Wetlands in Three Ecoregions of the Central Plains

Kansas Biological Survey Report No. 147

April 2008

by

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For

USEPA Region 7

Prepared in fulfillment of USEPA Award USEPA X7-98769801-0, KUCR # FED41930

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III. Introduction

Importance of describing nutrient criteria for wetlands

Wetlands constitute ecotones or fringe habitats between terrestrial and aquatic systems. They sustain regional biodiversity, store water and sediments, and provide protection from flooding. Wetlands can improve water quality in streams, rivers, and lakes by trapping sediments and transforming pollutants. They also stabilize critical areas that would otherwise be vulnerable to erosion. Despite these beneficial features, wetlands have been historically altered by drainage and conversion to cropland. Over half the wetlands in the conterminous United States have been converted, particularly in the Central Plains. Of an estimated 841,000 acres of pre-settlement wetlands in the state of Kansas, only 435,400 acres remain. Iowa and Missouri have lost nearly 90% of their pre-settlement wetlands (Dahl and Johnson 1991). Limited data on wetland water quality make it difficult to pinpoint appropriate nutrient criteria for wetland ecosystems. Until recently, there have been few studies that attempt to describe wetland reference conditions in terms of nutrients and water quality. In addition, nutrient input into wetlands has not been regulated. As with water monitoring initiatives for lakes, rivers and streams, there was no effort to establish nutrient criteria for wetlands in the US until 1998 when the USEPA began to develop numeric nutrient water quality standards (USEPA 1998).

To develop nutrient criteria for wetlands, we must first determine nutrient levels that would occur “naturally.” For this study, “natural” or “reference” conditions are those least impacted by anthropogenic activity. Reference conditions vary as a result of regional characteristics and individual wetlands within the same region may exhibit variability as a result of different levels of human interference. This interference can occur directly, through physical alteration of wetland ecosystems, or indirectly through adjacent land-use. Because there are very few remaining undisturbed wetlands that would constitute ideal reference sites, the method we used to determine the degree of human disturbance was an important variable.

The objectives of this study were to: (1) identify potential reference wetlands, (2) sample for common water quality parameters, and (3) add the data to the USEPA Region 7 wetland database being assembled by the Central Plains Center for BioAssessment (CPCB). After soliciting regional wetland experts for potential reference wetlands and receiving few nominations, CPCB used a method of site selection used in a previous Missouri River Floodplain wetland study (Kriz *et al.* 2007) to identify candidate reference sites using GIS screening tools. Candidate reference wetlands were examined in the field and included or excluded as based on “professional judgment.”

This study was designed to examine water quality conditions found in open-water segments of Region 7 wetlands. Hence, other aspects of wetland hydrology, such as subsurface flows, groundwater influence, and soil conditions were not considered. This is because open-water segments were treated as composite indicators of water quality conditions within candidate wetlands. Comparing the data obtained in this study with other water quality monitoring programs may help determine regional water quality goals and inform federal, state and tribal agencies on the selection of reference sites for further regional characterization of wetlands.

The concept of reference condition

The CPCB modeled its approach to defining wetland reference condition after a study used to classify stream reference conditions (Stoddard 2006). There are particular differences between streams and wetlands. Yet, when it comes to describing reference conditions, the conceptual issues remain the same. Stream reference conditions (for biological integrity) can be classified as historical conditions (HC), best attainable conditions (BAC), least disturbed conditions (LDC) and minimally disturbed conditions (MDC). For the Central Plains, any definition of historical condition is controversial because we do not have viable pre-settlement data. Similarly, best attainable conditions cannot be known until baseline LDC's or MDC's are well understood. LDC's and MDC's can be considered along a biological integrity gradient that shows a negative relationship when plotted against human disturbance (Figure 1). The assumption is that MDC's would be present in native or undisturbed wetlands, whereas LDC's may constitute the closest semblance to native wetlands in a highly degraded watershed.

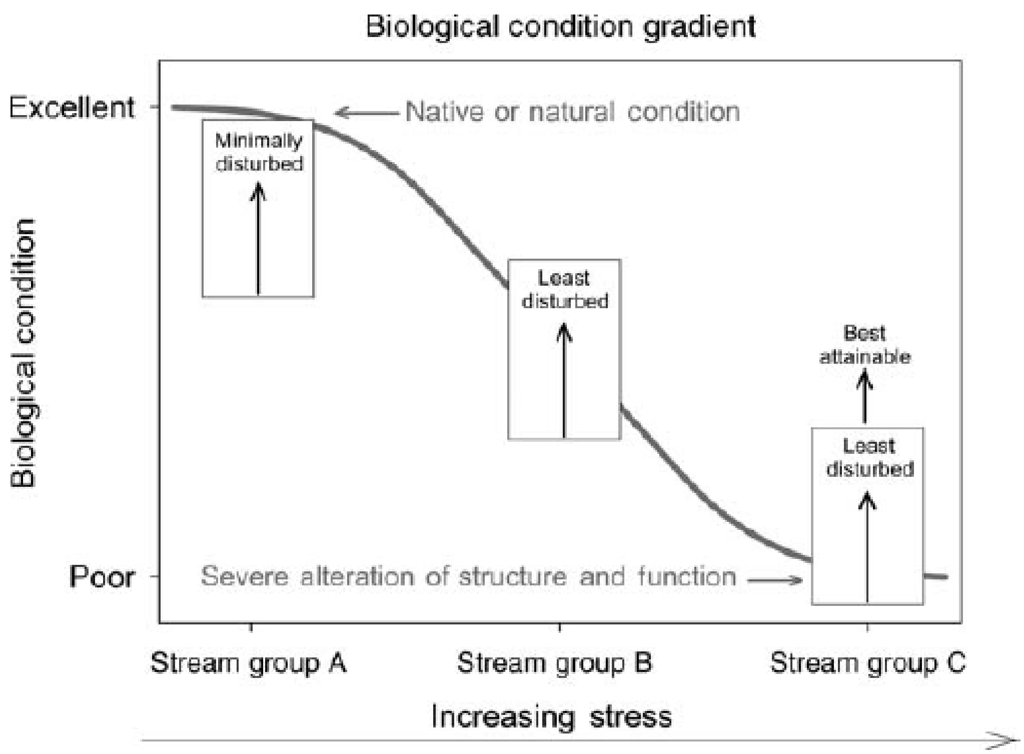

Figure 1: Minimally disturbed and least disturbed reference conditions shown as a conceptual relationship between human disturbance and biological condition. From Stoddard *et al*. 2006.

Determination of nutrient criteria should be based on examining nutrient levels in wetlands that are the least disturbed by anthropogenic activities. The CPCB is exploring how to quantify human disturbance by evaluating buffer zones around wetlands in three ecoregions of the Central Plains. Currently, water quality mitigation programs depend on the presence of narrow buffer zones that surround streams, rivers and wetlands. Yet, the question remains as to how much buffer area is appropriate to accurately gauge anthropogenic influence on wetland ecosystems.

IV. Methods

Site selection

To further populate the USEPA Region 7 wetland water quality database, the CPCB sampled 30 wetland sites located within major ecoregions (Omernik's Level 3) of USEPA Region 7 (Figure 2; Omernik 1995). The targeted ecoregions are the Central Great Plains (CGP), Central Irregular Plains (CIP), and Western Corn Belt Plains (WCB). The initial research effort focused on lacustrine wetlands at least 10 acres in size. These open water areas, which are generally associated with large, permanently flooded lakes and reservoirs, serve as ecotones between lakes and streams and act as corridors for terrestrial wildlife. They can also act as buffers that trap and filter agriculturally induced pollutants.

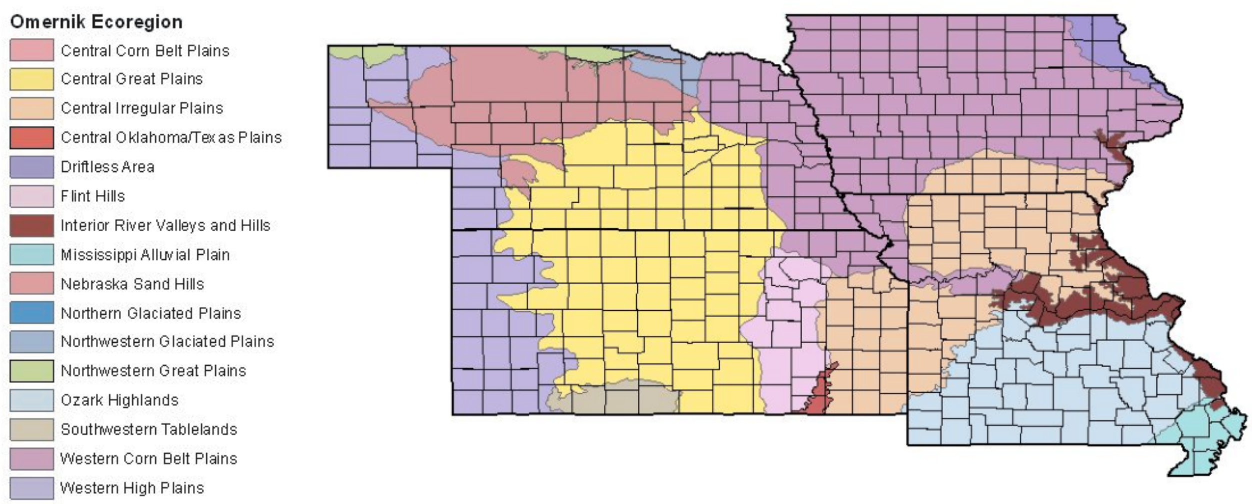

Figure 2: Omernik Level 3 ecoregions in USEPA Region 7. From Omernik 1995.

The CPCB first solicited nominations of reference sites from state agencies and university scientists who work in USEPA Region 7. To expand the number of potential reference sites, the CPCB used a method of site selection developed in a previous Missouri River Floodplain wetland study (Kriz *et al.* 2007), which identified candidate reference sites using GIS screening tools. The CPCB obtained a seamless National Wetlands Inventory (NWI 2004) dataset for USEPA Region 7 from the US Fish and Wildlife Service. Using ArcMap, lacustrine and non-woody palustrine wetlands were selected and separated from the seamless NWI data set. Of those lacustrine and non-woody palustrine wetlands, 21,863 wetlands equal to or greater than 10 acres were selected and saved to a separate file. A unique identifier was assigned to each these 21,863 wetlands and the file was converted from vector to raster data with a grid cell size of 30 m (the same grid cell size as the National Land Cover Dataset 1992). The 10 acre size criterion was necessary because: 1) it ensured a high likelihood of open water during sampling; 2) larger sites have a high probability of being correctly classified in the National Wetlands Inventory database; 3) larger sites generally support higher levels of native biodiversity, more wetland functions, and greater wildlife value; and 4) larger sites are likely to be in public ownership and therefore more likely to have been studied in the past.

The National Land Cover Dataset (30 m spatial resolution) was recoded to two classes: natural land cover and non-natural land cover. The recoded land cover data was imported to MatLab where the area of natural vegetation was calculated within a 250m buffer that surrounded but excluded the wetland. Stewardship layers (in vector format) were downloaded from the National GAP website for each state. Each vector layer was reprojected from its native projection to Alber's Equal Area (the same projection as the NWI and NLCD data sets). Unique identifiers were assigned to each public land name. The vector layers were converted to raster data with a grid cell size of 30 m. An intersect tool in ArcMap was used to generate a list of public lands and area proportion that intersect within each of the 21,863 wetlands. The centroid of each wetland polygon was extracted in ArcMap to provide latitude/longitude coordinates for the upcoming field campaign. This list was then narrowed to the three ecoregions of concern, and from each ecoregion 20 sites of highest reference buffer were selected for reconnaissance and possible sampling.

Sampling procedure

Each site was visited one time to obtain a "snap shot" or synoptic analysis of wetland water quality, especially nutrient conditions. A suite of *in situ* water quality measurements were obtained using a laboratory calibrated Horiba® U-10 Multiparameter Water Quality Checker. Specific measurements include pH, dissolved oxygen, turbidity, conductivity, air and water temperature, and salinity (by calculation). Secchi transparency data were also obtained. To account for spatial heterogeneity within each wetland site, multiple measurements were taken along a longitudinal transect that represented the longest distance across the open water area of the wetland and averaged for each site on standard data sheets.

CPCB field crews collected water samples at sites along the longitudinal transect and combined them into a composite sample. The number of samples collected at each site for the composite sample was determined by the size of the individual wetland and the number of available habitat types (e.g. open water, macrophyte beds) with a minimal sample size of three and a maximum number of five samples.

Sample analysis

Composite water samples were stored on ice and kept in the dark in coolers while in the field, and shipped to the Kansas Biological Survey Ecotoxicology Lab within 48 - 72 hours from time of collection. Analyses were conducted for total nitrogen, total phosphorus, soluble reactive phosphorus, nitrate, nitrite, and ammonia using Standard Methods (20^{th} ed.) or other EPA approved methods and a Lachat 8500 Flow Injection Analyzer. Chlorophyll *a* and pheophytin *a* samples were filtered and then extracted using an organic solvent (i.e. methanol). A fluorometer (Turner Model 10) was used to measure the sample response, which was converted to concentration (µg/L) using multiple point calibration. *In situ* and *ex situ* data obtained were carefully combined into a Microsoft Access database along with site information and reference buffer values in the same data entry format currently being employed to build the CPCB Region 7 wetland water quality database.

V. Results

Data acquisition

To assemble the USEPA Region 7 wetland database, water quality data from past CPCB wetland projects was first compiled. Unfortunately, it was difficult to obtain water quality data for wetlands from other agencies and research groups for comparison, thus this endeavor to sample wetlands to acquire more data. Initially, 60 sites from the three ecoregions were considered for this reference study using NWI and a reference buffer. From these, deep lakes, recently channelized tracts of land and degraded wetlands were excluded. At least 20 of the original 60 sites were lakes, although they were classified as wetlands by NWI. The 20 lake sites and an additional ten degraded wetlands sites were excluded from this study. Thus, ten wetlands per ecoregion were sampled for a total of 30 sites (Appendix A).

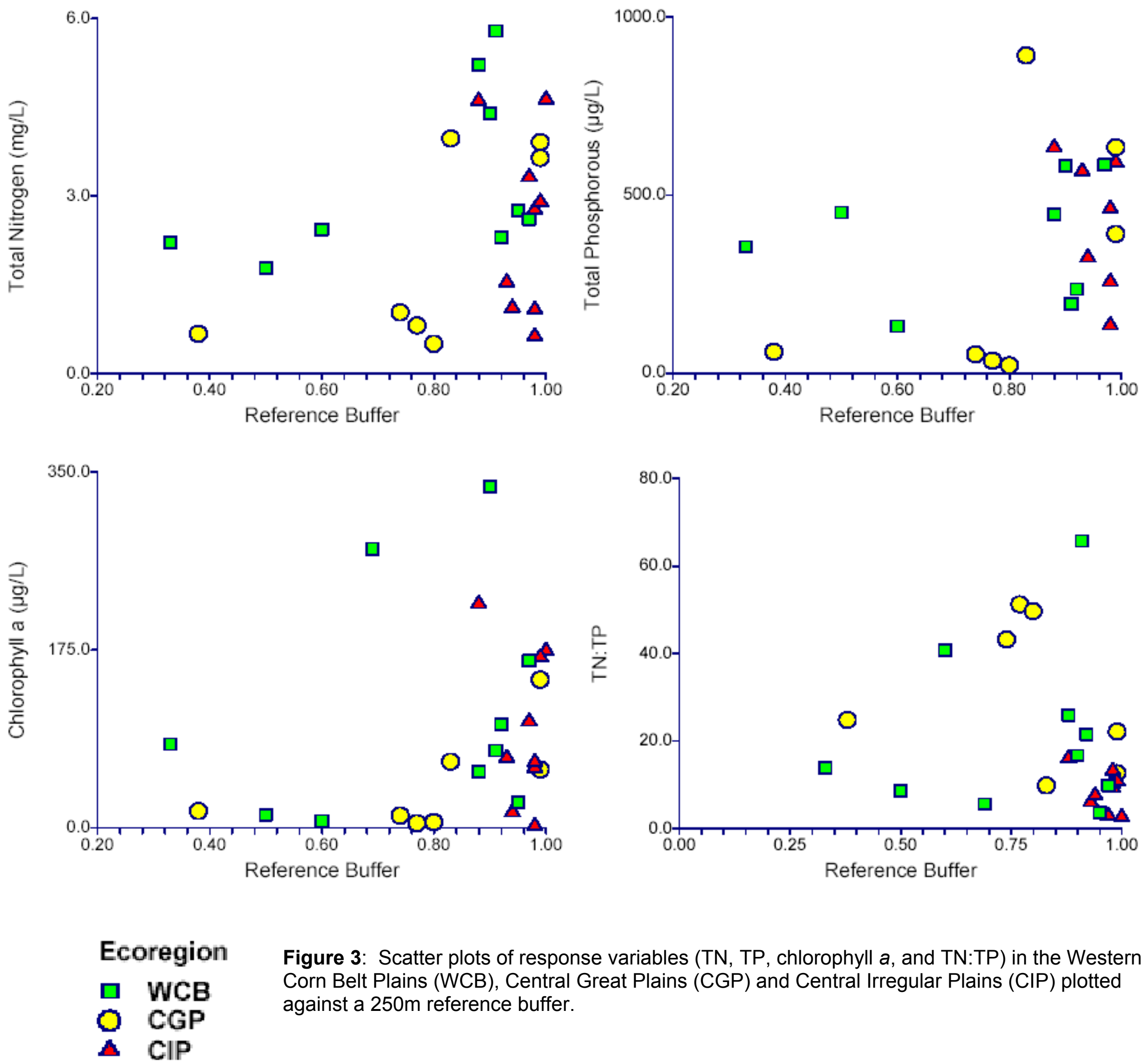

Figure 3: Scatter plots of response variables (TN, TP, chlorophyll *a*, and TN:TP) in the Western Corn Belt Plains (WCB), Central Great Plains (CGP) and Central Irregular Plains (CIP) plotted against a 250m reference buffer.

Reference buffer

Using the reference buffer as an independent variable produced no significant regression models and no clear relationships were observed between buffer quality and nutrients or sestonic chlorophyll (Figure 3). Typically, R^2 values for TN, TP, and chlorophyll *a* for specific ecoregions were < 0.50, of which half the models were >0.10. Reference buffers averaged 0.85 for all ecoregions (Figure 4). In some cases there were high nutrient concentrations from sites that scored > 0.95 on the reference classification (e.g. Squaw Creek National Wildlife Refuge). The reference buffer was < 0.5 for wetlands with low levels of human disturbance (e.g. Little Bean Marsh Conservation Area, Blevins 2004).

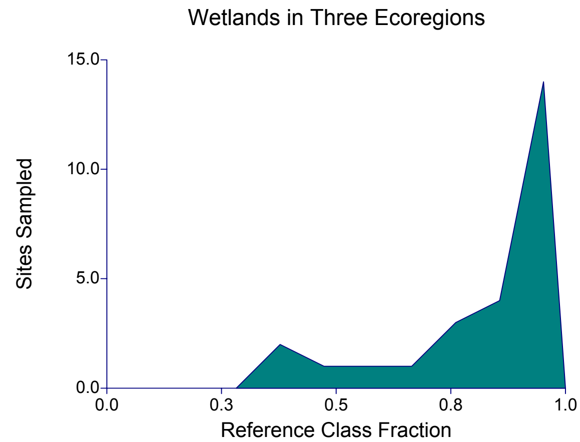

Figure 4: Distribution of reference buffer values given as a proportion of total buffer area.

Summary of regional water quality data

For all ecoregions, pH was measured at an average of 8.5 (±0.2) and dissolved oxygen at ~7 (±1) mg O_2/L (Appendix C). Wetlands allow large volumes of water to come into contact with soil for extended periods of time. An average pH at the higher range of natural waters (6.5–8.5) may be a result of extended contact with mineral soils containing limestone, which are common throughout USEPA Region 7. DO levels are high for these potential reference wetlands because measurements were taken in open-water at shallow depths during the daylight hours, when photosynthetic algae are predominant. This leaves an inconclusive result as to what is actually happening in the wetland soils and open-water depths (i.e. whether anoxic conditions are present and denitrification is taking place). Dissolved oxygen concentrations for wetland soils are normally close to zero as a result of inundation. This is because microbial activity in the soils generally uses up oxygen faster than it can be replenished from the atmosphere (Mitsch and Gosselink 2000, Gutnecht 2006). These DO concentrations and pH levels are sufficient to support most aquatic life, which is important for open-water segments of wetland ecosystems.

Table 1: Mean depth, Secchi depth, Turbidity and TN:TP grouped by ecoregion.

Ecoregion	Depth (m)	Secchi depth (m)	Turbidity (NTU)	TN:TP
CGP	0.583	0.476	125	28
CIP	0.273	0.127	398	9
WCB	0.254	0.135	331	23

Turbidity (p=0.030), Secchi depth (p=0.002), and molar TN:TP ratios (p=0.041) all showed statistically significant variance when grouped by ecoregion (GLM ANOVA; α=0.05). A Newman-Keuls Multiple Comparison Test run for all three response variables revealed significant differences between CGP and CIP regions in particular. Sample groups varied by ecoregion in mean depth, Secchi depth, turbidity and TN:TP ratios (Table 1).

Secchi depth measures light penetration through visibility and turbidity measures particulate absorbance in the water column. Therefore, high turbidity corresponds to shallow Secchi depth (Table 1). According to these data, light penetration is most limited in the CIP region, followed by the WCB region and the CGP region. The mean depth for wetlands sampled in the CGP region was nearly double the mean depth for the CIP and WCB. Therefore, wetlands sampled in the CGP region were on average much deeper, which may account for the observed increase in water clarity relative to the other regions. Deeper waters are less affected by factors that cause sediment resuspension (e.g. weather, wildlife) and may facilitate the settling of sediments and thereby reduce TP concentrations (Almendinger 1999).

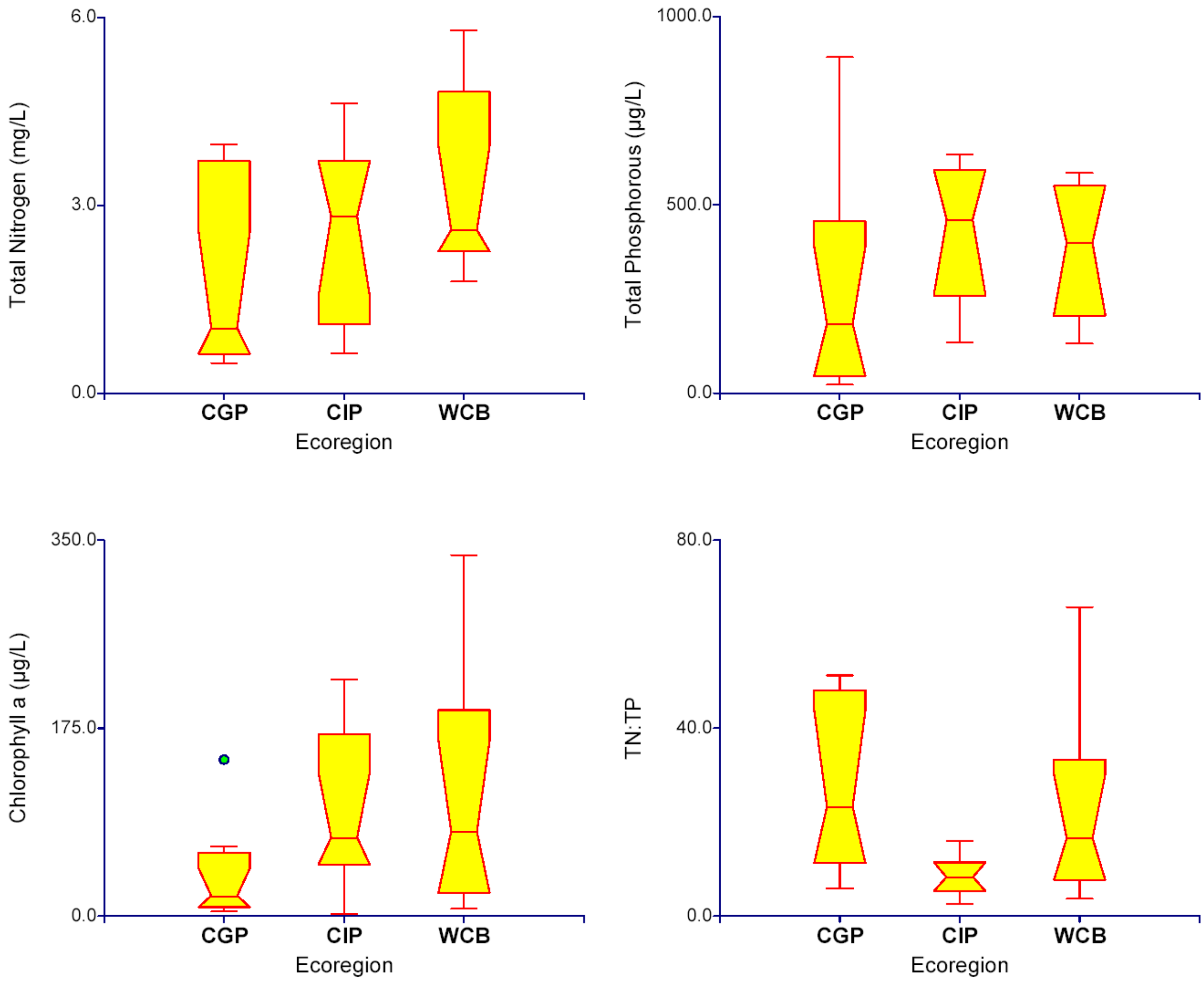

Figure 5: Notched box plots of TN, TP, chlorophyll *a*, and TN:TP grouped by ecoregion.

Turbidity and TN:TP ratios show an inverse relationship when grouped by mean values per ecoregion (Table 1). High turbidity corresponds to low TN:TP ratios, which implies an increase in total P relative to total N concentrations. Usually, high turbidity values indicate the presence of sediments and organisms in the water column as suspended solids. And, although there is no direct positive correlation between turbidity and TP, it is still reasonable to assume that high TP values (or at least low TN:TP ratios) indicate that a relatively substantial amount of sediment may be present. This is because most P containing compounds are adsorbed onto sediment particles whereas N containing compounds are more water-soluble and remain dissolved (especially NO_3).

Analyses of total nitrogen (TN), total phosphorous (TP) and chlorophyll *a* revealed no statistically significant difference in nutrient concentrations when reference wetlands were grouped by ecoregion (figure 5; Appendix B). ANOVA for TN ($p=0.062$) and chlorophyll *a* ($p=0.102$) suggests some degree of difference between nutrients in wetlands grouped by ecoregion. Dissolved nutrients showed no statistically significant differences ($p>0.20$). Wetlands in the WCB tended to have the highest TN concentrations overall, followed by those in the CIP and the CGP. Chlorophyll *a* concentrations exhibited a similar trend, which is consistent with known effects of increased nutrient concentrations on aquatic ecosystems. High chlorophyll *a* concentrations can imply algae are out-competing emergent vegetation for light and nutrients. These trends may also be consistent with known land-use practices and how different levels of human disturbance within each ecoregion can impact wetland ecosystems.

VI. Discussion

"Reference buffer"

Producing regression models depends heavily upon the method used to classify land-use buffers surrounding each wetland. The relationship between response variables (TN, TP, and sestonic chlorophyll) and land-use buffers is therefore a function of what factors went into calculating the buffers. With respect to the chosen response variables and the methods used to determine reference buffers, the results of this study are inconclusive. Generally, the biological integrity of aquatic ecosystems *is* related to surrounding land-use (Stoddard *et al.* 2006). Hence, a 250m buffer might be insufficient to gauge the level of human disturbance based on surrounding land-use because it underestimates the reach of anthropogenic impacts on wetland ecosystems. On the other hand, the 'critical' distance at which adjacent land-use degrades wetland water and sediment quality may extend 2000-4000m (Houlahan and Findlay 2004).

Reference condition

Omernik Level 3 ecoregions indicate common regional characteristics resulting from natural conditions. At the ecoregion scale, this classification scheme also reveals distinguishable degrees of human disturbance. This may be a broad result of pre-existent conditions in terms of what each region is most capable of producing (corn, wheat, pasture, timber, etc.) and also a result of large-scale alterations to pre-settlement hydrology. Although it may be common for wetlands to have high nutrient concentrations, eutrophication can favor invasive species and threaten biodiversity in surface waters (Smith *et al.* 1999).

High nutrient concentrations indicate the presence of runoff from anthropogenic activities, which are often accompanied by pesticides and metals that are toxic to wetland biota. Evaluating wetlands for water quality is problematic because wetlands influence regional water quality conditions by acting as sinks or sources of contaminants. Meanwhile, variables within wetlands affect the function of wetlands as a whole. Each of these variables is influenced by the ecoregion (what's already there) and adjacent land-use practices (human disturbance). The difficulty of describing reference conditions for wetlands lies in modeling these complex combinations of variables. Yet, because wetlands are biologically sensitive at such large spatial scales, they have the potential to become central components of federal, state and tribal water quality monitoring/improvement programs.

Future recommendations for sampling & data analysis

At the watershed scale, wetland nutrient criteria should be evaluated in the context of other available water quality data. Within each wetland, composite samples taken throughout the wetland may be inadequate. The potential for variability within a wetland might require multiple samples to be treated as individual data points because there may be significant differences in nutrient concentrations between inflow and outflow points as well as in more stagnant portions that are peripheral to main hydraulic flows.

The health of wetland microbial communities depends on soil characteristics (porosity, cation exchange capacity, etc.). Together, soil and hydrology determine whether contaminants will be sequestered or released (Mitsch and Gosselink 2000). Soil types can be used to reference permeability and subsurface flows. Grouping wetlands by ecoregion does attempt to characterize soils over large spatial scales, but relevant soil characteristics are site-specific and highly variable within ecoregions and over gradients of human disturbance.

Wetlands are sensitive to seasonal changes and rainfall events. So, it is difficult to use a "snap-shot" to determine criteria for how an individual wetland or group of similar wetlands in the same ecoregion *should* behave. Given a variety of circumstances that affect wetland health over a temporal gradient, monitoring efforts may have to be extended to visits throughout the growing season. These studies might also include analysis of surface water samples for alkalinity, total organic carbon (TOC) and total suspended solids (TSS) as well as biological responses measured by macroinvertebrates, vascular plants, arenchymous plants, algae taxa and amphibian populations.

VII. References

Almendinger, J. E. 1999. A method to prioritize and monitor wetland restoration for water-quality improvement. Wetlands Ecology and Management 6: 241-251.

Blevins, D. W. 2004. Hydrology and cycling of nitrogen and phosphorous in Little Bean Marsh: A remnant riparian wetland along the Missouri River in Platte County, Missouri, 1996-97. United States Geological Survey. Scientific Investigations Report 2004-5171.

Dahl, T. E., and C. E. Johnson. 1991. Status and Trends of Wetlands in the Conterminious United States mid-1970's to mid-1980's. US Fish and Wildlife Service, Washington DC.

Gutnecht, J. L., R.M. Goodman and T.C. Balser. 2006. Linking soil process and microbial ecology in freshwater wetland ecosystems. Plant Soil 289: 17-34.

Houlahan, J. E., and C. S. Findlay. 2004. Estimating the 'critical' distance at which adjacent land-use degrades wetland water and sediment quality. Landscape Ecology 19: 667-690.

Kriz, J., D. Huggins, C. Freeman, J. Kastens. 2007. Assessment of Floodplain Wetlands of the Lower Missouri River Using a Reference-based Study Approach. Open-file Report No. 142. Kansas Biological Survey, Lawrence, KS. 63 pp.

Mitsch, W. J., and J. G. Gosselink. 2000. *Wetlands 3rd ed.* John Wiley & Sons, Inc., New York.

National Wetlands Inventory – NWI. 2004. US Fish and Wildlife Service. www.fws.gov/nwi/

National Land Cover Dataset. 1992. USGS, USEPA. www.epa.gov/mrlc/nlcd.htm

Omernik, J. M. 1995. Ecoregions: a spatial framework for environmental management. In Biological Assessment and Criteria: Tools for Water Resources Planning and Decision Making. W.S. Davis and T.P. Simon (eds.). CRC Press, Florida.

Smith, V. H., G. D. Tilman, and J. C. Nekola. 1999. Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. Environmental Pollution 0: 1-18.

Stoddard, J. L., D.P. Larsen, C.P. Hawkins, R.K. Johnson and Richard H. Norris 2006. Setting expectations for the ecological condition of streams: the concept of reference condition. Ecological Applications 16: 1267-1276.

USEPA. 1998. National strategy for the development of regional nutrient criteria. USEPA pp. 45.

Appendix A: Reference Sites

CPCB ID	Reference Class Fraction	Site Name	State	County	Eco-region	Latitude	Longitude
7129	0.99	Big Salt Marsh	KS	Stafford	CGP	38.19	-98.54
7130	0.99	Little Salt Marsh	KS	Stafford	CGP	38.10	-98.50
7131		Texas Creek Lake	KS	Pratt	CGP	37.66	-98.98
7132	0.83	Slate Creek WMA	KS	Sumner	CGP	37.19	-97.21
7133	0.77	West Cozad WMA	NE	Dawson	CGP	40.86	-100.01
7134		East Willow Island WMA	NE	Dawson	CGP	40.86	-100.04
7135	0.74	Willow Island WMA	NE	Dawson	CGP	40.88	-100.07
7136	0.80	East Gothenburg WMA	NE	Dawson	CGP	40.89	-100.11
7137	0.38	Gothenburg Sand Pit	NE	Dawson	CGP	40.91	-100.16
7138		Blue Heron WMA	NE	Dawson	CGP	40.92	-100.18
7139	0.98	Douglas County SFL	KS	Douglas	CIP	38.79	-95.16
7140	0.93	Flint Hills WMA	KS	Coffey	CIP	38.22	-95.81
7141	0.98	Flint Hills WMA	KS	Coffey	CIP	38.26	-95.77
7142	0.97	Flint Hills WMA	KS	Coffey	CIP	38.30	-95.92
7143	0.94	Marais des Cygnes Unit A	KS	Linn	CIP	38.25	-94.70
7144	1.00	Shell-Osage CA	MO	Vernon	CIP	38.02	-94.06
7145		Baker-Haskell Wetland	KS	Douglas	CIP	38.92	-95.23
7146	0.98	Rathbun Lake	IA	Lucas	CIP	40.92	-93.20
7147	0.88	Marais des Cygnes Unit G	KS	Linn	CIP	38.29	-94.74
7148	0.99	Marais des Cygnes Unit F	KS	Linn	CIP	38.23	-94.70
7149	0.69	Arbor Lake	NE	Lancaster	WCB	40.90	-96.68
7150	0.88	Union Slough NWR	IA	Kossuth	WCB	43.24	-94.16
7151	0.91	Union Slough NWR	IA	Kossuth	WCB	43.29	-94.11
7152	0.95	Squaw Creek NWR	MO	Holt	WCB	40.06	-95.25
7153	0.97	Red Rock Lake	IA	Marion	WCB	41.36	-93.12
7154	0.90	Black Hawk Marsh	IA	Sac	WCB	42.28	-95.05
7155	0.92	Desoto NWR	IA	Harrison	WCB	41.52	-96.04
7156	0.60	Wilson Island SRA	IA	Pottawattamie	WCB	41.48	-96.00
7157	0.33	Bean Lake	MO	Platte	WCB	39.49	-95.02
7128	0.50	Little Bean Marsh CA	MO	Platte	WCB	39.50	-95.03

Appendix B: Summary of Nutrient/Chlorophyll *a* Data

Variable	Ecoregion	Mean	Range
Total P	CGP	284 µg/L	22—894 µg/L
	CIP	1047 µg/L	135—3825 µg/L
	WCB	923 µg/L	132—4600 µg/L
PO_4	CGP	111 µg/L	9—608 µg/L
	CIP	85 µg/L	33—209 µg/L
	WCB	402 µg/L	19—2810 µg/L
Total N	CGP	1.83 mg/L	0.48—3.97 mg/L
	CIP	2.60 mg/L	0.63—4.63 mg/L
	WCB	4.12 mg/L	1.78—11.7 mg/L
NO_3	CGP	0.18 mg/L	0.01—1.40 mg/L
	CIP	0.06 mg/L	0.03—0.23 mg/L
	WCB	0.68 mg/L	0.01—3.79 mg/L
NH_3	CGP	88 µg/L	3—454 µg/L
	CIP	77 µg/L	13—321 µg/L
	WCB	81 µg/L	9—267 µg/L
Chlorophyll a	CGP	36 µg/L	4—146 µg/L
	CIP	96 µg/L	2—220 µg/L
	WCB	114 µg/L	7—336 µg/L
Pheophytin a	CGP	11 µg/L	1—26 µg/L
	CIP	33 µg/L	3—70 µg/L
	WCB	34 µg/L	6—89 µg/L

Appendix C: In-Situ Measurements

Variable	Ecoregion	Mean	Range
pH	CGP	8.57	7.57—10.6
	CIP	8.25	7.35—9.17
	WCB	8.61	6.91—10.4
Conductivity	CGP	0.48 S/cm	0.12—0.81 S/cm
	CIP	0.37 S/cm	0.29—0.49 S/cm
	WCB	0.50 S/cm	0.31—0.76 S/cm
Dissolved Oxygen	CGP	8.12 mg/L	2.89—14.8 mg/L
	CIP	6.09 mg/L	1.25—14.1 mg/L
	WCB	8.03 mg/L	1.37—14.9 mg/L
Turbidity	CGP	125 NTU	20—436 NTU
	CIP	398 NTU	20—689 NTU
	WCB	331 NTU	30—866 NTU
Secchi Depth	CGP	0.476 m	0.08—1.01 m
	CIP	0.127 m	0.04—0.39 m
	WCB	0.135 m	0.05—0.29 m