SUSTAINABLE WETLAND HABITAT: RECLAMATION TARGETS, DESIGN CRITERIA AND WETLAND POLICY IMPLEMENTATION.

ANNUAL REPORT FOR ALBERTA INNOVATES – ENERGY AND ENVIRONMENT SOLUTIONS, 15 APRIL 2015.

PIs:

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Project Duration: 30 April 2013 – 30 April 2016, 3 years.

PROJECT SCOPE AND SUMMARY

Site specific and landscape scale tools are required to effectively implement the new provincial wetland policy and for the conservation, reclamation and restoration of wetland ecosystems in Alberta. We address an existing and significant knowledge and methodological gap in the establishment of design guidelines for the most frequent wetland types in Alberta; temporary, seasonal, and semi-permanent marshes. The funded components of the project include the development of 1) site-level wetland evaluation tools and 2) the characterization of natural wetland-rich landscapes. Component 1 is led by Dr. Rebecca Rooney and Component 2 is led by Dr. Derek Robinson. Dr. Suzanne Bayley is consulting and providing a base of operations for field work. The project involves the training of at least eight highly qualified personnel: seven graduate students and a technician. Further training opportunities will target undergraduate thesis and co-op program students. Outcomes will include a suite of wetland evaluation tools targeting non-permanent marshes in Alberta's Parkland and Grassland Natural Regions, an improved understanding of the ecological impacts of agricultural activity on wetland biota and physicochemical variables, an evaluation of existing wetland restoration projects in the White Zone, and the characterization of wetland rich landscapes, including both spatial and aspatial characteristics. Results will inform wetland reclamation and wetland policy implementation. We will ensure transfer of these outcomes through active engagement with consultants and government agents.

2014 RESULTS

OVERVIEW

We selected three sub-watersheds in each of the Parkland and Grassland natural regions that were comprised of glaciolacustrine and morainal landforms and that avoided borders with neighboring natural regions or political boundaries. Within each sub-watershed, we used the merged Alberta wetland inventory and geospatial data on land use to identify temporary, seasonal, and semi-permanent marshes spanning a gradient in the intensity of agricultural activity. Sites were selected at random from this pool of candidates to ensure that results were representative of all non-permanent marshes in the two natural regions. In total, we sampled 48 wetlands, eight per sub-watershed (Fig. A1; all figures and tables are in the appendix). We collected a variety of abiotic and biological information from each marsh over five visits from May to September.

CHEMICAL

Water samples were collected in May for analysis of total suspended solids, nutrients (DOC, Total N, Total P, Mg^{2+}, Ca^{2+}, K^{+}), dominant ions (SO_4^{2-}, Cl^{-}, Na^{+}) and a suite of more than 250 pesticides (2,4-D, glyphosate, neonics, etc.). In addition, *in situ* measures of *in vivo* chlorophyll-a, turbidity, conductivity, pH, and dissolved oxygen were taken on each visit. Sediment core samples were collected in August and analysed for macronutrients (N, P, Mg, K, S), micronutrients (Zn, Mn), organic content (LOI%, Total C, bulk density), and moisture content. *In situ* measures of soil pH and conductivity were also taken. This comprehensive dataset will be combined with hydrologic data to develop a stress gradient tool that characterizes physicochemical conditions at non-permanent marshes in relation to the influence of cropping and grazing activities (Fig. A2). This is because land use influences local conditions: e.g., note in Fig. A2 the association between the percent of cropland within 100 m of each marsh and the total concentration of pesticides. Similar associations are evident in soil chemistry and physical properties such as turbidity and seasonal drawdown. This physicochemical data will also be used to inform analyses of biological communities at each marsh.

HYDROLOGIC

Limited knowledge exists regarding how variations in water input and evaporation may affect changes in wetland persistence, or how winter and summer precipitation affect the overall water balance of the semi-permanent marshes within Alberta's prairies. At each site we installed a staff gauge on our first visit, and on each subsequent visit we took water level readings and collected stable isotope samples. Water isotope tracers can be used as a tool to determine the influence of evaporation, as well as to define water source (relative contributions of rainfall versus snow melt to an individual wetland). Our marshes experienced a varying degree of evaporative isotopic enrichment throughout the summer, indicating that marshes do not all behave in the same way, and will have unique water regimes (Fig. A3). Wetlands received the majority of their input water from snowmelt during the spring (Fig. A3). Initial findings indicate that there is no apparent difference between isotopic compositions of Parkland and Grassland sites (Fig. A4). Revisiting a sub-set of sites in 2015 will shed light on interannual variability.

VEGETATION

Vegetation provides a reliable and sensitive indicator of wetland health in permanent marshes in Alberta, and may be similarly useful in non-permanent marshes. Vegetation sampling was conducted during August at the period of reproductive maturity and peak biomass. Vegetation assemblages were delineated using a high-precision GPS to standardize the intensity of sampling. In total, we identified 180 plant species: 116 in the Grassland and 142 in the Parkland. None were listed as provincially or federally at-risk; however, we observed five species tracked by the Alberta Conservation Information Management System (ACIMS): *Campanula aparinoides* and *Gratiola neglecta* in the Parkland, and *Carex lacustris*, *Anagallis minima*, and *Spergularia salina* in the Grassland. Also, we observed 31 non-native plant species: 25 in the Grassland, 14 in the Parkland. All tracked species will be reported to ACIMS, with voucher specimens to be stored at the ALTA Vascular Plant Herbarium at the University of Alberta.

We will use this dataset to develop a multi-metric index of biological integrity (IBI) evaluation tool to assess the health of non-permanent marshes in the Grassland and Parkland regions, relative to the least disturbed or reference condition. Further, we will investigate associations among plant species to form distinct vegetation assemblages that might form reclamation or restoration targets. Preliminary cluster analysis revealed five distinct vegetation assemblages, each with at least one significant indicator species (Table A1, Fig. A5). Lastly, we will determine the physicochemical conditions associated with these different vegetation assemblages, which will inform reclamation and restoration efforts (Fig. A5).

AQUATIC INVERTEBRATES

Aquatic macro-invertebrates are one of the most commonly used taxa in biomonitoring. We collected 1581 aquatic invertebrate samples, equally distributed among three microhabitat types (vegetation, water column, sediment), and, where present, from two vegetation zones (open water, emergent vegetation). Samples were taken on three site visits. To date, we have sorted 620 samples, and the invertebrates in 303 of those have been identified. Invertebrates are being identified to the lowest practical taxonomic level and these data will be analysed using multivariate techniques to explore correlations with birds, physicochemical variables and land use including agricultural disturbance intensity. If time permits, we will also develop an IBI using invertebrates.

BIRDS

Waterbirds are sensitive to land use and highly valued for recreation. Birds were surveyed with a combined visual and auditory survey twice at each wetland, during the peak of breeding season. An analysis of recordings made before surveys revealed that the presence of an observer reduces the diversity of birds identified by an auditory survey alone, but that combining the auditory survey with a visual survey identified more species. In 2014, a total of 84 waterbird species were identified: 51 in the Grassland and 67 in the Parkland. Four “watched” ACIMS species were observed: Baird’s Sparrow, Rusty Blackbird, Sprague’s Pipit and Long-billed Curlew. Exploratory multivariate analysis was completed to identify trends in composition and functional traits. Unsurprisingly, bird composition differs between Grassland and Parkland regions (Fig. A6). Grassland communities support more dabbling ducks, shore birds and migrants, whereas Parkland communities include more residents and species using scrub and forest habitats. Sites with greater agricultural influence tended to have more Redwing Blackbirds (Fig. A6).

LANDSCAPE

The composition and configuration of wetlands and other land covers can affect ecosystem function, hydrologic pathways and processes, and species presence and abundance. To quantify landscape composition and configuration, a suite of landscape metrics (Table A2) were measured from the Alberta merged wetland inventory and annual crop inventory data produced by Agriculture and Agri-Food Canada. Landscape metrics provide quantitative measurements of fragmentation, diversity, shape, etc. Metrics can be applied to an individual wetland patch, to a type of wetland (e.g., Class II – temporary), or to all wetland and land cover types across a defined landscape.

In our study area, we computed over 100 metrics for both the wetland and land cover data. We then conducted a correlation analysis and grouped highly correlated metrics, yielding 14 and 17 independent groups for wetland and land-cover data respectively (Table 2A). Subsequent reduction will be performed by PCA. We will quantify 1) the effect of natural region and 2) the degree of anthropogenic disturbance from agricultural, residential, urban, and transportation on the composition and configuration of wetland classes and land cover types using the selected landscape metrics. By assessing the composition and configuration of wetlands within the mosaic of different land covers across the landscape, we can improve the integration of ecological and hydrological functions and enhance the long-term sustainability of wetland habitats.

Relevance to Water for Life

Our research supports the goals of Water for Life (2003, 2008): healthy aquatic ecosystems, safe secure drinking water, and reliable quality water supplies for a sustainable economy. Wetlands are vital components of the aquatic landscape and the measurement of wetland health is a necessary pre-requisite to their management, especially under the new provincial Wetland Policy (2013). Thus, our work is highly relevant to this first Water for Life objective. We are in frequent communication with the Wetland Policy implementation team to ensure that our project deliverables remain policy relevant. For example, in direct response to their input, we have adapted our sampling protocol to include restored and engineered wetlands. Less obvious, is how our work also supports the latter Water for Life objectives. Wetlands provide numerous ecological services, seven of which are directly noted in the Water for Life Facts about Water (2010) document. Among those, it is noted that wetlands are essential sites of groundwater recharge, which is important to the 90% of rural Albertans that rely on well water. Groundwater is also vital to agriculture, municipal, and industrial users: over 25% of all non-domestic water permits issued in Alberta are for groundwater. Further, wetlands filter and purify surface runoff, which directly contributes to a reliable and high quality water supply. The provision of evaluation tools and an improved understanding of wetland ecology thus support all three Water for Life objectives.

Research and Activity Plan

Our 2015 research plan expands on our 2014 activities. We will sample 72 non-permanent marshes, split between the Parkland and Grassland and spanning a gradient in agricultural impact. Of these, 24 will be resampled from 2014 to capture inter-annual variance. AESRD intends to use our IBI tools to evaluate compensation wetlands under the new provincial policy. In consultation with the Wetland Policy implementation team, we will provide an evaluation of existing Ducks Unlimited projects (Fig. A7).

This summer we will sample pesticide residues, water and sediment chemistry, water-level and evaporative influence, as well as the waterbird, aquatic macro-invertebrate and plant communities. Sites are in the process of being selected following the method used in 2014. After the summer fieldwork, lab and data analyses will resume. Our first HQP begin defending their theses in January 2016.

We are on track to have all assessment tools under component 1 developed and validated by April 2016 except for the invertebrate-based IBI. This is because invertebrate sorting and identification are resource intensive. Since September 2014, we had 9 volunteers, a full time co-op student, a MSc. Student, and an undergraduate thesis student working and they have sorted 40% of the samples. Component 2 is also on track to deliver a characterization of natural landscapes using spatial and aspatial metrics by April 2016.

Interactions and Events

1. March 2015. Collaboration with Ducks Unlimited to select restored and engineered wetlands.
2. March 2015. Assist Westhoff Engineering Resources Inc. with the implementation of wetland design criteria derived from the reference condition approach.
3. January 2015. Discussions with Alberta Environment and Sustainable Resource Development's Wetland Policy Implementation Team to incorporate restored and engineered wetlands.
4. December 2014. Assist Golder with analysis of wetland monitoring program data.
5. September – December 2014. Assist Environment Canada with monitoring program design and data analysis.
6. July 2013-November 2014. Work with Geospatial Group in Alberta Environment and Sustainable Resource Development to acquire geospatial data for component 2 and site selection in component 1.
7. February 2014. Assist Westhoff Engineering Resources Inc. Land and Water Resources Management Consultants with implementing our wet meadow IBI tool as part of wetland evaluation in the City of Red Deer.

PUBLICATIONS

Our project began in earnest in April 2014, following a July 2013 pilot field season; however, already four manuscripts are in prep. The first is titled "Use of water isotope tracers to characterize the hydrology of prairie wetlands in Alberta." The second is titled "Distinct responses of marsh vegetation to grazing and cropping in Alberta's Northern Prairie and Parkland Region." The third is titled "Bird community responses to agricultural disturbance in the Northern Prairie and Parkland Region of Alberta." The fourth is co-authored by Drs. Rebecca Rooney, Rich Petrone, and Derek Robinson and is titled "Reclamation planning and climate change."

REPORTS

1. Rooney R.C., Bayley S.E. 2013. Sustainable wetland habitat: reclamation targets, design criteria and wetland policy implementation project progress report. Alberta Innovates Energy and Environment Solutions.
2. Rooney R.C., M.T. Bolding. 2013. Enhancing carbon storage through wetland restoration project progress report. Alberta Parks. Edmonton, AB.
3. Bayley S.E., Wilson M.J., Rooney R.C., and Bolding M.T. 2014. Assessment methods for reclamation of permanent marshes in the oil sands: Handbook and video. University of Alberta, Edmonton, AB.
4. Rooney R.C., Polan, H.M., Kraft, A.J. and Meyers, N. 2014. Progress Report: Parks Canada EI-2013-14653.
5. Rooney R.C., Polan, H.M., Kraft, A.J. and Meyers, N. 2014. Progress Report: Alberta Parks 14-049.
6. Rooney, R.C., S.E. Bayley, D.T. Robinson, H. Durr. 2015. Deliverable 1 and progress report: Map of BTZ study watersheds and wetlands in year 1. Prepared for AIEES and Husky Energy Ltd.
7. Huang, S., R.C. Rooney. 2015. Comparing aquatic invertebrate samples from two vegetation zones and two natural regions in non-permanent wetlands in Alberta. University of Waterloo, Undergraduate Thesis.
8. Motz., J. R.C. Rooney. 2015. Does observer presence impact estimates of avian species richness?

PRESENTATIONS

SCIENTIFIC

1. Rooney, R.C. and S.E. Bayley. 31 Jan 2014. World Wetlands Day Symposium, Waterloo, ON.
2. Rooney, R.C. 15 July 2014. North American Congress on Conservation Biology, Missoula, MT.
3. Meyers, N., R.C. Rooney, B.B. Wolfe. 7 Feb 2015. Canadian Geophysical Union – Eastern Sections of Hydrology, Biogeosciences, and Earth Surface Processes. Waterloo, ON.
4. Huang, S., R.C. Rooney. 28 Mar 2015. Waterloo Biology Research Symposium. Waterloo, ON.
5. Motz., J. R.C. Rooney. 28 Mar 2015. Waterloo Biology Research Symposium .Waterloo, ON.
6. Kraft, A.J., R.C. Rooney. 31 May – 4 June 2015. Society of Wetland Scientists Annual Meeting, Providence, RI.
7. Polan, H.M., R.C. Rooney. 31 May – 4 June 2015. Society of Wetland Scientists Annual Meeting, Providence, RI.

INVITED PRESENTATIONS AND PUBLIC LECTURES

1. Rooney, R.C., S. Bayley, I. Creed, H. Durr. 9 April 2013. Sustainable wetland habitats: reclamation targets, design criteria and wetland policy implementation. Canadian Oil Sands Innovation Alliance.
2. Hodson, P., R.C. Rooney, H. Swanson, S. Swanson. 30 April 2013. Pipelines through paradise: a panel discussion on Alberta Oil. Public Lecture Series.
3. Rooney, R.C., S.E. Bayley, I. Creed, H. Durr. 26 Aug 2013. Sustainable Wetland Habitats: reclamation criteria and wetland design. Husky Energy Ltd.
4. Bayley, S.E. 26 Sep 2013. Visit to Husky Energy Sunrise Project.
5. Rooney, R.C. 7 Nov 2013. Integration and next steps for wetland policy implementation. Wetland Policy Implementation Team, Alberta Environment and Sustainable Resource Development.
6. Rooney, R.C. 10 June 2014. Wetland assessment and invasive plant species impacts. Ducks Unlimited.
7. Rooney, R.C. , S.E. Bayley. 13 Nov 2014. Multi-metric tools and the reference condition approach. Synthesis: Applying the reference condition approach for monitoring reclamation areas in the Athabasca oil sands region. CEMA Integrated Task Group.

Appendix

Figures

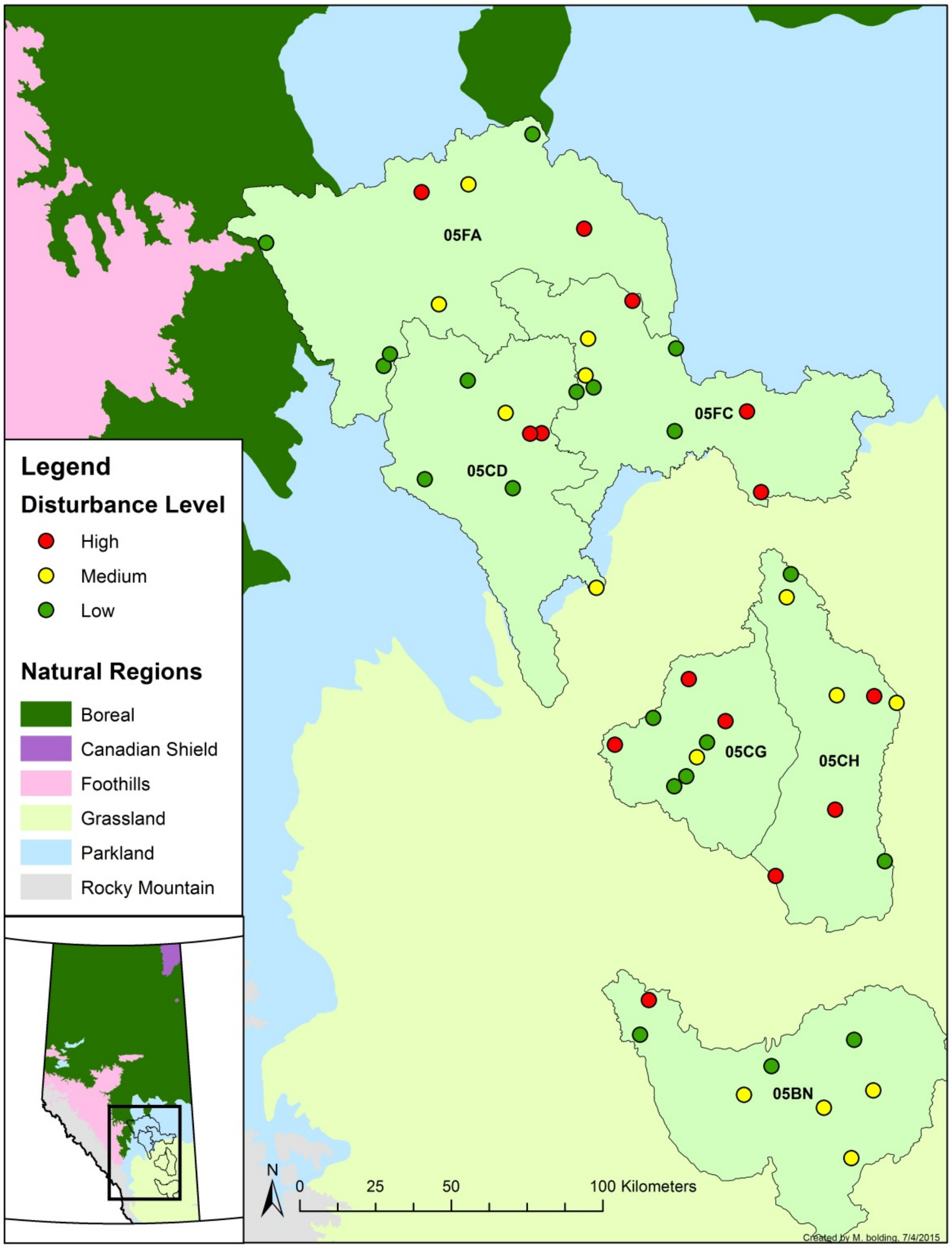

Fig. A1. Map of 2014 sampled marshes in the Parkland and Grassland natural regions. Sites are randomly selected within three sub-watersheds in the Parkland and three sub-watersheds in the Grassland natural regions. Symbology reflects the level of disturbance within 100 m of each marsh boundary.

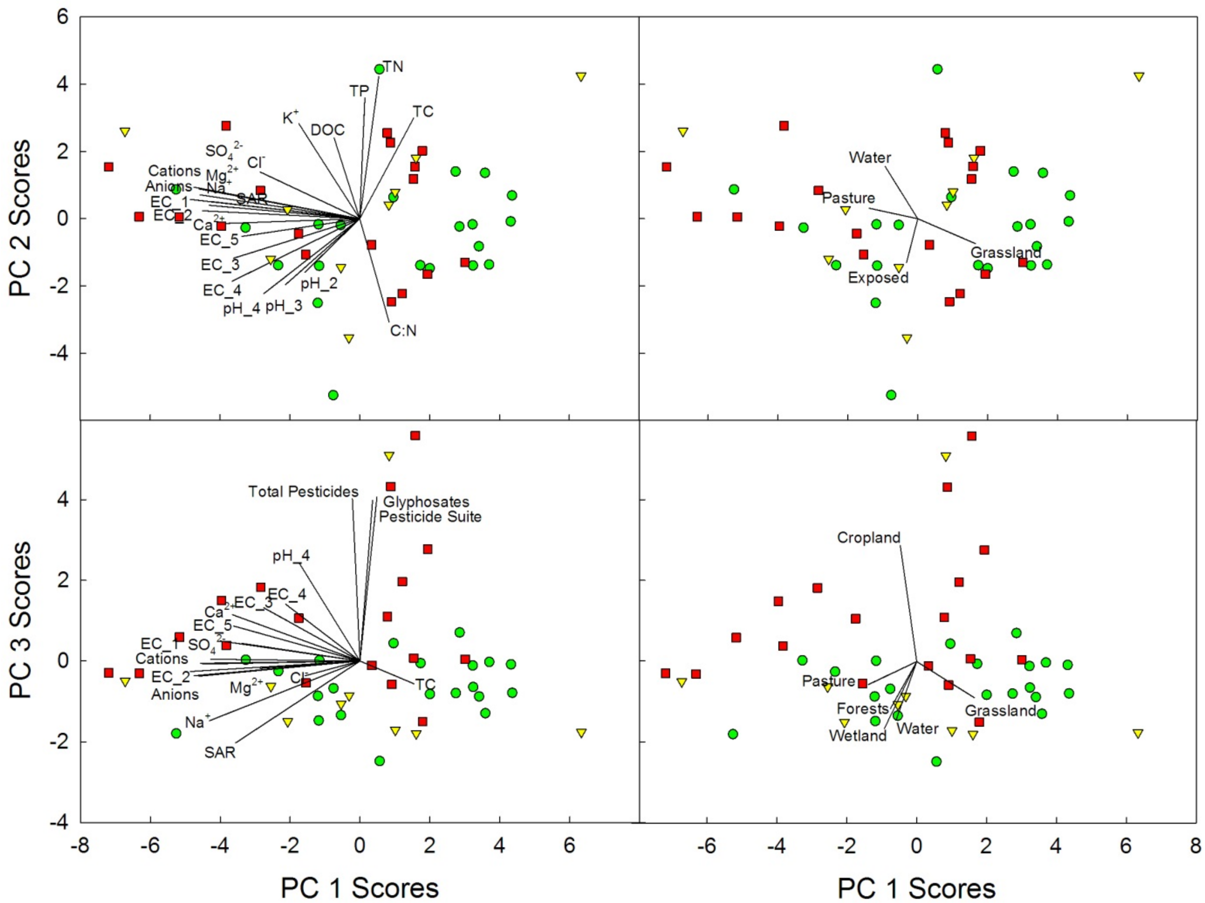

Fig. A2. Principal components analysis results wherein marshes (n=48) are situated such that the distance between them is proportional to the Euclidean distance in their water chemistry matrix. In the left-hand panel, vectors indicate positive correlations with water chemistry measurements and the synthetic ordination axes. The right-hand panel displays correlations between ordination axes and land use within a 100 m buffer around each marsh. Points are symbolized such that highly disturbed sites are red squares, medium disturbed sites are yellow triangles, and low disturbance (reference) sites are green circles. Note, for example, that both pesticides and cropland are positively correlated with axis 3, whereas both ion levels and pasture are negatively correlated with axis 1**.**

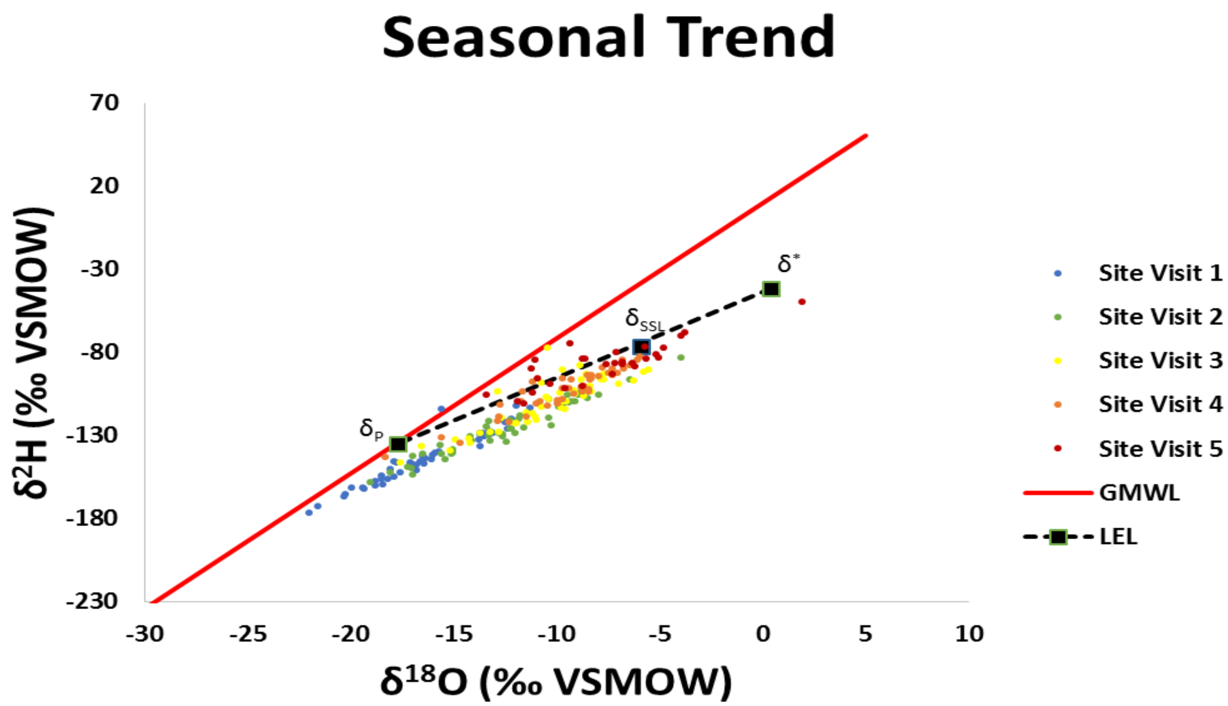

Fig. A3. Water isotope composition of wetlands by site visit (roughly monthly May-Septmeber). Wetlands experience isotopic depletion due to the dominance of snowmelt water in spring followed by evaporative enrichment throughout the summer.

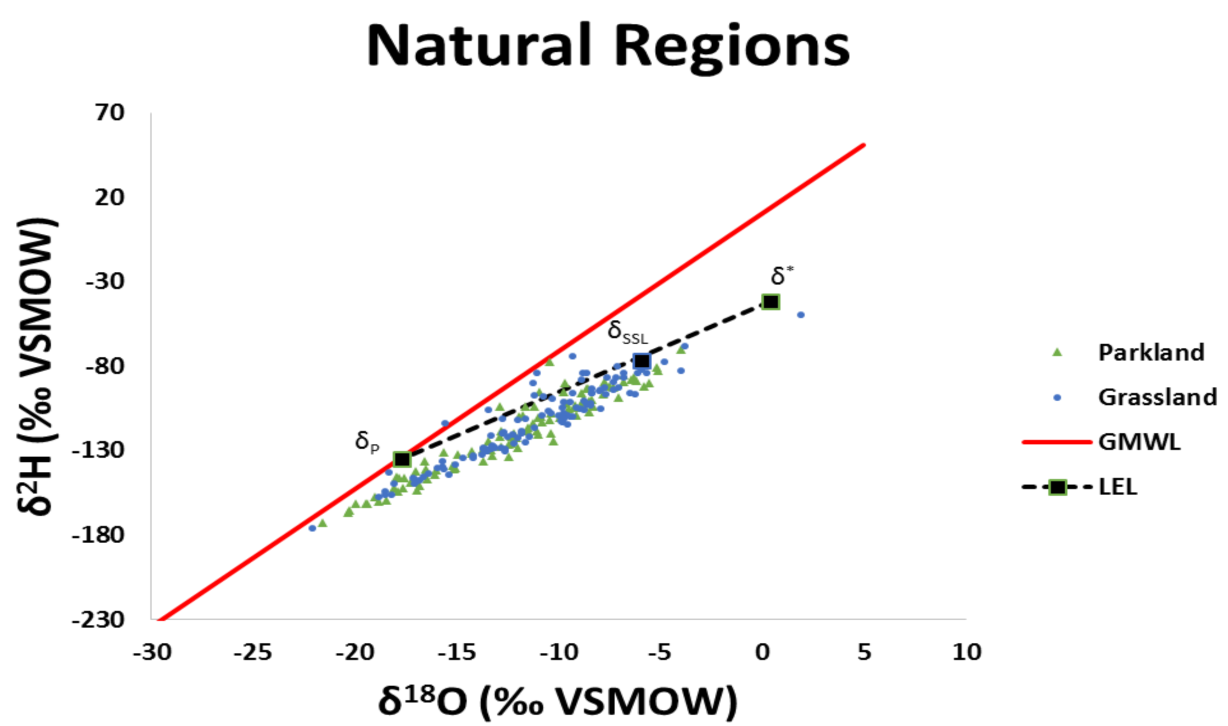

Fig. A4. Comparison of water isotope compositions for Parkland and Grassland regions in 2014. Note the overlap in the importance of evaporative influence in wetlands in both Natural Regions.

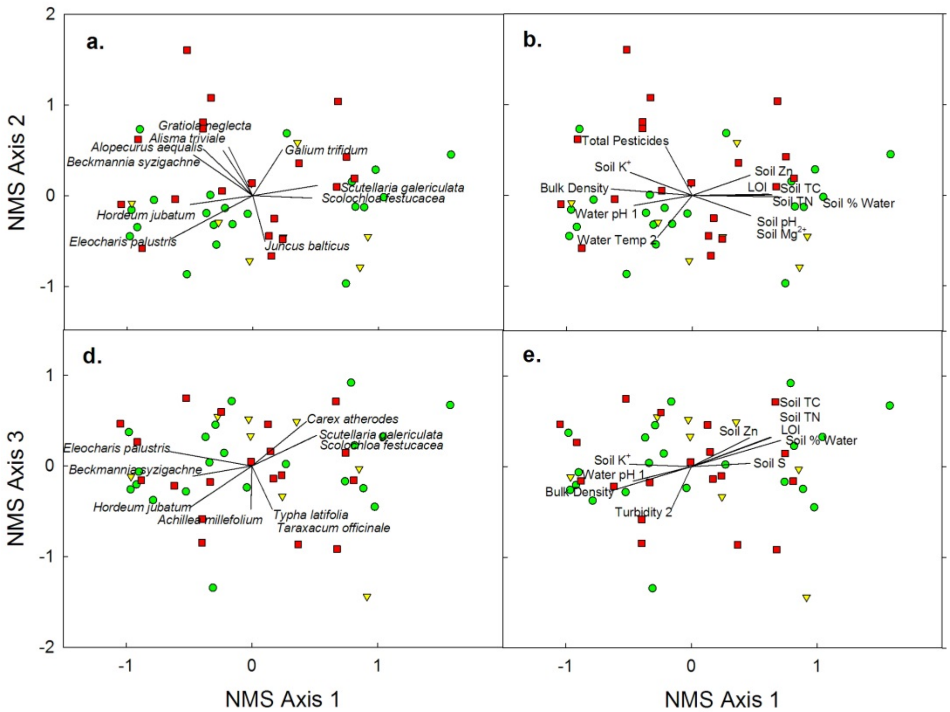

Fig. A5. Non-metric scaling ordination results where the distance between points is proportional to the Bray-Curtis dissimilarity in the vegetation composition of sites. Vector overlays in the left-hand panel indicate the correlation between plant species and ordination axes. Overlays in the right-hand panel reflect the correlation between physicochemical variables and ordination axes. This enables us to discern trends in vegetation and physicochemical conditions. Note, for example that *Scolochola festucacea* (Rivergrass) and *Scutellaria galericulata* (Common Skullcap) are associated with nutrient rich conditions, whereas *Hordeum jubatum* (Foxtail Barley) is associated with lower nutrient levels.

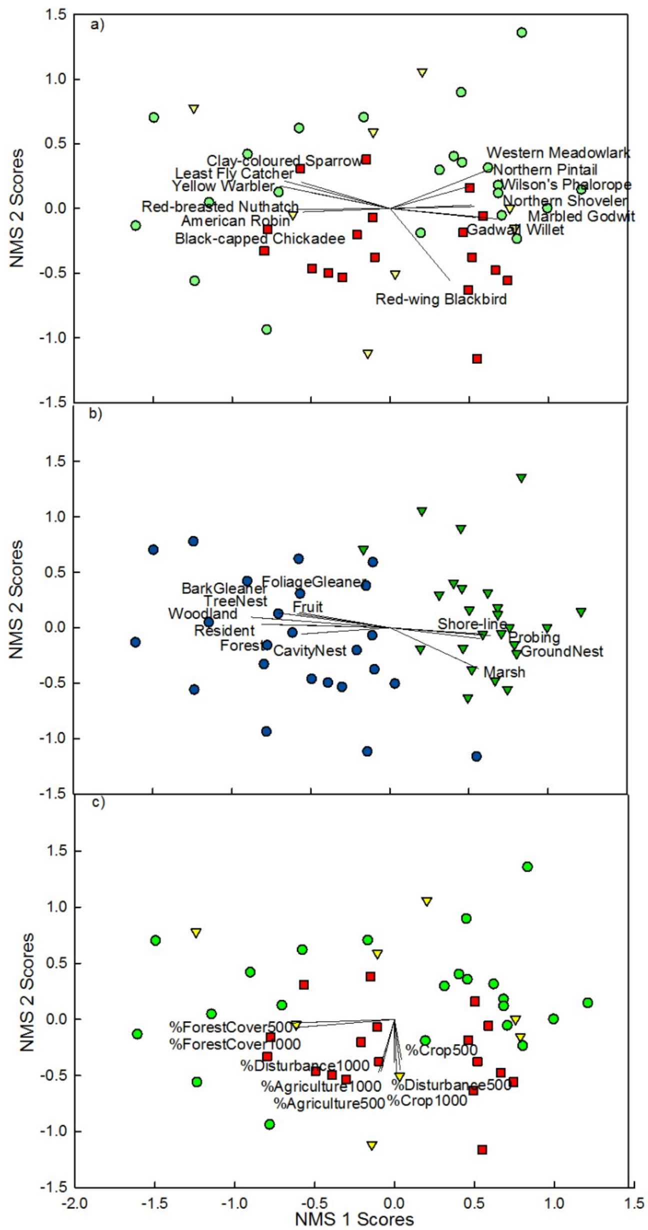

Fig. A6. Results of an NMS ordination of bird community data in the 48 marshes studied in 2014. The level of agricultural disturbance is indicated in panels A and C by red squares (heavy), yellow triangles (medium), and green circles (low). In panel B, green triangles indicate Grassland sites whereas blue circles indicate Parkland sites. Note the high abundance of Redwing Blackbirds in heavily disturbed sites, which are clustered low on axis 2. Panel C reveals that highly disturbed sites have greater proportions of crops, pasture, and other built-up land uses. Medium and low disturbance sites fall into two clusters, separated on axis 1. These clusters are associated with Parkland and Grassland natural regions, as evident in panel B. Also displayed in panel B, the different bird communities are functionally, as well as structurally different. The Parkland sites support birds that are more tree dependent: cavity or tree nesters that glean from leaves or bark. This difference in bird communities between the two natural regions is, unsurprisingly, related to a greater proportion of forest cover around Parkland sites (panel C).

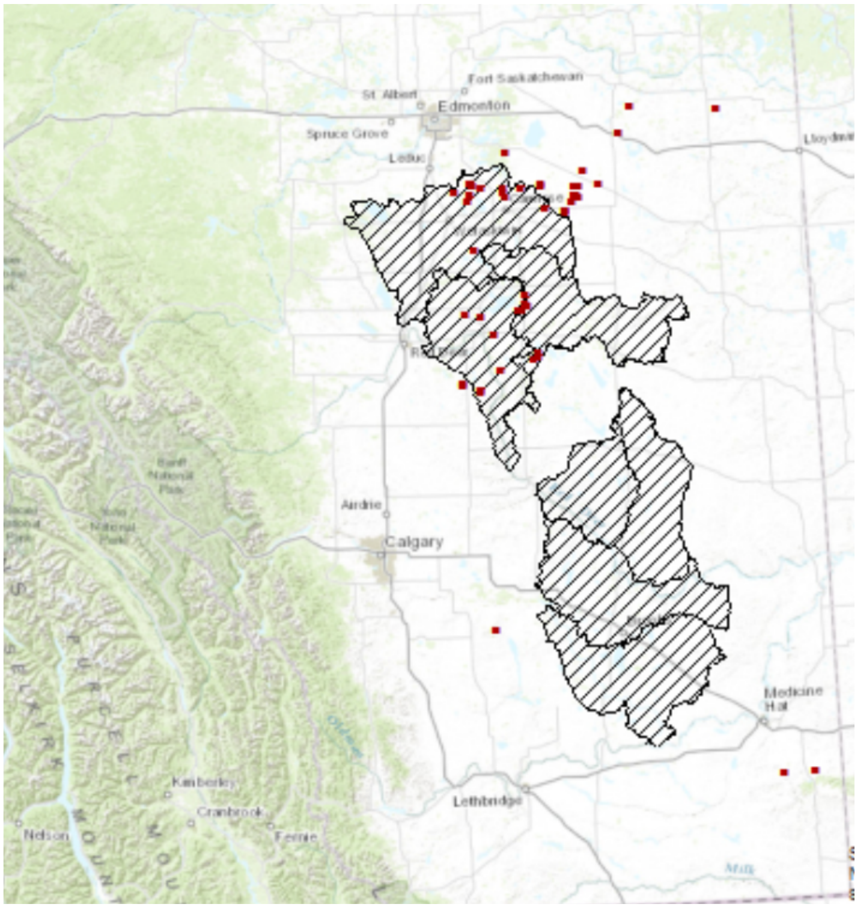

Fig. A7. Map of all restored and engineered wetlands owned by Ducks Unlimited in southern Alberta. We intend to sample as many of these projects as possible in 2015 to evaluate the success of restoration efforts at mimicking the reference condition. This component of the project was added in response to discussions with the Alberta Wetland Policy implementation team as we endeavor to assist government in policy implementation through provision of useful wetland evaluation tools and an improved understanding of regional wetland characteristics and non-permanent marsh ecology.

Tables

Table A1: Results of hierarchical cluster analysis and indicator species analysis on 2014 vegetation data. There are 5 distinct assemblages, each with at least one significant indicator species. The best indicator, along with its indicator value and associated p-value is presented below. Indicator values range from 0-100, with 100 denoting that the indicator is perfectly faithful and exclusive to the assemblage it indicates.

Vegetation assemblage	Number of Species	Number of Significant (<0.05) Indicators	Strongest Indicator Species	p-value	IV
1	23	1	*Eleocharis palustris*	0.0002	74.8
2	22	4	*Achillea millefolium*	0.0052	82.5
3	25	5	*Persicaria lapathifolium*	0.0064	81.4
4	33	4	*Vicia Americana*	0.0146	46.9
5	20	4	*Scolochloa festucacea*	0.0098	68.4

Table A2: Grouped landscape-level metrics for Alberta merged wetland inventory, reflecting 14 independent measures of wetland configuration. The most representative metric is noted, as are some other highly correlated metric options.

Number	Representative	Other Group Members
1	TA	MESH
2	NP	PD
3	LPI	DIVISION, SPLIT, SHDI, SIDI, MSIDI, SHEI, SIEI, MSIEI
4	TE	LSI
5	ED	PLADJ, AI
6	AREA_MN	GYRATE_MN
7	SHAPE_MN	FRAC_MN
8	PARA_MN	CIRCLE_MN, CONTIG_MN
9	PAFRAC	
10	ENN_MN	
11	CONTAG	
12	COHESION	
13	PR	
14	PRD	

Note: TA = total area, NP = number of patches, LPI = largest patch index, TE = total edge, ED = edge density, AREA_MN = mean patch area, SHAPE_MN = mean shape, PARA_MN = mean of the perimeter to area ratio distribution for patches in a class, PAFRAC = perimeter to area fractal dimension, ENN_MN = mean Euclidean nearest neighbor, CONTAG = contagion, PR = patch richness, PRD = patch richness density.

DELIVERABLES REPORT

DELIVERABLE	*STATUS*
List of sample sites (n=60) and GPS coordinates	Delivered for 2014, in progress 2015
Derived GIS data, including a map of reference landscapes and metadata	In progress
Remotely sensed metric scores and a means to calculate them from raw data or detailed explanation of how to derive them	By April 2016
Report chapter on remotely sensed metrics	By April 2016
Raw biological and abiotic field data and metadata (prepared for Ecological Archives)	In progress
Field-based metric scores and a database to calculate them from raw data	In progress
Copies of MSc. theses	In progress
Electronic copies of submitted manuscripts	In progress
Report chapter on field-based tools	By April 2016
Annual report and presentation 2014	Delivered
Annual report and presentation 2015	Report delivered, presentation to be delivered May 27, 2015
Final report and presentation 2016	To be delivered April-May 2016