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ODONATA AND WETLAND QUALITY IN SOUTHERN ALBERTA, CANADA: A PRELIMINARY STUDY

J.P. HORNUNG and C.L. RICE
751 General Services Building, University of Alberta,
Edmonton, Alberta, T6G 2H1, Canada

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The relationship between odon. and wetland quality was investigated in Brooks, from May until Sept. 1999. Sixteen study sites were each visited 7 times to survey adult dragonflies and aquatic macroinvertebrates, record environmental parameters, collect water samples, record vegetative characteristics, and assess beef cattle grazing influences. 25 odonate spp. were recorded, of which *Ischnura verticalis* is new to Alberta. A significant negative correlation was detected between cattle presence (measured as percent stems grazed surrounding the wetland) and odon. species richness ($p = 0.022$; $r^2 = 0.322$), teneral species richness ($p = 0.018$; $r^2 = 0.337$), and the Shannon–Weiner diversity indices ($p = 0.060$; $r^2 = 0.230$) of the study sites. In addition, vegetation species richness and odon. species richness show a positive correlation ($p = 0.066$; $r^2 = 0.221$). A logistic regression establishes that the absence of *Coenagrion angulatum*, *Enallagma ebrium* and *Aeshna interrupta* is associated with high cattle impacts, or low vegetation species richness. This study outlines the effect that cattle can have on wetland odon. species diversity and recommends that measures are taken to protect wetlands, while offering an incentive and reasonable cost/benefit ratio to both rangeland and wetland mangers.

INTRODUCTION

Beef cattle are commonplace in southern Alberta, and the vast majority of herds utilize prairie wetlands for a source of drinking water. These cattle spend a disproportionatê amount of time loafing or grazing in wetlands and will remove the submergent, emergent, and surrounding wetland vegetation (ADAMS & FITCH, 1999). In addition cattle will trample the shoreline area and add nutrients to the water through their urine and feces. No previous studies that we are aware of have investigated the impact these grazing cattle may have, by disturbing wetland vegetation and microhabitat, on the macroinvertebrate communities of prairie wetlands in Alberta.

Odonates are a vital component of a wetland ecosystem. Destruction and degradation of this critical habitat poses the greatest threat to odonate populations (MOORE, 1997) and, as a disproportionate number of threatened or endangered species are wetlands obligates, biodiversity as a whole (GIBBS, 2000). In other regions, shoreline disruption from cattle ranching has been implicated as having a deleterious effect on odonate species richness and abundance at lotic habitats (SAMWAYS, 1999).

In addition to contributing to the biodiversity of a wetland, odonates are ecologically important as both dominant predators and significant prey items for a considerable range of organisms. Odonates represent the quintessential surrogate species as defined by CARO & O'DOHERTY (1999), fulfilling requirements for all three basic types of surrogates, including indicator, flagship, and umbrella species. Their trophic position and sensitivity to environmental degradation allow odonates to function as indicators of ecosystem quality, (WESTFALL & MAY, 1999; STEWART & SAMWAYS, 1998; CLARK & SAMWAYS, 1996; SAMWAYS et al., 1996; TAKAMURA, 1991; WATSON et al., 1982) and are potentially useful in conservation and management efforts. In addition to their ecological value as biological indicators, odonates act both as flagship species, due to their charismatic nature and public appeal, and umbrella species, helping delineate minimum area requirements for aquatic macroinvertebrates as their critical habitat includes the terrestrial upland and offers a buffer for strict wetland obligates.

The cattle-influenced wetlands of southern Alberta provide critical habitat for odonates, and changes in water quality and vegetation characteristics at these wetlands can affect their reproductive success and abundance (WESTFALL & MAY, 1999; DE RICQLES, 1988; WATSON et al., 1982). In the spring of 1999, research was initiated on the odonate species composition and habitat characteristics at sixteen wetlands in southeastern Alberta across a gradient of beef cattle influence. In addition to addressing the lack of data on the odonate fauna of this eco-region, this project investigates the relationship between odonate adult presence and wetland quality, as defined by water chemistry measures, vegetative diversity, and grazing intensity.

FIELD METHODS AND STUDY AREA

Study sites were chosen from the dry mixed grassland ecozone around Brooks, Alberta, Canada (Fig. 1). This region was selected due to the lack of odonate data from the southeast portion of Alberta, the meticulous supervision and detailed descriptions of water resources in the area (facilitated by both the Eastern Irrigation District and Ducks Unlimited Canada), and the spectrum of human and cattle influences. Only permanent, easily accessed wetlands of relatively homogenous size and vegetation classification, embedded in grassland habitats (whether grazed or ungrazed) were selected for this study. Wetlands neighbouring agricultural fields or other anthropogenic influences (i.e. farmsteads, oil and gas activity) were not included

Fig. 1. Study sites in dry mixed grasslands of southeastern Alberta, Canada.

in this study. A gradient of grazed sites were haphazardly selected based on easily observable evidence of previous wetland utilization by cattle, such as cow patties, hoof tracks, cow-paths, and grazing evidence. Ungrazed sites were selected from fenced cattle management areas (i.e. parks, permanently fenced off areas). Sixteen sites were chosen, (12 in Newell Co., 2 in Vulcan Co., and 2 in the Municipal District of Cypress), representing six ungrazed and ten grazed sites, dispersed over an area of approximately 450 km^2. The statistical approach of this study was relaxed (i.e. alpha set at 0.10, and relatively small r^2 values accepted), as it was a pilot study.

ODONATE SAMPLING. – Odonates were sampled from 1 May until 5 September 1999, by manually netting the adult flying individuals with insect collecting nets, identifying them using a 20X field lens, and releasing the insects alive. In addition to species presence and abundance estimates, we also recorded breeding evidence (i.e. ovipositing females, tandem pairs), teneral odonates, and the relative abundance of males and females of the same species. Those that were difficult to identify or represented a significant finding were collected and identified using a dissecting microscope and WALKER & CORBET (1953, 1958, 1975). The entire shoreline of each wetland census area was walked haphazardly and dragonflies caught. Surveys did not occur on days that were unfavourable for odonate activity, which included days with high winds (i.e. greater than Beaufort 4), cooler temperatures (i.e. ambient air temperature less than 17°C), or heavy precipitation. On each visit enough time was spent at the site to adequately sample all the species actively flying, and surveys were terminated once the entire shoreline had been thoroughly surveyed and no new species were found after 45 min. Dependent upon the weather and level of odonate activity, a survey took from 50 min. to 4 h.

AQUATIC MACROINVERTEBRATES. – During each site visit aquatic macroinvertebrates were sampled using an aquatic D-shaped sweep net to obtain measurements on species richness, abundance and composition. Approximately 15 min. (i.e. 5 min. of sweeps at 3 different points along the shoreline) was spent sampling during each visit. Sampling was done haphazardly, sweeping the net in areas with abundant macrophytes and other substrates. The samples were never taken at a depth exceeding 1 m, and benthos samples were taken from all sites, during all visits. Insects and detritus were bagged and the insects were later identified using a dissecting microscope and MERRITT et al. (1996) and CLIFFORD (1991). After samples were sorted, only the Odonata, Ephemeroptera, Plecoptera, and Trichoptera larvae were identified to genus. These taxa have been implicated in the literature as being useful for bio-monitoring studies due to their sensitivity to disturbance (MERRITT et al., 1996; KARR & CHU, 1997).

RIPARIAN VEGETATION. – The vegetation cover and composition of each site was classified during July using STEWART & KANTRUD (1971). Four transect lines radiating from the middle of the wetland in the cardinal directions were established at each site beginning at the shoreline, and ending at the upland zone (STEWART & KANTRUD, 1971). Along each transect the dominant and incidental plant species were identified, size of the differential bands of vegetation were measured, and grazing intensity was recorded by estimating the percentage of stems grazed within a metre of each side of the transect line. Each of the four transects positions were marked and returned to three times (i.e. late July, early and late August) over the course of the study to document changes in grazing intensity. These three measures of percent stems grazed were averaged to acquire the percent grazing mean.

WATER CHEMISTRY. – Water samples were collected from all the sites once on 18 July (i.e. pre-cattle grazing) and again on 20 August (i.e. during or post-cattle grazing), 1999. Samples were collected from just under the surface in open water, and analyzed for concentrations of sodium (Na), sulfates (SO4), zinc (Zn), ammonium (NH3/N), nitrates and nitrites (NO3 + NO2), ortho-phosphorus (PO4-P), and turbidity (ntu) at Lakeside Research Laboratory in Brooks, Alberta. These substances were selected for analysis based on their ability to reflect cattle presence (i.e. present in cattle urine or feces) at a wetland.

RESULTS

Seven rounds of surveys at all sixteen wetlands were completed between 1 May and 5 September 1999, amounting to 1353:17 h of total censusing time. A total of 25 odonate species were recorded within our study area (Fig. 2), and approximately 193,000 individuals were encountered. *Ischnura verticalis* was first recorded for Alberta when ten Eastern Forktails were discovered at 12-Mile Coulee, Rolling Hills on 18 June 1999. A grazing gradient was evident throughout the 16 study sites (Fig, 3), ranging from three sites with constant cattle presence (i.e. Prince's Springs, Matzhiwin Creek, and Lonesome Lake #39) to five sites without cattle presence. Four of these five cattle--free sites were fenced and have not been grazed for at least the five years prior to this study (i.e. Sproule, Rock Lake East, Kinbrook Island, and Rolling Hills Spillway), while at the fifth site cattle were usually allowed but were excluded during the period of this study (i.e. southern-most tip of 12 Mile Coulee).

ADULT ODONATE FAUNA

An analysis of covariance (ANCOVA) with date and search time as covariates establishes a significant difference between the odonate species richness of all 16 sites ($p = 0.003$; $r^2 = 0.74$). Using the Shannon-Weiner Diversity Index, odonate diversity declines as grazing intensity increases ($p = 0.060$; $r^2 = 0.230$; Fig. 4a). In addition, odonate species richness demonstrates a significant negative relationship with mean percent stems grazed ($p = 0.022$; $r^2 = 0.322$; Fig. 4b). By refining the analysis to account

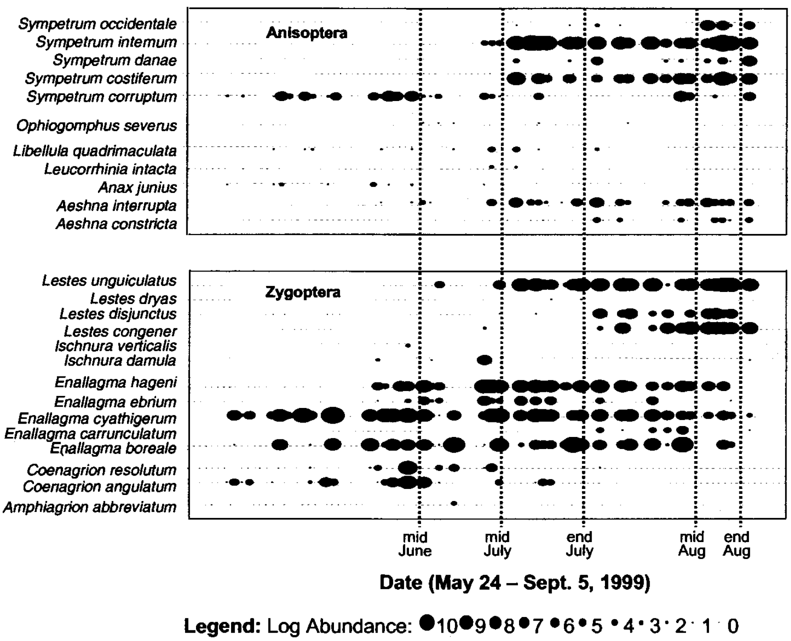

Fig. 2. List and seasonal flight periods of species encountered in the study area.

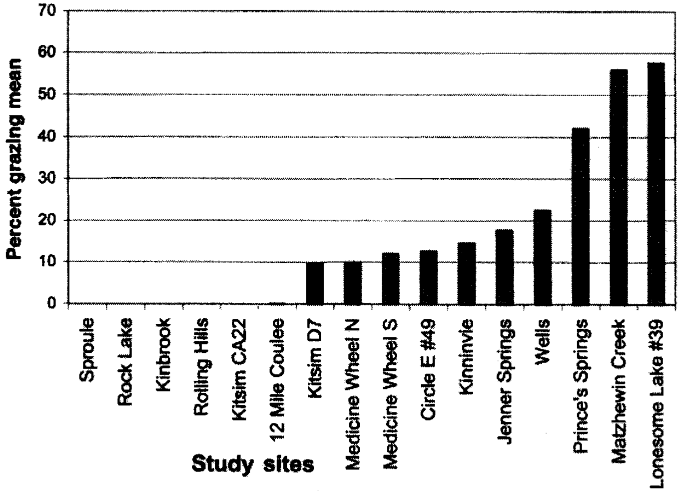

Fig. 3. Gradient of grazing intensity across 16 study sites in southeastern Alberta, Canada.

for the mobile nature of adult odonates and only including data from tenerals (i.e. recently emerged) ($p = 0.018$; $r^2 = 0.337$; Fig. 4c) or breeding adults (i.e. tandem pairs, ovipositing females), species richness still declines as grazing intensity increases ($p = 0.027$; $r^2 = 0.303$).

Odonate species' tolerance of wetland disturbance from cattle was investigated by analysing odonate presence/absence data. Because this presence/absence data is binary, a logistic regression was used to determine the probability of a species occupying a site, based on those variables shown to degrade wetland integrity (i.e. water quality, vegetation diversity, and grazing intensity as measured by percent stems grazed). To pick those variables that the odonates responded to best, a logistical stepwise regression was run on presence/absence of each species, using all the water chemistry variables, vegetative diversity, and percent mean stems grazed as independent variables. Vegetative diversity and mean percent stems grazed were the only variables that *Coenagrion angulatum*, *Enallagma ebrium* and *Aeshna interrupta* responded to significantly. This statistical analysis shows that the odds of finding either *A. interrupta* ($p = 0.04$) or *C. angulatum* ($p = 0.06$) at a site are initially high and decrease with grazing intensity, whereas the odds of finding *E. ebrium* at a site with low vegetative diversity are low, but increase with vegetative species richness ($p = 0.06$).

AQUATIC MACROINVERTEBRATES

No significant trends were found in species diversity, composition or abundance among the macroinvertebrate communities of the ungrazed, moderately grazed, or more heavily grazed sites.

RIPARIAN VEGETATION

A linear regression with data collected from vegetation transects shows a negative correlation between vegetative species richness and the presence of cattle at a site, ($p = 0.053$; $r^2 = 0.242$; Fig. 5a). Accordingly, a linear regression involving adult odonate species richness and vegetation species richness show a positive correlation ($p = 0.066$; $r^2 = 0.221$; Fig. 5b).

WATER CHEMISTRY

Water quality data analysed with non-parametric t-tests show that zinc (first round $p = 0.094$; second round = not significant), ortho-phosphates (1st round $p = 0.085$, 2nd round $p = 0.066$), and ammonium levels (1st round $p = 0.062$, 2nd round $p = 0.156$) are consistently higher in the wetlands that have cattle present.

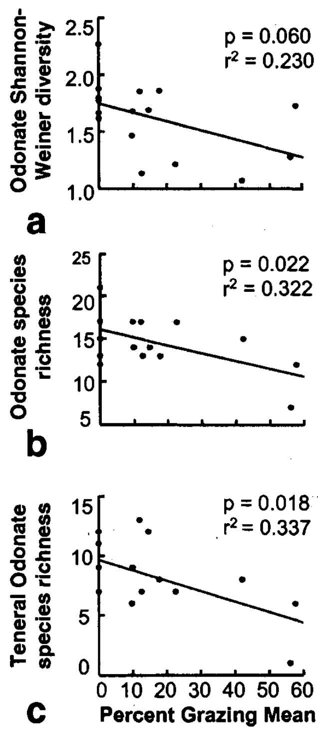

Fig. 4. Declining odonate diversity and species richness with increasing grazing intensity.

DISCUSSION

One must carefully consider the seemingly obvious assumption that cattle ranching practices have a deleterious affect on odonates, and therefore the biodiversity of wetlands. Although it is clear that cattle physically and chemically change shoreline vegetation and water quality, the extent and severity of their activities, and how these affect odonates and other invertebrates directly or indirectly, is neither easily quantifiable nor necessarily intuitive. This study's mandate is to investigate how these relationships might be quantified using odonate fauna. Certain considerations involving wetland history and origin incorporate a level of complexity when evaluating our sites. First is the historical association between the wetlands of southern Alberta and large herds of ungulate grazers (i.e. bison) suggesting that grazing does have an ecological role on this landscape. A second consideration is that every wetland used in this study is man-made, raising questions as to the conservation and management goals for these specific wetlands.

ADULT ODONATE FAUNA. — A negative relationship was found between the grazing impact of cattle and adult odonate species richness at wetlands. This relationship can be attributed to the direct impact that cattle grazing has on critical odonate habitat by the modification of submergent, emergent, and surrounding vegetation, the trampling of shoreline microhabitat, and the deterioration of water quality because of urination

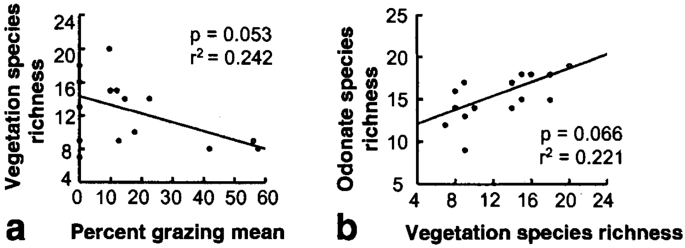

Fig. 5. Relationship of wetland vegetation to grazing intensity and odonate species richness.

and defecation. The physical structure of the emergent and surrounding vegetation at a wetland is crucial to odonates during the aerial adult stage of their life cycle and during emergence, while submerged vegetation structure provides microhabitat and cover for larvae. Odonates require aquatic and terrestrial vegetation as cues for ovipositing sites (and therefore larvae distribution and success), and mating strategies (i.e. perches for mating displays), (WESTFALL & MAY, 1999). Removal of this critical vegetation by cattle grazing and trampling thereby negatively impacts the odonate species richness and diversity of a wetland.

Species presence/absence data were used to investigate trends that may indicate a species' sensitivity to wetland degradation. A logistic stepwise regression indicated that both *Aeshna interrupta* and *Coenagrion angulatum* occur predictably when percent of stems grazed at a wetland is considered, while *Enallagma ebrium* occurs predictably when wetland vegetation species richness is considered. These data suggest that both *A. interrupta* and *C. angulatum* may be especially sensitive to the intensity of cattle grazing, and that *E. ebrium* may be especially sensitive to the vegetation composition at a wetland. It is important to note that these particular species are chosen from a sample size of 16 sites, incorporating a large margin of error in their estimation. Further research is needed to before these particular species can be clearly implicated as biological indicators of grazing intensity or wetland vegetation composition.

AQUATIC MACROINVERTEBRATES. – We suggest there are two explanations for the absence of a significant trend between the aquatic macroinvertebrate abundance, diversity and composition along a gradient of grazing intensity. The most probable explanation is that the haphazard method of sampling was inadequate, resulting in an inaccurate characterization of these 16 wetlands. The results from this pilot study will provide justification for more random, standardized, and rigorous sampling methods for aquatic invertebrates for future research projects characterizing the macroinvertebrate fauna of prairie wetlands.

A related, speculative explanation for the lack of significant trends linking the aquatic invertebrates with cattle presence may be due to the relationship between the shoreline available to cattle and the proportion of littoral area affected by their presence. With the shallow, relatively circular shape of the study wetlands (low shoreline to littoral area ratio), it is possible that organisms in areas unaffected by cattle act as colonizers for the disturbed areas, effectively buffering against the observed cattle effects. One could speculate that the majority of wetlands contain high larval odonate biodiversity and that the significant effects we did observe are only a response to terrestrial cues for the aerial adult phase of these insects.

RIPARIAN VEGETATION. – Most of the research on the response of vegetation to cattle grazing has been on upland rather than riparian vegetation. Cattle gravitate to wetlands to feed on the lush vegetation, preferring to loiter at the wetland edges - compounding their impacts (ADAMS & FITCH, 1998). Our results show that cattle grazing decreases the vegetative species richness of a wetland (Fig. 5a). This decrease in vegetative richness may be due to direct effects such as grazing or trampling, or indirect effects such as nutrient loading of the water resulting in a change in vegetative composition (i.e. species shift).

A linear regression involving adult odonate and wetland vegetation species richness demonstrates the causal effect that a diverse wetland plant community has on odonate populations, and therefore the 'health' or quality of a wetland (Fig. 5b). Several studies have confirmed the relationship of adult odonate breeding success with vegetative structure, diversity, and richness, which may be attributed to requirements for specific oviposition substrates (LENZ, 1991), cues vegetation give for breeding site selection (BUSKIRK & SHERMAN, 1985), obligatory adult mating rendezvous characteristics (MACKINNON & MAY, 1991), or life cycle microhabitat requirements (KREKELS et al., 1986). This reliance on aquatic vegetation undoubtedly helps characterize dragonflies as sensitive wetland invertebrates.

WATER CHEMISTRY. – The vast majority of wetlands in southeastern Alberta are used as a source of drinking water for beef cattle. The slope of these prairie wetlands is very gradual and easily accessible to cattle, which are given unrestricted access and loiter in the wetlands to drink, graze emergent and submergent vegetation, and cool off. This loafing time increases with warmer weather (e.g. rapid increases in water consumption above 25°C), and decreased water palatability (i.e. due to increased manure in wetlands) (WILLMS et al., 2000). Cattle affect these wetlands systems by removing emergent and submergent vegetation through grazing, and disturbing sediments by trampling the shoreline to reach open water. In addition to grazing and trampling, cattle routinely urinate and defecate directly into the water when given unrestricted access to a wetland, transmitting high nutrient loads to the wetland (ADAMS & FITCH, 1998; NADER et al., 1998).

The data collected on water chemistry at sites with and without cattle presence confirm that cattle affect the water quality of a wetland. Zinc, ortho-phosphates, and ammonium were found to be significantly higher (at alpha = 0.10) at sites with cattle presence. Increases in phosphates and ammonia result from the addition of cattle manure to the system (NADER et al., 1998), and have been linked to increases in stocking rates (SCHEPERS et al., 1982). The observed increase in zinc cannot be directly linked to cattle, but in other experiments it has been linked to the troughs that contain the cattle's drinking water (Orin Kenzie, Alberta Agriculture, pers. comm., 2000). It is unclear what impact these changes in water chemistry have on odonate life cycles because there was not enough data collected in this study on larval odonates for it to be statistically significant. It is known, however, that zinc accumulates in odonates (KARONUNA--RENIER & SPARLING, 2001), and that wetlands are critical habitats for odonates because their larval stage is strictly aquatic, long-lived, and incapable of leaving a wetland if environmental conditions become poor (CORBET, 1999; WESTFALL & MAY, 1999). Therefore, decreases in overall water quality will most likely have a negative impact on odonate larvae.

Restricting cattle access to wetlands would not only benefit the health of the aquatic and riparian environment, but also beef cattle. Cleaner water is more palatable to cattle and as a result they drink more water, spend less time loafing in a wetland and more time grazing, which can significantly increasing their weight gain by as much as 20% (WILLMS et al., 2000). Environmental and economic incentives work synergistically to suggest a restriction in cattle movements around these prairie wetlands.

RECOMMENDATIONS

Our data show that a reduction of the direct impacts that cattle have on wetlands will increase odonate diversity and vegetation species richness. Ideally, wetlands should be made inaccessible to livestock by fencing and the use of off-site watering methods economically powered by solar energy. This will eliminate the impact cattle have on the wetland vegetation, reduce their impacts on water quality and consequently benefit both cattle (i.e. increased weight gain and improved health) and odonates (i.e. increases in adult species richness and diversity), as well as the overall quality of the wetland. Although disturbance is a natural component of these prairie wetlands, more research is needed to establish the optimal frequency of this disturbance at the landscape level, and attempt to mimic historical disturbance regimes such as bison grazing and prairie fires.

All of the wetlands in this study, and nearly all in the study area, are constructed and currently managed via irrigation canals and infrastructure. More investigation is needed to characterize the invertebrate fauna of these wetlands under various water management regimes. Our study shows that increasing the vegetative diversity and species richness of a wetland will result in an optimum level of odonate species richness. In the future, the distinction between optimum- and natural-biodiversity should be explicit in wetland management plans. This distinction may result in a higher proportion of these managed wetlands being modeled after a more natural (i.e. seasonal or ephemeral) water regime, and guarded against the *Typha* spp. domination that prevails under more artificial (i.e. permanent) water conditions.

Additional investigation is needed to better understand the impact that cattle have on larval odonate populations and to further characterize the application of odonates as a biological indicator of wetland quality in this region. Future studies should contain more rigorous scientific design, address the impacts of restricted cattle access to a wetland (in addition to merely cattle presence/absence), and examine larval odonates more intensively as to their aquatic habitat requirements and physiological response to changes in water quality due to cattle presence.

Odonate surveys focusing on this region of the province should continue as these findings will significantly contribute to baseline data, and address the lack of long- -term monitoring of odonates within Alberta.

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