Annual Progress Report
for
Effects of cattle grazing on wetland parameters important to
breeding waterfowl in the Southern Interior of BC

W. Marc Jones, Bruce Harrison, and Lauchlan H. Fraser

December 2007
Abstract

Associations between livestock grazing, wetland vegetation, and breeding waterfowl were evaluated for Southern Interior depressional wetlands. We added 11 additional wetlands to our study in our second year of research and greatly expanded the aquatic invertebrate component of the study. The preliminary results of our analysis of all 36 wetlands are consistent with last year's findings: 1) aboveground vegetation biomass as well as vegetation community structure and composition are strongly associated with grazing intensity, and 2) waterfowl breeding use is associated with wetland size (for both dabbling and diving ducks) and vegetation biomass (for diving ducks only).

Additionally, we collected aquatic invertebrate data for 31 of our sample wetlands and detailed water chemistry data for 34 sample wetlands. We have not included these data in our analyses; we are currently processing and identifying aquatic invertebrate samples. Finally, we have identified predictor variables for our landscape-level analysis and are currently using GIS to calculate these variables.
Project Rationale

Wetlands provide numerous environmental and economic benefits, including wildlife habitat, regulation of water regimes, filtration of polluted water, and production of forage crops (Mitsch and Gosselink 2000). Functional wetlands are considered especially critical as habitat for breeding waterfowl (Weller 1999). Wetland ecosystems are strongly determined by the abiotic environment, especially site hydrology and chemistry (Keddy 2000, Mitsch and Gosselink 2000); however, livestock grazing can be a significant and pervasive stressor on wetlands. For example, grazing removes biomass, compacts soil, and adds nutrients. These factors have all been shown to negatively wetland functions, such as water quality, biodiversity, productivity, plant competitive interactions, and waterfowl breeding success (Kantrud 1986, Rader and Richardson 1994, Powell et al. 2000, Martin and Chambers 2001, Steinman, et al. 2003, Kauffman et al. 2004, Marty 2005). Understanding how grazing influences these complex interactions is critical for maintaining the biodiversity and productivity of wetlands and thereby sustaining their habitat and forage production values.

Objectives and Hypotheses

The overall objective of this research is to understand linkages between waterfowl breeding use of wetlands and livestock grazing intensity, especially as mediated by grazing-related changes to wetland vegetation and aquatic invertebrate communities. Specific hypotheses are:

Vegetation
1. Livestock grazing affects wetland vegetation composition, leading to an increase in ruderal and grazing-tolerant species (e.g., annuals/biennials) and a decrease in sensitive and grazing-intolerant species (e.g., palatable and perennial species).
2. Livestock grazing affects wetland vegetation structure, with increased grazing resulting in reduced biomass and litter and a decrease in the abundance of structurally robust species, such as tall emergent wetland plants, that provide habitat cover to wildlife.

Aquatic Invertebrates
1. Heavy livestock grazing pressure will decrease the diversity and richness of aquatic invertebrate taxa in these wetlands.
2. The greatest aquatic invertebrate taxa diversity and richness will be found in wetlands subjected to an intermediate level of cattle disturbance.

Breeding Waterfowl
1. Livestock grazing negatively affects waterfowl breeding pair use, primarily mediated through its effects on wetland emergent vegetation structure and aquatic invertebrate communities.
2. Wetland hydrology is likely to play a more important role than livestock grazing in limiting waterfowl brood use of wetlands.
Context of 2007 Work

Eleven additional wetlands were sampled in the summer of 2007, bringing the total number of wetlands sampled to 36. Sites sampled in this year are located in Lac du Bois Provincial Park (also sampled in 2006) and the Hamilton Commonage, which is located between Kamloops and Merritt. These wetlands are environmentally similar to sites sampled in 2006 (described in our 2006 progress report). We now have vegetation, grazing, and waterfowl use data for 2006 and 2007. We also have water chemistry data for 34 sites from 2007. The aquatic invertebrate community was sampled from 31 sites in 2007. These data are still being sorted and are not presented in this report.

This progress report models waterfowl use of all 36 wetlands as a linear function of vegetation biomass (which is strongly associated with grazing intensity) and wetland size. The project also involves using a model-based approach to evaluate the influence of multiple site- and landscape-level factors on waterfowl use. We are currently working to quantify a relatively small set of landscape variables (e.g., road and wetland density, distance to and amount of woody cover) to supplement the site-level data already collected (e.g., vegetation, grazing intensity, aquatic invertebrates, water chemistry, waterfowl use). We expect to have an initial set of models to evaluate in spring 2008.

Methods

Field Sampling

Sampling methods for vegetation, grazing disturbance indicators, and waterfowl are unchanged from 2006, except for the dates of waterfowl sampling, which ran from April 30th to June 11th for pair surveys and from June 9th to August 10th for brood surveys. Waterfowl breeding use was sampled on all wetlands. Specific conductance and pH were measured at all wetlands using a YSI probe in May, June, and July, and a number of water chemistry parameters, including alkalinity, total dissolved phosphorus, ammonia, chloride, and sulfate, were analyzed from water samples collected in June.

Sampling protocols for aquatic invertebrates differed from those used in 2006. Samples were collected from 31 depressional wetlands in May/June and 29 in July. The difference in number of wetlands resulted from two wetlands drying up before the commencement of the second sampling period. Sampling timing was chosen to correspond with waterfowl nesting and brood rearing. Quantitative sampling was performed using a collapsible aluminum ‘enclosure’ and a 250 μm mesh kick net. Six samples were collected per wetland for a total of 360 samples. Due to the number of wetlands sampled and the amount of sample collected at each of the 6 sites in a wetland, subsampling was necessary. The subsampling method chosen was a Caton subsampling tray. Aquatic invertebrates are currently being sorted and enumerated to the order level. Organisms will be further identified to the genus level where possible.

Data Analysis

Grazing Disturbance Indicators – Our two primary measures of grazing disturbance are soil bulk density and the amount of bare ground (we also plan to analyze soil carbon as a measure of grazing intensity). Both these measures have been found to be good indicators of grazing intensity (Greenwood and McKenzie 2001, Tate et al. 2004, Hendricks et al. 2005, Yeo 2005,
Manier and Hobbs 2007, Sharrow 2007). Unfortunately, our bulk density measures for 2007 suffer from a systematic measurement error. We will recollect these data in 2008. For this report we use bare ground as our measure of grazing intensity. Bare ground was measured as the mean number of vegetation quadrat corners that intersected bare ground. To aid the interpretation of this variable in regression models, we have rescaled it so that it varies between 0 and 100.

**Vegetation** – We used two multivariate techniques to examine patterns of plant community composition. First we used a clustering technique, partitioning around medoids (similar to \( k \)-means clustering), to classify sites into groups based on differences in vegetation. Consistent with last year's results, classifying sites into two groups was the most meaningful number of partitions. We used logistic regression to determine the strength of the association, if any, between vegetation-based groups and two environmental variables, grazing intensity and pond specific conductance. We used likelihood ratio tests as a model selection tool for these covariates. Vegetation community patterns were also examined with an indirect ordination technique, nonmetric multidimensional scaling based on a Bray-Curtis distance measure of vegetation frequency data. NMS is calculated solely with vegetation data and the results are not constrained by environmental covariates. Instead, correlations between ordination axes and environmental variables were evaluated with joint-plot overlays on ordination diagrams and their significance was assessed by permutation. Separate ordinations were run for wet meadow and marsh vegetation. Finally, we used ordinary least squares regression to evaluate the strength of the association of plant aboveground biomass with bare ground and specific conductance. These statistical analyses and their implementation are described in greater detail in our 2006 progress report.

**Breeding Waterfowl** – Waterfowl breeding pair and brood data were modeled using quasi-Poisson generalized linear models with a log link function but with the dispersion parameter estimated from the data. This allowed for an ad-hoc adjustment of coefficient standard errors due to overdispersion. We modeled four indicators of waterfowl breeding use: the number of indicated breeding pairs (IBPs) and broods of diving and dabbling ducks. IBPs were calculated as described in our 2006 progress report. Model predictors were wetland size and aboveground vegetation biomass.

All analyses were run using the R statistical environment and associated packages (Ihaka and Gentleman 1996, Maechler et al. 2005, R Development Core Team 2007, Oksanen et al. 2007).

**Preliminary Results**

Dividing sample wetlands into two groups is the most meaningful partition of these sites based on their vegetation. Specific conductance had no relationship with group membership (proportion of deviance explained = 0.03, p = 0.46). In contrast, bare ground was strongly predictive of group membership (proportion of deviance explained = 0.58, p = 0.0005, error rate = 0.08) (Figure 1). With two groups, Group 0 (light grazing pressure) and Group 1 (heavy grazing pressure), the probability of classification as Group 1 = \( \logit^{-1}(-3.24 + 0.10[\text{bare ground index}]) \). The predicted relationship between bare ground and group classification is a sigmoidal curve on the probability scale; however, for the average value of the bare ground index (=33), a 10 unit increase in bare ground increases the probability of a site being classified as Group 1 by 0.22. Given the strength of this association, we think these groups reflect a wetland's grazing intensity and distinguish between lightly and heavily grazed sites.
Ordination results show a good separation between lightly and heavily grazed sites for both wet meadow and marsh vegetation (Figure 2), implying that grazing intensity is an important factor in structuring these vegetation communities. Bare ground is significantly correlated with ordination axes for both ordinations (marsh ordination: $R^2 = 0.72$, $p < 0.001$, wet meadow ordination: $R^2 = 0.67$, $p < 0.001$), as is specific conductance (marsh ordination: $R^2 = 0.46$, $p < 0.001$, wet meadow ordination: $R^2 = 0.17$, $p = 0.048$). Ordinations have been rotated so that the variance among sites is maximized on the first dimension, and it appears that the importance of salinity (measured by specific conductance) increases relative to grazing intensity (measured by bare ground) for marsh vegetation when compared to wet meadow vegetation.

Aboveground vegetation biomass is significantly associated with both grazing intensity and specific conductance, although grazing intensity has a much greater effect ($R^2_{adj} = 0.66$, residual standard error = 20.38) (Table 1, Figure 3). For the wetlands sampled, a 10 unit increase in bare ground is associated with a 9.1 g/0.25 m$^2$ decrease in aboveground vegetation biomass and a 1 percent increase in salinity is associated with a 0.12 g/0.25 m$^2$ decrease in biomass.

Predictions of the breeding waterfowl models were consistent with last year's results: wetland size but not grazing intensity (at least as represented by the amount of bare ground) is a useful predictor of the number of dabbling breeding pairs and broods, while both variables are significant predictors of diver breeding pair and brood numbers (Table 2, Figure 4). For dabbling ducks, a 10 percent increase in wetland size is associated with a positive difference of 6.1 percent in the number of indicated breeding pairs and a positive difference of 7.1 percent in the number of broods. For diving ducks, a 10 percent increase in wetland size is associated with a positive difference of 6.3 percent in the number of indicated breeding pairs and a positive difference of 4.7 percent in the number of broods. Vegetation biomass is also a significant predictor of diving duck breeding use, with a 10 g/0.25 m$^2$ increase in biomass corresponding to a 24 percent increase in the number of breeding pairs and a 29 percent increase in the number of broods.
Figure 2. Ordination results for marsh and wet meadow vegetation (stress-based $R^2 = 0.97$ and 0.96, respectively). Ordinations have been rotated so that the first axis (NMDS 1) explains the greatest amount of variation. Lightly and heavily grazed sites are represented by green circles and red triangles, respectively. Vector labels refer to bare ground (bare), specific conductance (spcond), and pH. Only covariates that are significantly correlated with ordination axes are shown ($p \leq 0.05$); vector length corresponds to the strength of correlation.

Figure 3. Multiple linear regression showing the relationship of aboveground vegetation biomass with bare ground and specific conductance. Solid lines show predicted values and dashed lines show 95% confidence intervals for the specified term when the other term is held constant at its mean value. Lightly and heavily grazed sites are represented by green circles and red triangles, respectively.
Table 1. Coefficients, standard errors, and significance of model terms for an ordinary least squares regression of bare ground and specific conductance on aboveground biomass.

<table>
<thead>
<tr>
<th>Model Term</th>
<th>$\beta \pm 1 \text{ se}$</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>bare ground</td>
<td>-0.91 ± 0.12</td>
<td>-7.38</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>log(conductance)</td>
<td>-11.51 ± 4.24</td>
<td>-2.71</td>
<td>0.011</td>
</tr>
</tbody>
</table>

Discussion

Wetland vegetation is strongly controlled by abiotic factors such as hydrology and site chemistry (Keddy 2000). Our results are consistent with this assertion. Although we do not yet have measurements of site hydrology, water (and by extension, soil) chemistry was significantly correlated with vegetation composition. However, within the wetland class sampled, we found wetland vegetation to be strongly determined by the intensity of livestock grazing.

Grazing-related changes to wetland vegetation, in turn, are important for some types of breeding waterfowl. Our hypothesis that grazing reduces waterfowl pair use was corroborated for diving ducks. This effect was apparently due to grazing-related reductions in wetland vegetation biomass, which presumably limited the number of potential nest sites for most divers, or led to decreased success for initiated nests. The decrease in diving duck pairs may also have been mediated via changes to the aquatic invertebrate community, although we are not able to evaluate this yet. The absence of an observed impact on dabbling duck pair use was not entirely unexpected; these species tend to nest more often in upland vegetation, and grazing effects may have been manifested differently in these habitats. In terms of waterfowl brood use of wetlands, grazing reduced only diving duck brood use. The mechanism for this effect is less clear than for pairs; diver broods typically move to open water as an escape mechanism, and therefore, at this time of year, wetland vegetative cover is more important to them for its role in nurturing invertebrate (food source) communities. The lack of an observed impact on dabbling duck broods was unexpected, as dabbler broods typically use emergent vegetation as escape cover.

The strongly significant association between wetland size class and waterfowl use was consistent with several larger, long-term waterfowl breeding pair datasets compiled and maintained by DUC (Bruce Harrison, unpublished data). We are as yet unable to evaluate our hypothesis re the relative role played by wetland hydrology.

Model results using all sites were consistent with last year's analysis. For a more direct comparison of models between years, we reparamaterized last year's model by log-transforming wetland area instead of treating it as a second-order polynomial and fitting a quasi-Poisson instead of a negative binomial regression. Model coefficients and significance of terms and proportion of deviance explained were very similar, even though waterfowl breeding use was substantially greater in 2007 than 2006 (for the 2006 sites, 162 breeding pairs were observed in 2007 compared to 136 in 2006 and 83 broods were observed in 2007 compared to 60 in 2006).
Figure 4. Quasi-Poisson regression showing the relationship of dabbler and diver indicated breeding pairs (IBPs) and broods to wetland size and aboveground vegetation biomass. Solid lines show significant predicted values and dashed lines show 95% confidence intervals for the specified term when the other term is held constant at its mean value.
Table 2. Coefficients, standard errors, and significance of model terms of the predicted relationship between waterfowl breeding use, wetland size, and aboveground vegetation biomass based on a quasi-Poisson generalized linear model. IBPs are indicated breeding pairs.

<table>
<thead>
<tr>
<th>Model Term</th>
<th>$\beta \pm 1$ se</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dabbler IBPs</strong> (proportion of deviance explained = 0.28)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>log(wetland size)</td>
<td>0.61 ± 0.18</td>
<td>3.40</td>
<td>0.002</td>
</tr>
<tr>
<td>biomass</td>
<td>0.01 ± 0.004</td>
<td>1.76</td>
<td>0.088</td>
</tr>
<tr>
<td><strong>Dabbler Broods</strong> (proportion of deviance explained = 0.23)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>log(wetland size)</td>
<td>0.71 ± 0.27</td>
<td>2.61</td>
<td>0.014</td>
</tr>
<tr>
<td>biomass</td>
<td>0.01 ± 0.01</td>
<td>1.28</td>
<td>0.210</td>
</tr>
<tr>
<td><strong>Diver IBPs</strong> (proportion of deviance explained = 0.62)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>log(wetland size)</td>
<td>0.63 ± 0.14</td>
<td>4.38</td>
<td>0.0001</td>
</tr>
<tr>
<td>biomass</td>
<td>0.02 ± 0.004</td>
<td>6.09</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Diver Broods</strong> (proportion of deviance explained = 0.46)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>log(wetland size)</td>
<td>0.47 ± 0.23</td>
<td>2.07</td>
<td>0.046</td>
</tr>
<tr>
<td>biomass</td>
<td>0.03 ± 0.01</td>
<td>4.30</td>
<td>0.0002</td>
</tr>
</tbody>
</table>

**Changes to Experimental Design and Methods**

The overall experimental design and sampling methods will not change. In 2007, we pursued the use of a double-observer waterfowl brood sampling protocol to develop site-specific visibility correction factors, but were unsuccessful due to a lack of qualified local observers. A water chemistry sampling protocol was added to our sampling design in 2007. Water chemistry data collected included levels of total dissolved phosphorus, nitrogen as NH$_3$, sulfate, chloride, alkalinity, pH, and specific conductance. We will incorporate these data into our analyses this winter. We will also further develop our waterfowl analysis by including landscape-level predictors into our models of breeding waterfowl use. We will also improve our understanding of wetland hydrology through analysis of a historic dataset and by establishing and monitoring piezometers at selected wetlands. We have secured additional funding to expand the aquatic invertebrate component of the study. This work was begun this year and will include at least one more field season. We have also entered into a partnership with the BC Ministry of the Environment and will include an analysis of breeding amphibians at selected sample wetlands this winter.

Our plans for next year include collecting waterfowl, grazing disturbance, water chemistry data for all project wetlands. Invertebrate sampling will occur using a modified protocol. The 2008 field season will represent the third and final year of data collection.

**References Cited**


composition along livestock grazing intensity gradients in a Namaqualand (South Africa) protected area. Plant Ecology 176:19-33.


