K.1: Looking Ahead Toward Future Management of Shallow Lakes (Organizers: Nicole Hansel-Welch, Mark Hanson)

K.1.1: Anteau

A Watershed Approach for Conservation of Prairie-Pothole Wetlands

Michael J. Anteau[1]*, Mark T. Wiltermuth[1], Lisa A. McCauley[2,3], Max Post van der Burg[1]

[1] U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA, manteau@usgs.gov
[2] South Dakota State University/U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA
[3] Present Address: Department of Forest and Wildlife Ecology, University of Wisconsin–Madison, Madison, Wisconsin, USA

Wetlands of the Prairie Pothole Region directly support production of 50-80% of North American ducks and provide critical spring stopover habitat for ducks bound for arctic and boreal breeding areas. These wetlands face a myriad of threats from interacting responses to changes in climate and land-use practices. Effective conservation of these wetlands requires considering connections of wetlands with their surrounding upland habitats, but may also require consideration of hydrologic connections among wetlands. For example, consolidation drainage is a practice of draining smaller and more temporarily ponded wetlands into larger ones in effort to increase tillable acreage for agriculture. We review impacts of consolidation drainage on ecological communities, wetland size, and water-level dynamics based on studies that examined responses of wetlands to climate variability and land use changes from 1937 to present. Our results suggest that consolidation drainage has caused marked increases in water levels and is essentially decoupling water-level dynamics from climate variation. Moreover, past consolidation drainage appears to progressively increase water levels through successive wetting and drying phases. Based on our results, flood abatement is an ecosystem service that is under threat in the current land-use paradigm. Furthermore, ecological communities in larger prairie wetlands are shifting towards those supported by permanent lakes. These results call to question whether current tools used for conservation of wetlands are adequate to protect ecosystem services provided by remaining wetlands. Moreover, they suggest that considering hydrologically defined wetland complexes (watersheds) when making conservation decisions would lead to more effective conservation, especially for larger prairie wetlands. Lastly, considering other ecological services, such as flood control, in addition to waterfowl conservation would allow the public and policy makers to make more informed cost/benefit decisions about wetland conservation; this could lead to strengthening of these programs which would benefit waterfowl.

K.1.2: Vitense^

Predicting Total Phosphorus and Assessing State Transition Risk in Shallow Lakes

Kelsey Vitense[1]*^, Nicole Hansel-Welch[2], Mark A. Hanson[3], Brian R. Herwig[4], Kyle D. Zimmer[5], John Fieberg[1]

[1] Department of Fisheries, Wildlife, and Conservation Biology, University of Minnesota, St. Paul, Minnesota, 55108, USA, viten003@umn.edu
[2] Shallow Lakes Program, Minnesota DNR, Brainerd, Minnesota, 56401, USA
[3] Wetland Wildlife Populations & Research Group, Minnesota DNR, Bemidji, Minnesota, 56601, USA
[4] Fisheries Research Unit, Minnesota DNR, Bemidji, Minnesota, 56601, USA
[5] Biology Department, University of St. Thomas, Saint Paul, Minnesota, 55105, USA

Shallow lakes provide critical habitat for migratory waterfowl and aquatic invertebrates, but they can become degraded due to excess nutrient input from intensive agriculture and because their interconnectedness allows exchange of nutrients, chemicals, and aquatic invasive species. Shallow lakes can quickly transition between two alternative stable states: a clear state dominated by submerged aquatic vegetation, which provides an important food source for waterfowl, and a turbid state dominated by phytoplankton. Theoretical models suggest that critical nutrient thresholds differentiate highly resilient clear lakes, lakes that may switch between clear and turbid states due to system perturbations (e.g., weather events, zooplankton community changes), and highly resilient turbid lakes. Managers need tools to help identify these critical nutrient levels, to determine where lakes sit in relation to these thresholds, and to clarify state-dependent relationships between nutrients and key system variables. Such tools would help managers assess the relative risk of lake transitions (from turbid to clear and vice versa) and subsequently, to identify and prioritize appropriate management actions. We developed an integrated framework, using Bayesian regression models with lake states and TP thresholds treated as latent variables, to (1) identify critical Total Phosphorus (TP) thresholds, (2) classify attracting lake states, and (3) estimate steady-state relationships between TP and chlorophyll a. We evaluated the method using data simulated from a stochastic differential equation model approximating shallow lake dynamics, finding that sample size and degree of system perturbation are limiting factors for the successful estimation of system parameters. We also applied the modeling framework to data from a multi-year study involving 118 shallow lakes in Minnesota. Our approach resulted in similar lake classifications as k-means clustering, but with the advantage that uncertainty in nutrient thresholds and lake states is properly accounted for when estimating state-dependent relationships. Lastly, we used linear mixed-effects models to predict TP levels from watershed and in-lake features. We found that percent woodland cover in the upstream watershed, lake depth, and benthivore abundance can be used to predict TP levels in Minnesota shallow lakes, and we discuss the possible influence of soil parent materials on predicted lake phosphorus levels. Together, these analyses provide a foundation for a decision support tool for shallow lake management, and future work will focus on translating our results into a simple tool to assess the relative state transition risk of shallow lakes.

K.1.3: Wiltermuth

Landscape-scale Evaluation of the "Alternative Stable State" Hypothesis Within Large Northern Prairie Wetlands in Context of Waterbird Conservation

Mark T. Wiltermuth[1]*, Michael J. Anteau[1]

[1] U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, ND, 58401, USA, mwiltermuth@usgs.gov

The "alternative stable states" hypothesis predicts two general alternative states in prairie pothole wetlands, one where primary productivity is dominated by phytoplankton and the other by submerged aquatic vegetation (SAV). Wetlands with SAV-dominated communities provide better habitat for most waterfowl species because they have food webs with higher densities of invertebrate prey than those of phytoplankton-dominated wetlands. If landscape conditions can be used to predict where or when these alternative states manifest, this information could help managers prioritize conservation efforts. We conducted a landscape-scale evaluation of the alternative stable state hypothesis by examining the distribution of remotely-sensed chlorophyll-a (chl-a) concentrations—a proxy for phytoplankton concentrations—during 2011 within 978 randomly selected semipermanently and permanently ponded wetlands in the Prairie Pothole Region of North Dakota. Under this hypothesis we predicted that two alternative states should be observable as a bimodal distribution in a large sample of wetlands. Additionally, we evaluated how wetland chl-a concentrations were related to consolidation drainage, upland land use, and fish abundance. The distribution of wetland mean chl-a concentrations was unimodal, skewed right, and lacked evidence of discontinuity. Chl-a concentration was positively correlated with the percent of the wetland basin filled by the pond ($\hat{\beta}$=0.009 ±0.002 SE) and negatively correlated with the percent of surrounding upland that was grassland ($\hat{\beta}$=-0.642 ±0.199 SE). Our evaluation did not support predictions of the alternative stable state hypothesis. Rather, our data suggest that these wetlands behave in a continuum of trophic structure, and the trophic structure is influenced by a continuum of perturbations. Accordingly, for the purposes of improving conservation planning, our findings suggest that a continuous model would be more useful than characterizing wetlands within the framework of alternative stable states. However, a longitudinal study is needed to examine if individual wetlands may have varying manifestations of alternative states.

K.1.4: Hanson

Rehabilitating Turbid Shallow Lakes: Harder Than We Think?

Mark A. Hanson[1]*, Brian R. Herwig[2], Kyle D. Zimmer[3], Nicole Hansel-Welch[4], Kelsey Vitense[5], John Fieberg[5]

[1] Wetland Wildlife Populations & Research Group, Minnesota DNR, Bemidji, Minnesota, 56601, USA, mark.alan.hanson@state.mn.us
[2] Fisheries Research Unit, Minnesota DNR, Bemidji, Minnesota, 56601, USA
[3] Biology Department, University of St. Thomas, Saint Paul, Minnesota, 55105, USA
[4] Shallow Lakes Program, Minnesota DNR, Brainerd, Minnesota, 56401, USA
[5] Department of Fisheries, Wildlife and Conservation Biology, University of Minnesota, 2003 Upper Buford Circle, Suite 135, Saint Paul, MN, 55108, USA

Shallow lakes are critical for waterfowl and other wetland-dependent species, but many lakes are characterized by turbid conditions with poor water quality, sparse communities of plants and invertebrates, and limited habitat suitability. Lake managers must choose whether to focus rehabilitation on watershed improvements or on in-lake projects, and lake responses are frequently disappointing. We reviewed results of recent lake management efforts and compared these with patterns from studies that explored links between shallow lake communities and properties of adjacent watersheds. Whole-lake projects across Europe and North America indicate that reducing nutrient loading sometimes favors improvements, but that lakes often respond slowly to watershed-scale approaches and responses may not be evident for decades. Alternative strategies focusing on in-lake measures such as drawdowns or fish removals often stimulate rapid improvements, but benefits rarely persist beyond 5-10 years. Comparisons among shallow lakes highlight the fact that integrating features such as phytoplankton biomass and invertebrate community patterns are often only weakly related to land cover or other characteristics of watersheds. This seems surprising, but consistent with predictions of conceptual models for lake dynamics, and with empirical data showing resilience of both clear- and turbid-states. We suggest that effective shallow lake management in modern landscapes should be based on a tiered approach. Strictest protection should be applied to watersheds containing resilient clear-water shallow lakes. Other areas will benefit from restoration of cover types and other natural features in lake watersheds, but may also require perpetual in-lake intervention if projects are to achieve and maintain favorable conditions within decadal timeframes. Finally, extensive nutrient loading, hydrologic changes, and other factors have thoroughly exhausted ecological resilience in some turbid shallow lakes. Here, lakes may be so severely altered that improvements will be possible only in response to ongoing, intensive in-lake management such as biomanipulation, drawdown, and sediment removal.

K.1.5: Zimmer

Is Island Biogeography a Good Model for Biodiversity in Shallow Lakes?

Kyle D. Zimmer[1]*, Luke E. Nolby[1], Mark A. Hanson[2], Brian R. Herwig[3], William O. Hobbs[4], Joy M. Ramstack Hobbs[4], and Kevin M. Theissen[5]

[1] Biology Department, University of St. Thomas, Saint Paul, Minnesota, 55105, USA, kdzimmer@stthomas.edu
[2] Wetland Wildlife Populations & Research Group, Minnesota DNR, Bemidji, Minnesota, 56601, USA
[3] Fisheries Research Unit, Minnesota DNR, Bemidji, Minnesota, 56601, USA
[4] St. Croix Watershed Research Station, Marine on St. Croix, MN 55047, USA
[5] Geology Department, University of St. Thomas, Saint Paul, Minnesota, 55105,USA

The island biogeography model (IBM) predicts biodiversity will be maximized in large habitats close to or connected to other habitats, and this concept has become a core principal in conservation biology. However, few studies have tested the applicability of the IBM for shallow lakes, and one weakness is the IBM does not account for effects of biotic interactions on biodiversity. Biotic interactions involving fish are intense in shallow lakes, and benthivorous and planktivorous fish (hereafter fish) can induce shifts to turbid-water states which may reduce biodiversity. We used a two-prong approach to assess whether patterns of biodiversity in shallow lakes follow the IBM. First, we examined relationships among lake size, lake connectivity, fish biomass, turbid versus clear states, and species diversity of fish, aquatic invertebrates, and submerged aquatic plants. Second, we used sediment cores from lakes as case studies to explore long-term stability of lake communities relative to lake isolation and fish communities. Results showed fish biodiversity and biomass were highest in large, connected lakes, and these systems were more likely to be in turbid states. In contrast, biodiversity of invertebrates and aquatic plants showed no relationship with lake size and connectivity, likely due to negative effects of high fish abundance in large, connected lakes. Sediment cores indicated that small, more isolated lakes with low fish biomass have remained in stable clear-water states with high diversity over the last 150 years, while larger lakes with high fish biomass or with known human perturbations have shifted to stable turbid states with lower diversity. Our results indicate IBM does not predict biodiversity patterns of plants and invertebrates in shallow lakes very well, and that small, isolated shallow lakes are important reservoirs of biodiversity on the landscape. Management efforts should strive to protect these important ecosystems at the landscape scale.

K.1.6: Hansel-Welch

Management or Restoration - What Are We Doing with Shallow Lakes in Minnesota?

Nicole Hansel-Welch[1]*, Tammy Baden[1], Todd Call[1], Jenny DuBay[1], Ann Geisen[1], Steve Kittelson[1], Melissa Thompson[1]

1 Shallow Lakes Program, Minnesota DNR, Brainerd, Minnesota, USA 56401, nicole.hansel-welch@state.mn.us

The Department of Natural Resources in Minnesota has been working to increase waterfowl habitat in select shallow lakes for decades through water level drawdowns, chemical treatments and other means. Early attempts to improve habitat on these lakes were often referred to as “restorations.” Managers and the public often viewed these undertakings as one-time events and expectations were subsequent improvements would last indefinitely. However, many of the managed lakes have a long legacy of impacts from nutrient loading, changes in hydrology, decreased frequency of fish winterkill and other landscape alterations. Through on-going research on shallow lakes and wetlands in the state, more information is becoming available to managers so informed decisions can be made on where management efforts are more likely to have longer lasting results. In addition to research, monitoring efforts have increased with over 1600 point-intercept vegetation surveys conducted on ~1100 lakes across Minnesota since 2002. Before and after monitoring data of shallow lakes where various management tools have been applied and across different landscape settings illustrate the complexities of managing these systems. Examples will highlight the technical aspects, difficulties and successes of management aimed at improving waterfowl habitat and water quality. Efforts have also focused on communicating the need for continued monitoring and management intervention on impacted lakes. Protection of shallow lakes that remain in good condition is a priority as it seems that true “restoration” of lakes once they are impaired is a goal that may not be realistic.

L.1: Looking Ahead Toward Future Management of Shallow Lakes (Organizers: Nicole Hansel-Welch, Mark Hanson)

L.1.1: Hagy

Evolution of Backwater Lakes along the Illinois River with Waterfowl as a Sentinel of Change

Heath M. Hagy[1]*, Aaron P. Yetter[1], Michelle M. Horath[1], Joshua Stafford[2]

[1] Illinois Natural History Survey, Bellrose Waterfowl Research Center and Forbes Biological Station, Prairie Research Institute at the University of Illinois, Havana, IL 62644 , USA, hhagy@illinois.edu2
[2] U.S. Geological Survey, South Dakota Cooperative Fish and Wildlife Research Unit, Department of Natural Resource Management, South Dakota State University, Brookings, SD 57007, USA

Backwater lakes within the Illinois River Valley (IRV) historically provided habitat for >20% of the Mississippi Flyway's mallard (*Anas platyrhynchos*) population during autumn, but use has declined more than 80% since the 1950s. Similarly and more dramatically, lesser scaup (*Ayathya affinis*) use has declined more than 90% since the 1970s. Despite declines in species historically common and widespread loss of aquatic vegetation communities in the region, use and peak abundances of several other species of waterfowl have dramatically increased within the last decade. For example, total use days for ducks (29,681,598 use days) during autumn 2013 were the highest recorded since 1985 in the IRV. Similarly, peak abundances of northern pintail (*Anas acuta*), American green-winged teal (*A. carolinensis*), gadwall (*A. strepera*), and northern shoveler (*A. clypeata*) were the greatest recorded since initiation of aerial surveys in 1948. Even diving ducks have increased in recent years. We estimated a peak abundance of 118,830 diving ducks along the Illinois River in 2013, which was 258% above the 5-year average. While species traditionally common, such as lesser scaup, have not recovered to historical use levels, other species have apparently responded to recent habitat restoration in the region (e.g., ring-necked duck [*Aythya collaris*] and ruddy duck [*Oxyura jamaicensis*; highest peak abundance ever recorded in 2013]). Waterfowl abundances in the IRV have increased concurrent with restoration of several backwater lakes in the region which provide a diversity of aquatic vegetation communities previously eliminated from the region. For example, Emiquon Preserve is a restored wetland complex that accounts for more than 30% of the total waterbird use days in the IRV. We will describe backwater lake restoration strategies used, illustrate how a few signature restoration projects can change patterns of waterfowl use for an entire region, and recommend indicators to assess restoration success and trajectory.

L.1.2: Evelsizer

Ten Years of Shallow Lake Renovations: Applying What's Been Learned to Future Management

Vincent D. Evelsizer[1]*

[1] Iowa Departement of Natural Resources, 1203 North Shore Drive, Clear Lake, Iowa 50428, USA, vince.evelsizer@dnr.iowa.gov

Does the outcome match the expectations? Shallow lake management is unique, fun, and at times really frustrating – much like a puzzle! Just when we think we have somewhat of a handle on them, something arises and we may not fully understand 'why'. Beginning in 2006, dedicated effort and funds were devoted to renovate degraded shallow lakes in Iowa. Since then, several shallow lakes and large marshes have undergone extensive measures in an attempt to improve their ecological health for wildlife, water quality, and overall recreational enjoyment. While many of these systems share similar characteristics, each one is also unique in how they've responded to active management scenarios. A wide variety of factors such as hydrology, watershed land use, and size can play into how a shallow lake system responds initially and then longer term to a renovation. In addition to those physical factors, water quality efforts and community support from local citizens has also been an important factor in managing a shallow lake renovation successfully. During these ten years lessons, observations, and data have been gathered. Our objective here is to share how larger projects such as shallow lake renovations that benefit waterfowl often means linking together and partnering with water quality interests, community citizens, fisheries managers and other partners to achieve an outcome that meets the expectations - because it is a puzzle, but often very rewarding!

L.1.3: Wrubleski

Restoring a Large Freshwater Coastal Wetland on the Prairies; Delta Marsh, Manitoba

Dale A. Wrubleski[1]*

[1] Institute for Wetland and Waterfowl Research, Ducks Unlimited Canada, P.O. Box 1160, Stonewall, Manitoba, R0C 2Z0, Canada

For over one hundred years, Delta Marsh has been an important waterfowl hunting area. However, similar to other shallow freshwater ecosystems, it is suffering from the effects of an artificially regulated water regime, eutrophication and invasive species, all of which have contributed to declining waterfowl numbers and hunting opportunities. A multi-agency partnership has embarked on a ten-year restoration project to address the factors contributing to the deterioration of the marsh. Complicating restoration efforts is the fact that Delta Marsh cannot be managed in isolation. It is intimately connected to Lake Manitoba with which it exchanges water, nutrients and fish. The first phase of the restoration project consists of management efforts to reduce the impacts of an invasive fish species, Common Carp (Cyprinus carpio), that overwinters in the lake. Experimental field studies have already demonstrated that Carp are responsible for several changes observed in the marsh, including increased turbidity, phytoplankton blooms and loss of submersed vegetation. Carp exclusion structures have been constructed on the channels connecting the marsh to Lake Manitoba, and are designed and operated to reduce Carp access to the marsh while minimizing impacts on native fish species that also use the marsh for feeding, spawning, and rearing. A five-year monitoring program will adjust management efforts as required to favor improvements and balance needs of the native fish community. Initial monitoring results are showing improved water clarity and increased abundance of submersed vegetation. Additional scientific investigations of marsh hydrology, hydraulics, and nutrient inputs are now underway. These investigations will inform additional management actions to further improve the quality of this important wetland.

L.1.4: Hutchins

Time-lapse Photography: Documenting Wetland Restoration and Shallow Lake Management in Minnesota

Emily J. Hutchins[1]*, John E. Maile[2]

[1] Section of Wildlife, Minnesota Department of Natural Resources, 204 S. Main St., Crookston, MN 56716, USA, emily.hutchins@state.mn.us
[2] Minnesota Department of Natural Resources, 10 – 1st Street SW, Glenwood, MN 56334, USA

A continuing challenge in planning and implementation of wetland management is for professionals as well as the general public to gain a comfort level with the high degree of variability common to wetlands with different geomorphic and hydrological settings. For the inexperienced, it is difficult to gain an appreciation for this variability without direct exposure to these conditions over time. In Minnesota, the use of time-lapse photography demonstrates one opportunity to speed the process of understanding wetland variability. The goal of this project was to establish time-lapse cameras at a variety of wetland restoration and shallow lake management projects occurring throughout Minnesota to serve as a new information and education tool. Additionally, the project serves as an assessment tool for wetland managers and researchers. Time-lapse photography is a technique used to document changes that occur slowly or over long periods of time. Photos from multiple years can be compressed into a short video presentation. This method enables managers to document shallow lake management and wetland restoration in an innovative way the public can see and understand. Time-lapse cameras record activities at project sites before, during, and after management or restoration, and the resulting video quickly shows the hydrologic and vegetative changes that occur over a period of two to three years. Seven sites portraying a range of wetland types and management activities were selected from across the state, including a wetland restoration on private land, management of a shallow lake through water-level drawdown, and hybrid cattail management on public land. Cameras were installed in 2013 and set to take one photo per hour of daylight. Photos were downloaded every 2-3 months. Some cameras will remain installed for up to 3 years. A sample video will be shown, and the completed videos will be posted to the Minnesota Department of Natural Resources website for public viewing.

L.1.5: Anthony^

Seed-Bank and Invertebrate Potential of Moist-Soil Wetlands in the Southwest

Ryan S. Anthony[1]*^, Ryan O'Shaugnessy[1], Ryan S. Luna[1], Daniel P. Collins[2]

[1] Borderlands Research Institute, Sul Ross State University- Alpine, Alpine, TX, 79830, USA, ryan.s.anthony@gmail.com
[2] Migratory Bird Office, U.S. Fish and Wildlife Service, Region 2, Albuquerque, NM, 87102, USA

Moist-soil wetlands across the U.S. provide food and habitat resources to waterfowl, shorebirds and other wildlife. However, there are few moist-soil wetlands in the arid Southwest U.S. which makes them invaluable for the conservation of migratory birds and other wetland dependent species. Waterfowl and shorebirds consume seeds and invertebrates to meet the nutritional needs of migration, molting and to a lesser extent, breeding while in the Southwest. Knowing how to optimize seed and invertebrate production in arid moist-soil wetlands is critical to wetland managers in arid landscapes. Our primary goal was to manipulate and test conditions in the greenhouse and on moist-soil wetlands that will yield the greatest biomass of invertebrates and seeds for waterfowl and shorebirds. Our secondary goal is to provide wetland managers and landowners at Sandia Wetland, Texas, with a chronology of bird use and a strategy for timing drawdowns and inundations on the moist-soil wetlands. We explored the use of e-bird.net, a website for birders to record their findings, in developing a preliminary chronology for shorebird and waterfowl at Sandia Wetlands, Texas. Data collected from the website indicates the presence of ducks and geese at the site from August-April with a peak in November. Shorebirds are present throughout the year but display a bimodal peak in August and April. Invertebrate production was compared across inundation levels by collecting water column and benthic core samples from within preexisting moist-soil wetlands within the Chihuahuan Desert. We assessed the effects of moist and flooded treatments on germination rates of wetland dependent plant species by experimentally maintaining soil samples under moist (i.e. no water above the surface of the soil) and waterlogged conditions (i.e. <4 cm water above the surface of the soil) in planting trays housed within a greenhouse. Soil samples for the seed bank germination experiment were attained from benthic core samples collected from three arid moist-soil wetland sites within the Chihuahuan Desert Biome of Texas and New Mexico. 204 benthic samples were collected for seed bank analysis and were divided in two equal samples. Upon germination and identification seedlings were removed at 30 day intervals, and any unidentified seedlings were planted in potting soil until identified. Seedlings were categorized as desirable/undesirable. Desirable species are those that provide energy or other nutrients useful for wintering and migrating waterfowl. Non-desirable species produce a lower quantity and quality of seeds. We took 2 soil core samples for invertebrate biomass analysis and recorded bird chronology and use twice a month throughout the length of inundation. Knowledge of migratory shorebird and waterfowl chronology is useful for timing the peak of migration within the inundation period of wetland impoundments. Our research will assist arid wetland biologists to make informed decisions for maximizing food resources for waterfowl and shorebirds in managed and unmanaged wetlands throughout the desert Southwest region of the United States and will specifically and directly impact wetlands at our study sites by providing a thorough management plan.

L.1.6: Hansel-Welch, Hanson

Discussion