the extent to which a wetland may be impacted or degraded under the Clean Water Act section 401 permitting process (Ohio EPA, 1998). Category 1 includes wetlands that have the least protection under the standards and Category 3 wetlands that have the most protection. The five wetlands in this study will be assigned FQAI scores and OWAM scores as a basis for comparison. To achieve the goals of comparing the recently constructed wetlands with four natural wetlands and looking at a time series comparison of the quality of the constructed wetlands each year using the Floristic Quality Assessment Index, the following objectives were met:

1. Perform vegetation surveys of the four natural wetlands;
2. Perform vegetation surveys of two deepwater marshes at the constructed wetland site;
3. Calculate the FQAI score and compare all wetlands surveyed;
4. Obtain vegetation census information for each growing season of the constructed wetlands to compare annual FQAI scores;

5. Use OWAM scores from field assessments to determine wetland categories for the state of Ohio.

Methods

Four emergent, depressional wetlands (varying in levels of human disturbance) were surveyed by the Ohio Environmental Protection Agency in the summer of 1997 (Fig. 1). The constructed deepwater marshes at the Olentangy River Wetland Research Park (ORWRP) in Columbus, Ohio were also surveyed in the summer of 1997.

Reference Wetland Floristic Survey

Four emergent, depressional wetlands were selected in the Eastern Cornbelt Region of Ohio based on the wetland hydrogeomorphic (HGM) classification (Brinson, 1993). Calamus, located in Pickaway County, is a permanently flooded emergent wetland with a wet meadow along the southwest edge. It has a forested perimeter and is bounded on the south by an abandoned railroad bed, on the west by SR 22 and on the north and east by agricultural fields (Fennessy et al., 1998). Dever, located in Franklin County, is a seasonally flooded emergent wetland in the middle of an agricultural field. Row crops are grown to the east, north and west of the wetland and the field is mowed up to the cattails along the southern edge (Fennessy et al., 1998). Keller Low, located in Fairfield County, is a seasonally flooded emergent wetland also situated in an agricultural field. Row crops surround this site (Fennessy et al., 1998). Lawrence Low, located in Hardin County, is a seasonally flooded emergent wetland on the property of the Ohio Department of Natural Resources (ODNR) Natural Areas and Preserves. It is part of the Lawrence Woods Preserve and lies in an old cattle pasture near County Road 200 (Fennessy et al., 1998). A brief comparison of hydrology, dominant vegetation and area of each wetland is given in Table 1.

Vegetation surveys were completed at each site during the 1997 growing season (Appendix). Three transects were surveyed across each wetland—one long transect from end to end of the wetland and two short, parallel transects bisecting the long transect. A nested quadrat sampling method was used with thirty 0.45 m^2 quadrats placed consecutively along the three transects every 20-40 m depending on the size of the wetland. All species inside each quadrat were recorded, as well as all species between quadrats for one meter to each side along the transects. Any unknown species were collected and taken to the lab for identification. Plant keys used for identification included Gleason and Cronquist (1991), E. Lucy Braun (1967, 1989), and Newcomb's Wildflower Guide (1977). Upon identification of all species possible, a Coefficient of Conservatism (Cc) was assigned to each species from the floristic checklist compiled by Andreas and Lichvar (1995). (A rating of zero is given to native opportunistic invaders and all non-native taxa.) The Cc values are determined as follows (Andreas and Lichvar, 1995; Fennessy, 1995):

Figure 1. Map of central Ohio showing the four reference wetlands

Table 1. Comparison of the four reference wetlands surveyed in 1997 (from the Ohio EPA Ecological Assessment Final Report to the U.S. EPA, 1998)

Site	Size (ha)	Dominant vegetation	Hydrologic regime
Calamus	6.0	*Nuphra advena* *Lemna minor* *Polygonum* spp.	Permanently flooded
Dever	1.2	*Typha latifolia* *Lemna minor*	Seasonally flooded
Keller Low	2.0	*Typha latifolia* *Leersia oryzoides* *Scirpus cyperinus*	Seasonally flooded
Lawrence Low	0.8	*Alisma subchordatum* *Carex* spp. *Polygonum* spp.	Seasonally flooded

Values of 1-3: applied to taxa that are widespread and are not an indicator of a particular community.

Values of 4-6: applied to species that are typical of a successional phase of some native community

Values of 7-8: taxa that are typical of stable or "near climax" conditions

Values of 9-10: taxa that exhibit high degrees of fidelity to a narrow set of ecological parameters.

The FQAI score was calculated for each wetland by the formula (Andreas and Lichvar, 1995):

$$I=R/\sqrt{N}$$

with: I=FQAI score;
R=Sum of Coefficient of Conservatism (Cc);
N=Number of native species.

OWAM scores for the four reference wetlands were taken from the actual field assessments (Fennessy et al., 1998).

Constructed Wetland Floristic Survey

The Olentangy River Wetland Research Park was constructed in 1993. It is an urban, freshwater marsh complex that lies in an alluvial floodplain north of The Ohio State University main campus in Columbus, Ohio. Two deepwater marshes, each one hectare in size, were initially flooded in the spring of 1994 (Mitsch, 1998). Wetland 1 was planted while the vegetative community of Wetland 2 has been allowed to develop without interference. Vegetation surveys were conducted during the 1997 growing season using the same method as the Ohio EPA surveys. Three transects were sampled in each wetland basin with fifteen quadrats. A total of thirty quadrats were sampled over the entire site (Fig. 2). Sampling was performed from the boardwalks using a rope to toss out and retrieve the quadrat. All species were recorded or collected and identified in the lab. All were assigned Cc values and the FQAI score was calculated. Each basin was scored separately and together for further comparison. The OWAM score was determined upon a field assessment of the site in the summer of 1998.

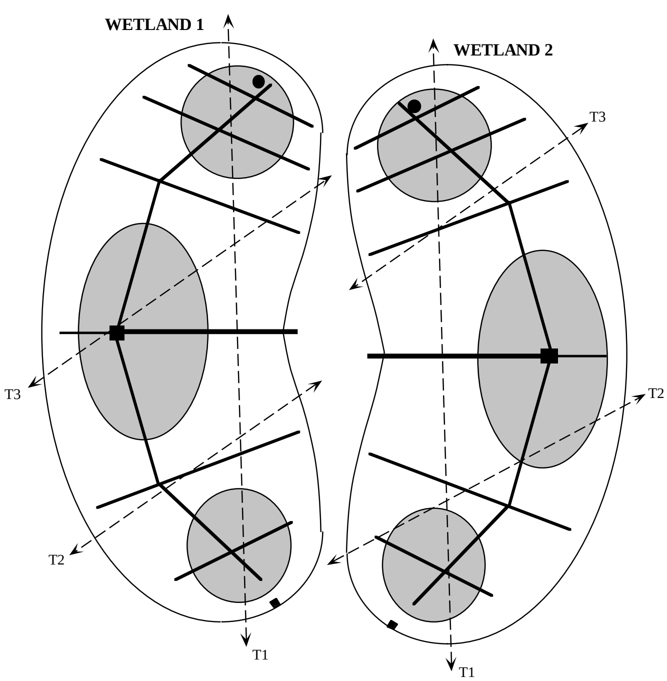

Figure 2. Location of the vegetation sampling transects at the ORWRP deepwater marshes.

ORWRP Comparison of Basins

Wetland 1 was planted in the first growing season (1994) and Wetland 2 was not planted. Vegetation census information was obtained from each growing season since the construction of the deepwater marshes. The census data include species introduced during the first season (Mitsch and Weihe,1995) as well as colonizing species. The 1995 season includes more colonizing species in basin 1 because some of the introduced species did not survive (Weihe and Mitsch, 1996). Cc values were assigned to all plants identified to species level, and the FQAI score was calculated. The two basins were compared separately and as one wetland for each year.

Results and Discussion

Comparison of Natural and Constructed Wetlands

The four natural wetlands displayed a range of FQAI scores and OWAM scores depending on the degree of human disturbance. The constructed wetland (as one site instead of two separate basins) ranked third out of the five wetland sites three years after it was constructed and one basin planted (Table 2).

It is proposed that the OWAM scores will be used in part to designate the categories to which each wetland is assigned according to the Ohio EPA Wetland Water Quality Standards. Category 3 wetlands are high quality; category 1 wetlands are low quality. A field assessment was performed

Table 2. FQAI scores for the natural and constructed wetlands surveyed in the 1997 growing season (data from the 1997 surveys as part of the Ecological Assessment Project-OEPA).

Wetland Name	FQAI Score
Natural wetlands	
Dever	15.97
Keller Low	17.32
Lawrence Low	19.60
Calamus	27.61
Constructed wetlands	
ORWRP	18.37

at each wetland and OWAM scores assigned (Table 3).

Annual Floristic Development of Constructed Wetlands

The annual FQAI scores for the ORWRP as a single wetland show a lower score for the second year because some of the introduced species from the first year did not survive and only half of the site was planted. The scores increased again in 1996 and 1997 due to colonization (Table 4).

The annual comparison of the ORWRP as two separate wetlands shows a difference between a planted wetland (Wetland 1) and a wetland that was allowed to develop naturally (Wetland 2) (Table 5). The FQAI score for Wetland 1 dropped after the first growing season because some of the introduced species did not survive (Weihe and Mitsch, 1995). As colonizing species gained a foothold in Wetland 1 following the second growing season, the FQAI score increased dramatically (Table 5). The vegetation community in Wetland 2 developed steadily over the four growing seasons as is shown by a general increase in its FQAI score (Table 5). However, the species that were identified in basin 2 and assigned Cc values in the first two growing seasons were mainly high-scoring woody species around the wetland perimeter. There were only two emergent species that were assigned Cc values in 1994 and 1995. These data reflect the fact that there was little growth in the unplanted basin during these (W.J. Mitsch, pers. comm.).

The decrease in the FQAI score from 1994 to 1995 in wetland 1 reflects some of the high quality (high Cc value) species that were planted the first growing season which did not survive to the next growing season (Weihe and Mitsch, 1995). Both wetlands were colonized rapidly, as can be seen by the increased scores in 1996, representing a greater number of species that were scored. The large increase in the FQAI score from 1995 to 1996 is also because more plants were identified to the species level (Liptak et al., 1996). This allows a Cc value assignment. Plants are not scored unless they are identified as a species. The data from the first two years contained some plants that were not identified to species level and therefore could not be assigned a Cc value or be included in the FQAI calculations. This study indicates that the constructed wetlands have indeed progressed ecologically toward a natural ecosystem as seen by the development of its vegetation community. It is encouraging to see that the FQAI may be a useful metric for determining whether restoration and mitigation projects are meeting the goals of achieving natural ecosystem functions.

Table 3. OWAM scores and Ohio EPA Wetland Water Quality Standards categories for the natural and constructed wetlands surveyed in the 1997 growing season.

Rank	Wetland	OWAM score	Category
1.	Calamus	35	3
2.	**ORWRP**	32	2-3
3.	Lawrence Low	19	2
4.	Keller Low	16	1-2
5.	Dever	11	1

Table 4. Annual FQAI scores for ORWRP as one wetland. Scores based on vegetation census. Data from Weihe and Mitsch (1996), Liptak et al. (1997) and Bouchard and Mitsch (1998)

Year	FQAI Score
1994	16.09
1995	12.41
1996	24.82
1997	28.70

Table 5. Annual FQAI scores for two experimental wetlands at ORWRP. Scores are based on vegetation studies carried out over the years, not on data collected for this assessment

Year	Wetland 1 (planted)	Wetland 2 (unplanted)
1994	15,7	8,2
1995	10.1	10.6
1996	23.9	19.3
1997	28.3	23.3

Conclusions and Recommendations

This study demonstrated that the constructed wetland does compare favorably in quality to the natural wetlands. It is progressing from a newly constructed wetland where there was no vegetation toward a higher quality wetland than those natural wetlands impacted by human activity (i.e., Dever and Keller Low, both of which are in the center of agricultural fields). The FQAI scores show differences in the quality of the wetlands studied. However, the vegetation communities must be surveyed thoroughly and all species identified and assigned Cc values to obtain a more accurate FQAI score and a more realistic picture of the wetland quality.

There is a need for continued research in using biological criteria for water quality standards. Thus there is a need for metrics such as the FQAI. More research should be done using the FQAI on natural and constructed wetlands to determine if restoration and mitigation projects are meeting the goals of achieving natural ecosystem functions.

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Appendix A. Plant species list and C of C Value for Calamus Wetland in summer 1997 (August 6, 1997)

Acer negundo	3
Acer saccharinum	3
Acorus calamus	4
Alisma subchordaturn	2
Asclepias incarnata	5
Bidens connata	2
Bidens frondosa	2
Boehmeria cylindrica	4
Calystegia sepium	1
Campsis radicans*	0
Carex comosa	2
Carex frankii	5
Carex lupulina	3
Carex stricta	6
Carex tribuloides	4
Cephalanthus occidentalis	7
Cichorium intybus*	0
Cirsium arvense*	0
Cornus amomum	2
Cyperus esculentus	2
Daucus carota*	0
Decodon verticillatus	6
Elymus virginicus	3
Erigeron annuus	1
Eupatorium perfoliatum	3
Fragaria vesca	4
Fraxinus pennsylvanica var. subintegerrima	6
Galium trifidurn	7
Geum canadense	2
Geum laciniatum	2
Glyceria striata	2
Hibiscus militaris	9
Impatiens capensis	2
Iris versicolor	6
Juncus effusus	1
Juncus tenuis	1
Leersia oryzoides	1
Lemna minor	4
Lobelia cardinalis	7
Lotus corniculatus*	0
Lycopus americanus	3
Maclura pomifera*	0
Medicago lupulina*	0
Mentha arvensis	2
Mentha piperita*	0
Morus alba *	0
Nuphar advena	5
Oenothera biennis	2
Oxalis europea	0
Oxalis stricta	0
Penthorum sedoides	3
Phalaris arundinacea	0
Plantago major*	0
Polygonum amphibium	5
Polygonum hydropiperoides	5
Polygonum pensylvanicum	1
Populus deltoides	5
Potamogeton foliosus	4
Prunus serotina	3
Rosa multiflora*	0
Rubus allegheniensis	1
Rumex crispus *	0
Sagittaria latifolia	2
Salix exigua	1
Salix nigra	3
Scirpus fluviatilis	5
Scirpus polyphyllus	4
Scutellaria lateriflora	3
Setaria faberi*	0
Setaria glauca*	0
Sium suave	5
Solanum dulcamara*	0
Sonchus arvensis*	0
Sparganium eurycarpum	4
Spirodela polyrhiza	5
Toxicodendron radicans	1
Trifolium pratense*	0
Typha angustifolia	0
Typha latifolia	2
Ulmus americana	1
Utricularia vulgaris	7
Verbena urticifolia	4
Verbesina alternifolia	4
Vitis riparia	4
Wolffia columbiana	6
C of C value sum	224
Number of native plant species present	68
Total number of plant species present	85
FQAI Score (1)	27.2

Appendix B. Plant species list and C of C Value for Dever Wetland in summer 1997 (June 26, 1997).

Alisma subchordatum	2
Apocynum cannabinum	3
Brassica nigra*	0
Carex frankii	5
Carex shortiana	5
Carex vulpinoidea	3
Cirsium arvense*	0
Daucus carota*	0
Dianthus armeria*	0
Eleocharis acicularis	3
Eleocharis ovata	2
Erigeron annuus	1
Festuca elatior*	0
Galium palustre	9
Geum aleppicum	3
Geum canadense	2
Juncus tenuis	1
Leersia oryzoides	1
Lemna minor	4
Lycopus americanus	3
Melilotus alba*	0
Mentha spicata*	0
Phleum pratense*	0
Plantago major*	0
Populus deltoides	5
Ranunculus sceleratus	2
Rosa palustris	4
Rubus allegheniensis	1
Rudbeckia hirta	3
Rumex crispus*	0
Salix amygdaloides	4
Salix exigua	1
Salix nigra	3
Scirpus acutus	5
Scirpus americanus	5
Scirpus atrovirens	2
Scirpus cyperinus	1
Spirodela polyrhiza	5
Tragopogon pratensis*	0
Trifolium hybridium*	0
Trifolium pratense*	0
Typha latifolia	2
Vitis riparia	4
C of C value sum	94
Number of native plant species present	30
Total number of plant species present	43
FQAI Score(I)	17.2

Appendix C. Plant species list and C of C Value for Keller Low Wetland in summer 1997 (July 17, 1997).

Acer negundo	3
Acer saccharinum	3
Alisma subchordatum	2
Apocynum cannabinum	3
Asclepias incarnata	5
Boehmeria cylindrica	4
Calystegia sepium	1
Carex frankii	5
Carex tribuloides	4
Carex vulpinoidea	3
Cirsium arvense*	0
Eleocharis ovata	2
Erigeron annuus	1
Fraxinus pennsylvanica var. subintegerrima	6
Geum aleppicum	3
Juncus effusus	1
Juncus tenuis	1
Lactuca serriola*	0
Leersia oryzoides	1
Lemna minor	4
Oenothera biennis	2
Oxalis stricta	0
Pilea pumila	4
Polygonum amphibium	5
Polygonum hydropiperoides	5
Polygonum pennsylvanicum	1
Polygonum sagittatum	3
Rosa multiflora*	0
Salix nigra	3
Scirpus cyperinus	1
Scirpus fluviatilis	5
Scirpus validus	6
Typha latifolia	2
Ulmus rubra	2
Vernonia gigantea	3
Vitis riparia	4
C of C value sum	98
Number of native plant species present	32
Total number of plant species present	36
FQAI Score (I)	17.3

Appendix D. Plant species list and C of C Value for Lawrence Woods Low Wetland in summer 1997 (August 5, 1997).

Agrostis gigantea*	0
Alisma subchordatum	2
Callitriche terrestris	8
Carex frankii	5
Carex stipata	2
Carex vulpinoidea	3
Cirsium arvense*	0
Crataegus mollis	3
Echinochloa crusgalli*	0
Eleocharis erythropoda	4
Eleocharis ovata	2
Erigeron annuus	1
Eupatorium purpureum	7
Fraxinus pennsylvanica var. subintegerrima	6
Gnaphalium purpureum	3
Gratiola neglecta	4
Hordeum jubatum*	0
Juncus effusus	1
Juncus tenuis var. dudleyi	4
Ludwigia palustris	4
Mimulus ringens	5
Penthorum sedoides	3
Phleum pratense*	0
Phyla lanceolata	6
Polygonum hydropiperoides	5
Quercus bicolor	7
Rosa palustris	4
Rumex crispus*	0
Salix nigra	3
Vitis riparia	4
C of C value sum	98
Number of native plant species present	25
Total number of plant species present	31
FQAI Score (I)	19.6