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Effects of cattle grazing on Platte River caddisflies (*Ironoquia plattensis*) in central Nebraska

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Abstract. The Platte River caddisfly (*Ironoquia plattensis*) is a semiterrestrial limnephilid that inhabits sloughs along the Platte River in central Nebraska (USA). The species was discovered in 1997, and little is known about what controls its limited distribution or threatens its existence. We investigated effects of grazing by cattle (*Bos taurus*) on caddisfly abundance in a grassland slough. In April 2010, we established exclosures to isolate cattle from areas with caddisflies. We measured aquatic larval densities in April 2010 and 2011. We estimated grazing intensity from the normalized difference vegetation index (NDVI) values extracted from aerial images made in autumn 2010. Grazing intensity varied among plots, but ungrazed plots had more vegetation (higher NDVI values) than grazed plots. In April 2011, larval densities were greater in ungrazed than in grazed plots. Larval densities and NDVI values were strongly positively correlated, a result suggesting that reduction in vegetative cover from grazing was associated with decreased densities of caddisflies. Increased vegetative cover may have provided structure needed for adult courtship and inputs of organic matter to support larval feeding. Repeated, season-long grazing may have long-term negative consequences for the Platte River caddisfly in grassland sloughs when vegetation does not recover and other effects of cattle persist year after year. Resting pastures from grazing to permit vegetation to rebound appears to allow cattle and Platte River caddisflies to coexist in sloughs along the Platte River.

Key words: *Ironoquia plattensis*, Platte River caddisfly, grazing, aquatic density, vegetation structure, slough, Platte River, Nebraska, NDVI, wetlands.

In 1997, the Platte River caddisfly (*Ironoquia plattensis*) was described from an intermittent grassland slough (shallow, linear wetland) along the Platte River in central Nebraska (Alexander and Whiles 2000). In subsequent surveys, it was observed in isolated wetlands along a 320-km reach of the Platte River from Lincoln County to Merrick County (Vivian 2010). The Platte River caddisfly develops in sloughs through 5 larval instars from autumn to spring, but unlike most caddisflies, larval *I. plattensis* emigrate from aquatic to terrestrial habitats in spring to aestivate for summer and then pupate in autumn (Whiles et al. 1999, Geluso et al. 2011). The terrestrial phase of its life cycle coincides with periods when off-channel aquatic habitats, especially sloughs, dry or have intermittent flow (Whiles et al. 1999). The complete life cycle of *I. plattensis* occurs within a relatively small area near the slough. Adults emerge from adjacent terrestrial areas in late September and early October and return to the slough channel to deposit eggs. Specific habitat requirements and potential threats to the Platte River caddisfly remain largely unknown. To date, only a few publications have been focused on the species (Whiles et al. 1999, Alexander and Whiles 2000, Geluso et al. 2011).

Off-channel aquatic habitats used by the Platte River caddisfly have been reduced substantially in the Platte River valley by flow regulation, conversion of wet meadows to agricultural fields, and depletion of the regional aquifer (Williams 1978, Eschner et al. 1983, Sidle et al. 1989, Friesen et al. 2000). Where suitable habitat remains, management practices, such as prescribed fire and livestock grazing, are used to mimic natural disturbances that once shaped the

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prairie landscape (Helzer 2010). However, effects of these management activities on the Platte River caddisfly are unknown. Recently, *I. plattensis* was petitioned for listing as federally endangered in the USA (Rosmarino and Tutchton 2007, USFWS 2009). Multiple factors, including habitat loss and degradation, were outlined as support for listing the species (USFWS 2009).

Abiotic factors linked to river hydrology and flooding ultimately create and maintain aquatic habitats required by *I. plattensis*, but other factors, such as fish predation (Whiles and Goldowitz 2001, 2005) and livestock grazing (Goldowitz 2004, Vivian 2010), also may affect population dynamics. Goldowitz (2004) noted that season-long cattle grazing had "visually striking impacts on the habitat" at 1 site with *I. plattensis*, but it was unclear what effects, if any, such management had on caddisflies. We investigated relationships between cattle grazing and abundance of aquatic larval caddisflies along the only slough known to have high densities of the caddisfly and a long history of cattle grazing.

Methods

Study site

In 2010 and 2011, we studied *I. plattensis* in a slough on the floodplain of the Platte River on Shoemaker Island, Hall County, Nebraska (lat 40°47.660′N, long 98°26.722′W). The floodplain supports mixed and tallgrass prairie vegetation and is traversed by numerous sloughs that create a ridge/swale structure on the landscape (Henszey et al. 2004). Sloughs remain inundated for various durations depending on precipitation, groundwater elevation, and river flow (Whiles and Goldowitz 2001, 2005, Henszey et al. 2004, Harner and Whited 2011). As a result, the mosaic plant communities in the floodplain are structured largely by availability of soil moisture (Henszey et al. 2004). Dominant upland vegetation includes many native and nonnative grasses and a diversity of forbs (Helzer and Jelinski 1999). Sedges, rushes, grasses, and forbs dominate the vegetation in the low-lying areas (Meyer et al. 2010).

The grassland surrounding our slough was managed with a 4-y rotation of prescribed fire and cattle grazing to promote heterogeneity in habitats and optimal grassland production (Kim et al. 2008, Helzer 2010). This rotation involved spring burning followed by early and late grazing in the season (Year 1), grazing mid-season (Year 2), and no burning or grazing (Years 3 and 4). At our study site, the pasture was rested in 2008 and 2009 and burned on 17 March 2010. Cattle grazed the pasture 14 May to 30 June 2010 and September to October 2010, and cattle were rotated to a neighboring pasture in July and August 2010. Sixty animal units, primarily cow–calf pairs, grazed the 83-acre (34 ha) pasture. This protocol resulted in a stocking rate of 2.5 animal unit months (AUM)/acre for the 2.5 mo that cattle were in this pasture. However, when the adjacent 96-acre (39 ha) pasture, where cattle grazed for 2 mo during midsummer, was included, the overall stocking rate was 1.8 AUM/acre. Recommended stocking rates are 1.7 to 1.9 AUM/acre for season-long, continuous grazing on rangeland in excellent condition in similar habitats in this region (Waller et al. 1986). At our site, stocking rates were within this recommended range when the mid-season rotation was included. Cattle obtained water directly from the slough and a river channel along the southern border of the pasture.

The slough segment we examined had flowing water all year, except in the uppermost 30 m (Geluso et al. 2011). Its deep-channel morphology and proximity to groundwater caused it to have longer periods of inundation than other sloughs on Shoemaker and adjacent Mormon Island (Harner and Whited 2011). Slough banks were 25 to 50 cm high, the wetted channel perimeter ranged from 65 to 150 cm, and maximum water depth ranged from 6 to 17 cm along the section of slough where *I. plattensis* larvae were present (27 April 2010; 6 cross-sections measured at 50-m intervals). Water temperature averaged 11 ± 1°C (SD), with pH = 7.8 ± 0.1, conductivity = 1047 ± 33 μS/cm, and dissolved O_2 = 6.6 ± 1.4 mg/L (sampled from 6 cross-sections on 27 April 2010) (Geluso et al. 2011). The Platte River caddisfly was first observed in this slough in May 2003 (Geluso et al. 2011), and the slough supported among the greatest densities of the Platte River caddisfly known (Vivian 2010, Geluso et al. 2011).

Larval sampling in aquatic habitats

To examine effects of cattle grazing on *I. plattensis*, we established 8 plots (12.5 × 12.5 m) along the length of the slough in April 2010 and excluded cattle from ½ of the plots with electric fence. Grazed and ungrazed plots alternated along the length of the slough and were adjacent to one another except that the 2 central plots were separated by a space that housed a herpetofaunal monitoring array. Plot centers were in the slough channel, and plots extended from the slough to the surrounding uplands.

On 29 April 2010, we sampled aquatic larval caddisflies to determine densities in plots before cattle were introduced. We then sampled larvae on 28 May 2010, 12 April 2011, and 28 April 2011. We

TABLE 1. Mean (SD) densities (individuals/m^2) and p-values associated with Mann–Whitney U tests comparing aquatic larvae of Platte River caddisflies (*Ironoquia plattensis*) in grazed and ungrazed plots along a grassland slough on Shoemaker Island, Hall County, Nebraska, in April 2010 (before grazing) and April 2011 (after grazing). $n = 4$ for all summary statistics.

Date	Before/after grazing	Ungrazed plots	Grazed plots	p
29 April 2010	Before	668 ± 194	587 ± 190	0.309
12 April 2011	After	775 ± 218	220 ± 99	0.021
28 April 2011	After	361 ± 67	118 ± 91	0.021

sampled larvae in and on sediments in a region 30 cm wide × 30 cm long × ~2.5 cm deep with a single sweep of a 30-cm D-loop dip net in the center of stream flow. On each sampling date, we collected 3 subsamples, each consisting of a single sweep of the dip net, in each plot. We sieved samples (3-mm mesh) and counted larvae. We deposited several voucher specimens of larvae and adult *I. plattensis* at Southern Illinois University, Carbondale, Illinois.

On 28 October 2010, aerial images were recorded of the study site. These images included spectral reflectance measurements. We calculated the normalized difference vegetation index (NDVI) as an indicator of vegetation productivity and of inverse grazing intensity (Tucker 1979). NDVI was calculated as:

$$\mathrm{NDVI} = (\mathrm{NIR} - \mathrm{VIS})/(\mathrm{NIR} + \mathrm{VIS})$$

where VIS is the spectral reflectance acquired in the visible region, and NIR is the spectral reflectance acquired in the near-infrared region. NDVI values range from 0 to 1, with 1 indicting more productive vegetation. We used a 0.5-m buffer on each side of the slough to extract NDVI values for each plot. Our NDVI values were captured late in the year (October), so they did not reflect maximum vegetation productivity that would have been present in mid-summer. However, the values provided a relative index of differences in vegetative productivity between grazed and ungrazed plots when adult caddisflies were emerging to mate and lay eggs, and a relative index of availability of vegetation during winter and spring larval growth in the slough.

Data analyses

We compared larval densities and NDVI values between grazed and ungrazed plots with Mann–Whitney U tests. Count data for the insect were not normally distributed, so we used the Mann–Whitney U test on ranked data, but for descriptive purposes we report means and associated standard deviations rather than medians. We examined the relationship between NDVI and larval densities with Spearman rank correlations. Our sampling violated assumptions of independence because plots were established along only 1 slough, but we were constrained by the availability of sloughs with caddisflies and cattle grazing. We set significance levels at $\alpha = 0.05$ and conducted analyses in PASW (version 18; SPSS Inc., Chicago, Illinois).

Results

Aquatic larval densities were indistinguishable between exclosed and open plots on 29 April 2010 before initiation of cattle grazing (Table 1). We intended to test for grazing effects on aquatic larvae later that spring, but larvae emigrated from the slough early, and virtually no larvae remained in the slough to make such a comparison. We observed an average of ~30 individuals (ind.)/m^2 on both grazed and ungrazed plots on 28 May 2010. However, 1 y later (12 and 28 April 2011), densities of aquatic larvae were greater in ungrazed than in grazed plots (Table 1). In addition, larval densities were lower on 28 April 2011 (361 ± 67 ind./m^2) than on 29 April 2010 (668 ± 194 ind./m^2; $p = 0.021$) on ungrazed plots, demonstrating an overall decline in densities the 2nd year.

Plant cover was visibly different among plots and ranged from bare ground to dense, tall grasses (>1 m). Grazed plots had lower NDVI values (0.239 ± 0.015) than ungrazed plots (0.297 ± 0.014; $p = 0.021$) in October 2010. A strong, positive correlation existed between larval densities and NDVI values on both dates (Fig. 1A, B).

Discussion

The Platte River caddisfly occupies a limited number of sloughs along the Platte River in central Nebraska (Goldowitz 2004, Vivian 2010). Neither site characteristics for inhabitance nor threats are fully understood. We initially designed our study to investigate immediate, direct effects of cattle grazing on caddisfly larvae before they emigrated from the slough in spring 2010. However, this objective could not be met because larvae left the slough earlier than

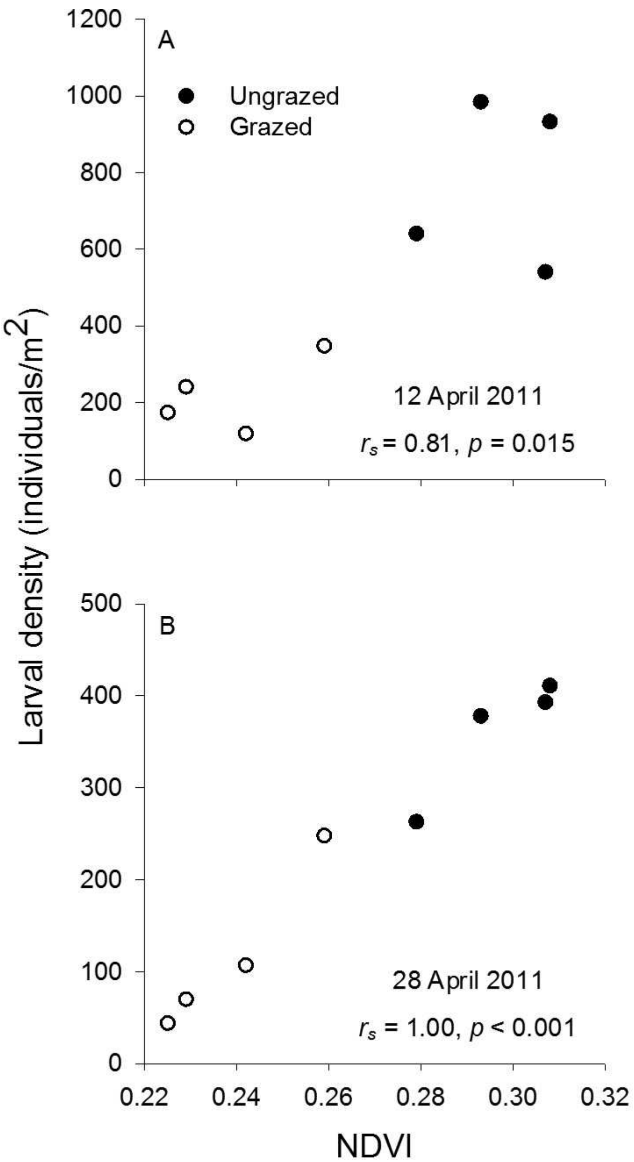

FIG. 1. Association between normalized difference vegetation index (NDVI) values and density of aquatic larvae of the Platte River caddisfly (*Ironoquia plattensis*) in a grassland slough in Hall County, Nebraska, on 12 April 2011 (A) and 28 April 2011 (B).

expected based on prior surveys (Whiles et al. 1999) and before cattle had extensively grazed the pasture (Geluso et al. 2011). However, 1 y later, we observed larval densities that were significantly lower in grazed than in ungrazed plots. We had expected that the new cohort of larvae would hatch, move around within the channel, and distribute themselves evenly once cattle were removed from the pasture in autumn 2010, but this was not the case. In April 2011, larval densities were 3× higher in plots not grazed the previous summer than in plots that had been grazed, a result indicating a possible lingering effect of grazing on caddisfly densities.

The strong positive association between NDVI and larval densities suggested that cattle grazing may have negatively affected the caddisfly by reducing plant biomass. As a shredder (Whiles et al. 1999), the caddisfly requires inputs of organic matter to support feeding, and we expect allochthonous inputs to be greater in ungrazed than in grazed regions. Furthermore, above-ground vegetation may have provided structure required by adults for courtship and mating. In September 2010, we observed adult caddisflies only along slough segments where cows had not removed standing vegetation. All adults seen were crawling on vegetation or flying within cover ≤1 m from the water (Geluso et al. 2011). Larval densities may have reflected where eggs were distributed in autumn, and future studies could examine this hypothesis.

Changes in vegetation may have been correlated with unmeasured effects of cattle. Grazing reduces bank stability and widens channels, increases inputs of fine sediments, and alters water chemistry via inputs of feces and urine (Kauffman and Krueger 1984, Belsky et al. 1999). Grazing can affect aquatic macroinvertebrates by decreasing bank cover and stability (McIver and McInnis 2007), increasing fine sediment loads (Braccia and Voshell 2006), and reducing inputs of benthic organic matter (Braccia and Voshell 2006). All of these alterations could have occurred in our system.

We hypothesize that grazing is not necessarily detrimental to *I. plattensis*, despite the association of grazing with reduced caddisfly densities, as long as grazing is applied in a rotational framework. Grazing at our study site clearly was compatible with the caddisfly because this site has one of the highest known densities of the insect (Vivian 2010, Geluso et al. 2011). Grazing pressure at our site probably was at or below recommended regional practices (Waller et al. 1986). The pasture surrounding our slough was moderately to heavily grazed, but was allowed to recover for a period during the year of grazing and for 2 y during the larger rotational plan. Moreover, the 250-m reach of the slough with caddisflies in 2010 (Geluso et al. 2011) traversed 2 pastures on different years of the grazing rotation. Thus, vegetation and undisturbed benthic substrate were available to the caddisfly every year along this slough.

Long-term effects of grazing and other land-management activities on *I. plattensis* require future investigation. To date, our study site is the only site known to support both the caddisfly and cattle grazing, but previous searches for terrestrial larvae on the surface (e.g., Vivian 2010) may have failed to detect buried larvae (Geluso et al. 2011). In future studies, investigators should search for terrestrial larvae below ground, especially in grazed sites, and should investigate other effects of cattle (e.g., trampling, alterations to water chemistry) across multiple time scales. Furthermore, most known populations of *I. plattensis* are associated with forested sloughs (Vivian 2010). Tree-clearing is a common management practice in the valley to reestablish prairies (National Research Council 2005) because of afforestation of rivers in the Great Plains (Johnson 1994). Removal of trees often opens sites to cattle grazing, so caddisfly populations in cleared areas should be closely monitored to ensure that populations that were previously insulated from grazing are not harmed.

In conclusion, we have added to knowledge of slough characteristics required by the caddisfly for life-history functions and have documented that cattle grazing is a potential threat to the species. Cattle grazing is a common management tool for prairie conservation and a profitable industry in the central Platte River valley, especially on productive lands with high groundwater levels that generally preclude row-crop agriculture. The rarity of this species today might be partly associated with grazing in wet meadows and associated sloughs. We hope that better understanding the interactions between cattle and the Platte River caddisfly will enable them to coexist in the remaining sloughs along the Platte River.

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