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GREAT PLAINS RESEARCH

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CENTER FOR GREAT PLAINS STUDIES
UNIVERSITY OF NEBRASKA-LINCOLN

CENTER FOR GREAT PLAINS STUDIES

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GREAT PLAINS RESEARCH is a peer-reviewed, biannual, multidisciplinary science journal, which publishes original research and scholarly reviews of important advances in the natural and social sciences with relevance to the Great Plains region and with special emphases on environmental, economic, and social issues. It includes reviews of books.

Articles include:

- **original research findings**, such as have been published in *GPR* since 1991;
- **synopses** of the "state of the science" on topics relevant to the Great Plains;
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WORKPLACE RELIGIOUS ACCOMMODATION FOR MUSLIMS AND THE PROMISE OF STATE CONSTITUTIONALISM

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ABSTRACT—This article considers whether state constitutionalism provides greater possibilities for workplace religious accommodation than is currently available to religious minorities within federal law under Title VII of the Civil Rights Act of 1964. We approach this question via a case study of the controversy over religious accommodation for practicing Muslims employed by the JBS Swift and Company meatpacking plant in Grand Island, NE. The case study consists of analyses of the requirements for religious accommodation under federal law, examination of the reasons why religious accommodation under federal law was not achieved in the Grand Island case, and analysis of Nebraska constitutional law on the subject of religious free exercise. We find that the language in the Nebraska Constitution regarding protection of religious practice provides grounds for Muslims and other religious minorities in Nebraska to seek religious accommodations in the workplace through state government venues that they have been unable to achieve under federal law.

Key Words: accommodation, free exercise of religion, Muslims, Nebraska, state constitutionalism, Title VII, workplace

INTRODUCTION

This article considers whether state constitutionalism provides greater possibilities for workplace religious accommodation than is currently available to religious minorities within federal law under Title VII of the Civil Rights Act of 1964. In matters pertaining to pluralism, particularly religious pluralism, the dominant approach is to examine federal law and the U.S. Constitution for guidance. But while the parameters of our constitutional rights are set by federal authorities, the states may provide broader protections to these basic rights under their own constitutions, provided that they do not offend against the U.S. Constitution. For this reason, state law has a vital role to play in resolving tensions between majoritarianism on the one hand, and the values of religious pluralism and liberty on the other.

We approach this question via a case study of the controversy over religious accommodation for practicing Muslims employed by the JBS Swift and Company meatpacking plant in Grand Island, NE. First, we summarize the facts of the Grand Island case. Second, we consider the federal requirements for religious accommodation.

Third, we examine how religious accommodation for the Muslim employees at the plant was framed by the news media and public opinion. Fourth, we examine two competing constitutional frameworks for resolving tensions between economic interests and fundamental rights. Finally, we consider whether Nebraska's state constitution provides a suitable framework to secure religious liberty.

CASE BACKGROUND

Often short of laborers, packinghouses offer employment opportunities to a diverse array of new settlers, including practicing Muslims from Somalia. The JBS Swift and Company meatpacking plant in Grand Island, NE, became the locus for tensions between Muslim employees, predominantly Somali refugees, and other employees over religious accommodations that the Muslim employees sought in September 2008 during their holy month of Ramadan.

After hundreds of Muslim employees at the Grand Island plant staged a walk-out in protest for break time in which to pray, representatives of the Muslim employees negotiated an agreement with the plant managers and the

workers' union, United Food and Commercial Workers Union Local 22, to move the dinner break for workers on the evening B-shift 15 minutes earlier so the Muslim employees could pray and break their daylong fast shortly after sunset. The announced agreement provoked a much larger counterprotest by other workers, including Caucasian, Latino, and Christian Sudanese employees. The counterprotesters complained about favoritism toward the Muslim workers. The walk-out by the counterprotesters led to a temporary plant shutdown. The agreement with the Muslim employees was subsequently withdrawn, leading some of the Muslim workers to again walk off the job or quit in protest. According to the workers' union, 86 employees, mostly Muslim, were fired due to unauthorized absences from work during the controversy.

The need for workers seems to suggest that the meatpacking industry is willing to accommodate the religious requirements of its employees. Meatpacking is physically demanding and dangerous work (Nebraska Appleseed Center 2009). The nature of the work shapes the boundaries of accommodation, because the workers on shift must take their breaks all at the same time. The accommodation negotiated in the Grand Island case entailed a change in the work schedule that affected all employees on the shift, not just the Muslim employees. Although the management and the union were willing to make the change, the other employees resented being forced to a change they did not seek or desire. The other workers' refusal to agree to the change made the accommodation impossible and caused hardship to the plant in work stoppage, reductions in personnel, and verbal altercations between the opposing groups that disrupted plant operations.

RELIGIOUS ACCOMMODATION UNDER FEDERAL LAW

Freedom of religion under federal law is protected by the First Amendment. Its two clauses focus on complementary aspects of religious liberty, for the establishment clause seeks to define the limits on government's activities pertaining to religion, while the free-exercise clause seeks to define the extent of the individual's right to religious practice. The issue of workplace religious accommodation lies along the intersection of these two aspects of religious liberty, raising such questions as these: How far does the individual's right of religious free exercise extend into the workplace? How far may the government go in obliging private employers to accommodate the religious practices of their employees? In regulating religious accommodation in the workplace, does the government

entangle itself so extensively in the policing of religious belief and practice that the result is an establishment of religion? In order to understand the context for religious accommodation under Title VII, we first must understand the U.S. Supreme Court's interpretations of the establishment and free-exercise clauses. We turn now to a brief consideration of the relevant First Amendment case law.

In defining the extent of the right to free exercise of religion, the Court applied a compelling interest test in *Sherbert v. Verner* (374 U.S. 398 [1963]). The petitioner in the case, Ms. Adeil Sherbert, was denied unemployment compensation after being discharged from her job for refusal to work on Saturday, the day of Sabbath in the Seventh-Day Adventist Church of which she was a member. The Court ruled that the state of South Carolina imposed a burden on Ms. Sherbert's exercise of her faith with its restrictive qualifications for unemployment benefits, and that such a burden could only be justified by a compelling state interest achieved by narrowly tailored means; the Court found that no compelling state interest was present in Ms. Sherbert's case. The *Sherbert* rule was used subsequently in several additional cases in which state unemployment benefits were denied to employees who were terminated over conflicts between their work responsibilities and their religious beliefs (*Thomas v. Review Board of the Indiana Employment Security Division*, 450 U.S. 707 [1981]; *Hobbie v. Unemployment Appeals Commission of Florida*, 480 U.S. 136 [1987]; *Frazee v. Illinois Department of Employment Security*, 489 U.S. 829 [1989]).

The *Sherbert* compelling-interest test was transformed into a test for intentional discrimination in *Employment Division, Department of Human Resources of Oregon v. Smith* (494 U.S. 872 [1990]). In the *Smith* case, two Native Americans were denied unemployment compensation after being discharged from their jobs for use of peyote in their church's religious rituals. The use of peyote was illegal under Oregon state law, even for religious purposes. The Court found that a generally applicable law, such as Oregon's drug law, was valid despite the burden that it may place on an individual's religious practices, as long as the law did not intentionally discriminate based on religion. So whereas under *Sherbert*, incidental burdens on religious free-exercise were deemed unconstitutional unless the means were narrowly tailored to achieve a compelling state interest, since *Smith*, incidental burdens on religious free-exercise are permissible; only religious bigotry made into law violates the U.S. Constitution.

As Duncan (2005:1185–86) has observed, the *Smith* Court “transformed” rather than overturned the precedent

in *Sherbert*. For example, if a state permits unemployment compensation based on an individualized evaluation of whether the applicant had “good cause” to refuse work, to deny benefits to an applicant who refused work for religious reasons is to demonstrate intolerance for religion. Thus the law defining eligibility for unemployment benefits would be neither neutral nor generally applicable, and so subject to strict scrutiny. Duncan believes that the *Smith* ruling holds promise for religious-liberty petitions against “public schools, state universities, governmental employers, and state agencies. [Because w]herever there are rules in government schools and bureaucracies, there is almost always a process for seeking a discretionary waiver of (or exemption from) those rules” (Duncan 2005:1187–88). When government agents are given discretion in the granting of exemptions, a paramount question will arise as to whether religious bases for seeking exemptions are considered equally with secular bases.

The principle that the government is to maintain neutrality regarding religion is central to jurisprudence on the establishment clause. The controlling case for establishment issues is *Lemon v. Kurtzman* (403 U.S. 602 [1971]). The Court’s opinion in that case developed a three-pronged test to determine religious establishment, now called the “Lemon Test.” To pass constitutional muster, actions of government must (1) have a secular purpose; (2) in their principal effect, neither advance nor inhibit religion; and (3) not create “excessive entanglement” between government and religion. The challenge for religious-accommodation statutes lies in the third prong of the Lemon Test, since it is possible that scrutinizing the faith of those requesting accommodation in order to determine whether the request is legitimate might cross the line into “excessive” entanglement of the government into religious matters. In the *Lemon* case itself, state laws providing financial aid to church-affiliated schools to support the instruction of secular subjects were deemed unconstitutional, due in part to the excessive entanglement into the church’s business that was expected from the state’s need to ensure that its money was spent as the statute prescribed.

The requirement for employers to provide religious accommodation to their employees derives from Title VII of the Civil Rights Act of 1964, which was clarified by the 1972 amendments to Title VII, particularly Section 701(j). Reasonable religious accommodation is mandated, unless it would create “undue hardship on the conduct of the employer’s business” (42 U.S.C. 2000e(j) [1970 ed. Supp. V]). The exact parameters of the protection for religious belief, practice, or observance remain

uncertain, because the legislature provided little guidance on what constituted “reasonable” accommodation or what hardships should be regarded as “undue.”

The U.S. Supreme Court interpreted undue hardship expansively in *TransWorld Airlines v. Hardison* (432 U.S. 63 [1977]). In denying religious accommodation to a TransWorld Airline (TWA) employee whose religious beliefs forbade him to work on Saturday, his religion’s day of Sabbath, the Court found that it would constitute an undue hardship for TWA to circumvent a seniority system that was part of the collective bargaining agreement with the employees’ union in order to assign another employee to work Mr. Hardison’s Saturday shift. The Court stated:

It was essential to TWA’s business to require Saturday and Sunday work from at least a few employees even though most employees preferred those days off. . . . [T]o give Hardison Saturdays off, TWA would have had to deprive another employee of his shift preference at least in part because he did not adhere to a religion that observed the Saturday Sabbath. (80–81)

So in the Court’s estimation, Hardison’s religious requirement to keep the Sabbath carried no additional weight or force than the nonreligious reasons that other employees had for wishing to have Saturdays off.

Central to the Court’s reasoning in *TWA v. Hardison* was a concern about “unequal treatment of employees on the basis of their religion” (84). As the quotation above makes clear, the Court viewed it as unreasonable for another employee to be required to work a Saturday shift against his/her preferences in Hardison’s place. To reinforce the point, Justice White ends the Court’s opinion as follows: “[W]e will not readily construe the [Title VII] statute to require an employer to discriminate against some employees in order to enable others to observe their Sabbath” (85). Based on the reasoning the Court employed in this case, it appears that any accommodation that affects another employee may be deemed unreasonable; an exception would be if the accommodation involved finding another employee to *volunteer* to swap shifts (81).

Justice Marshall, in his dissenting opinion in *TWA v. Hardison*, finds the Court’s lack of concern for religious pluralism troubling. He challenges the Court’s determination that it is impermissible for an employer to allocate privileges on the basis of an employee’s religious beliefs:

The accommodation issue by definition arises only when a neutral rule of general applicability conflicts with the religious practices of a particular employee. . . . [T]he question is whether the employee is to be exempt from the rule's demand. To do so will always result in a privilege being "allocated according to religious beliefs," ante, at 85, unless the employer gratuitously decides to repeal the rule in toto. (87–88)

Implicit in Marshall's dissent is a complaint that the Court interprets the requirements of accommodation too narrowly. It follows that, if employers are not required to exempt employees from generally applicable workplace rules in order to accommodate religion, then employees like Mr. Hardison are forced to choose between their jobs and their faith.

Although the language of Title VII seemingly would require employers to bear some hardships, just not "undue" ones, the Court's holding in *TWA v. Hardison* blurs to the point of erasing this distinction. In its reversal of the decision of the Court of Appeals, the Court also refutes the appeals court's suggested means of providing accommodation to Mr. Hardison, including permitting him to work a four-day week or paying premium wages to another employee to incentivize volunteers to work the less-desirable Saturday shift. In rejecting these options as unreasonable, the Court stated: "Both of these alternatives would involve costs to TWA, either in the form of lost efficiency in other jobs or higher wages" (84). The Court's reasoning suggests that any additional costs for TWA constitute an undue hardship.

The Court's interpretation of the reasonableness and undue hardship standards under Title VII is of course reflected in the Equal Employment Opportunity Commission's (EEOC) compliance manual on religious discrimination. The compliance manual instructs on the undue hardship standard as follows: accommodation creates an undue hardship "where the accommodation diminishes efficiency in other jobs, infringes on other employees' job rights or benefits, impairs workplace safety, or causes co-workers to carry the accommodated employee's share of potentially hazardous or burdensome work" (Equal Employment Opportunity Commission 2008). The EEOC explicates undue hardship in the context of scheduling changes and shift swapping as follows: "it would pose an undue hardship to require employees *involuntarily* to substitute for one another or swap shifts, [however] the reasonable accommodation requirement

can often be satisfied without undue hardship where a volunteer with substantially similar qualifications is available to cover" (Equal Employment Opportunity Commission n.d., "Questions and Answers," emphasis in original). Following the Court's direction, the EEOC has defined any involuntary change in work scheduling in order to accommodate the religious needs of an employee to be an undue hardship on the employer.

A Freedom of Information Act request to the St. Louis district office of the Equal Employment Opportunity Commission produced the following information regarding Title VII complaints about religious discrimination in the state of Nebraska. Between October 1, 2003, and September 30, 2009, there were 358 allegations of religious discrimination made to the Nebraska Equal Opportunity Commission and 178 formal charges were filed. Eighty-six of the charges are still open, and 92 have been closed. Of the closed charges, 88 were closed by a no-cause finding being issued, one was an administrative closure, two were closed because the complaining party withdrew or failed to cooperate, and one was closed by issuance of a Notice of a Right to Sue, which indicates that the complaining party was given permission to file a lawsuit against their employer but that the EEOC found an insufficient basis to pursue the claim. These statistics demonstrate that complaints about religious discrimination against Nebraska employers nearly always resolve in favor of the employer, in keeping with the expansive interpretation of undue hardship that the Court and EEOC employ. It is important to recognize that overall, few Title VII charges are resolved in the complaining party's favor. The EEOC's national statistics for fiscal year 2009 report that, of the 68,710 charges filed, less than one in five (19.9%) were closed with a favorable outcome for the complaining party (merit resolutions) (Equal Employment Opportunity Commission n.d., Title VII charges). No doubt some of the other 80.1% of charges genuinely were without merit, but the test used to weigh these charges also clearly favors the employer.

Prekert and Magid (2006) develop what they term a "Hobson's choice model" as a framework for determining how religion should be accommodated. Their model prescribes a review to establish the sincerity of the employee's religious belief, practice, or observance. It also prescribes that the employer produces concrete evidence of undue hardship. Under their framework, a reasonable accommodation would weigh the evidence of hardship against the evidence of the significance of religion to the employee. The difficulty with such a balancing test is that hardship for the employer could be easily quantified in

economic terms, while the religious sincerity of the employee or the consequences to the employee of violating the tenets of his or her religion in order to meet obligations of employment would be difficult or impossible to quantify. This disparity makes it unlikely that “weighing” hardship against sincerity could produce predictable protections for workers seeking religious accommodation. In addition, as previously mentioned, an attempt to evaluate the employee’s sincerity may run afoul of the third prong of the Lemon Test, entangling government in religion to the extent of violating the establishment clause.

More helpfully, Prenkert and Magid’s model recommends disentangling charges of disparate treatment from religious accommodation. They note that the “notion of neutrality toward religion, which is the hallmark and goal of disparate treatment, is present in situations calling for accommodation. As a result, it remains important to keep the two claims distinct” (Prenkert and Magid 2006:510). In situations calling for accommodation, the religion-neutral, generally applicable work rule or policy conflicts with the employee’s religious belief, practice, or observance. Exempting the employee from the rule or policy will not be religion-neutral, as Justice Marshall also noted in his dissent to *TWA v. Hardison*. When disparate treatment is conflated with religious accommodation, the effect is to undermine the reasoning in support of accommodation. The Supreme Court, in its 1990 *Smith* decision, ruled that the free-exercise clause does not require the granting of religious exemptions from generally applicable laws. This reasoning implies the same principle for workplace accommodation: neither are employers required to exempt employees from generally applicable workplace rules or policies. However, there is one area of discrimination law in which accommodation is regarded as necessary to equality in the workplace rather than being regarded as special or disparate treatment. In this regard, accommodation within the context of the Americans with Disabilities Act (ADA) provides a useful comparison.

Christine Jolls has argued that the disparate impact liability under Title VII overlaps with accommodation under ADA, because contrary to disparate treatment claims, disparate impact “occurs when employers rely on facially neutral practices that cause disproportionate harm to a particular group of employees and are not justified by job relatedness and business necessity” (Jolls 2001:647). There is a clear similarity between the two types of claim in that the policy at issue is neutral and claimants need not demonstrate intent to discriminate. However, a crucial difference remains:

The standard judicial remedy in a Title VII disparate impact case requires the employer to change the policy or standard for everybody, not just the protected group. . . . By contrast, a successful ADA reasonable accommodation case requires the employer to take special steps to [benefit] a particular group, but not for everybody. (Schwab and Willborn 2003:1238)

The accommodation requirement in ADA places greater burdens on employers than does the accommodation requirement under Title VII. As Schwab and Willborn (2003) observe:

Under Title VII’s disparate impact doctrine, the courts explicitly look for economic costs. If found, the analysis ends and the employer wins. . . . The ADA, at its core, requires employers to absorb these costs unless they are unreasonable or create an undue hardship; Title VII, at its core, avoids imposing these costs on employers. (1246)

To achieve its goal of integrating persons with disabilities as full participants in the workforce and the society, the ADA acts as an affirmative action policy, requiring employers to treat qualified employees with disabilities more favorably than others, even if they cost more to employ or are less productive (Schwab and Willborn 2003:1204). Title VII seeks to eliminate bias against individuals based on characteristics such as race, sex, religion, national origin, or other characteristics that are deemed irrelevant to employment, but not to function as affirmative action for individuals from those groups.

Even though the ADA statute mimics the language of Title VII regarding “reasonable accommodation” and “undue hardship,” the standards for accommodation of disabled persons are quite different from the standards for accommodation based on religion. As Schoenbaum explains, both statutes prohibit employers from making adverse decisions about employment based on a prospective employee’s disabilities or protected traits. This prohibition is defensible as a means to prevent discrimination in the hiring process, but it obstructs accommodation once the person is employed:

The limitations on preemployment inquiries construct who the applicant is to the employer, determining which characteristics are relevant to the employment relationship and which

are relegated to the realm of the personal. Removing these facets of people's lives from consideration creates a very particular vision of the model employee—white, male, straight, middle-class, not primary caregiver, not disabled, of an unobtrusive religious faith, speaking English as a primary language—because these are the default traits that are assumed to fit the structure of the overwhelming majority of American workplaces today. (Schoenbaum 2007:120)

The prohibition on preemployment inquiries is supposed to foster impartiality, but in practice it may “disguise how the particularized views of dominant groups appear universal” and make accommodation requests “appear as particularized claims for special interests rather than elements that have been ignored by the supposedly neutral standard” (Schoenbaum 2007:122). In this regard, an advantage of the ADA standards for reasonable accommodation is that after the hiring decision, the ADA reaffirms the relevance of the person's trait—disability—to the employment relationship “by requiring employers to accommodate employees' traits that fall outside the stereotype of the model employee” (Schoenbaum 2007:141). The ADA defines employment discrimination as, among other things, a failure to make “reasonable accommodations to the known physical or mental limitations of an otherwise qualified individual with a disability” (quoted in Emens 2008:877). Title VII, of course, also prohibits discrimination based on religion, using both a similar structure and similar language to the ADA statute. But because of the Court's expansive rendering of “undue hardship” for employers under Title VII, in practice the ADA accomplishes what Title VII does not—it makes clear that accommodation is essential to achieving the goal of *equality* within the workplace rather than construing accommodation as *special treatment* for a particular group of employees.

As was discussed earlier in the case background section, JBS Swift and Company was prepared to make a reasonable accommodation to the plant's Muslim employees, but the agreement was abandoned due to a backlash from other plant employees who regarded the accommodation as special treatment for the Muslim employees. The consequences of the other employees' opposition to the accommodation created hardship for the plant; the accommodation itself did not. Thus it is important to understand how the religious accommodation issue was perceived in the local community. The

following section provides some empirical information on these matters.

NEWS FRAMING AND PUBLIC OPINION ABOUT RELIGIOUS ACCOMMODATION

Local News Coverage of the Controversy

Because the primary obstacle to religious accommodation for the Muslim workers at the Grand Island plant was opposition to the accommodation from non-Muslims, it is important to understand how the controversy was covered in the local press. Perceptions about issues are shaped by the manner in which information about the issues is framed. Local news reporting gives us a systematic means of examining how information about the controversy was framed within the Grand Island community.

The data reported in this section consist of content analyses of the news articles and editorials about the JBS Swift and Company Grand Island plant controversy that were published in the sole local newspaper, the *Grand Island Independent*. The articles were located on the *Grand Island Independent* website, which contains a searchable archive. A search was conducted using the terms “JBS Swift Muslim,” which returned 19 valid articles. (Duplicate articles from later editions, letters to the editor, and articles in which the plant controversy was not the focus were eliminated from analysis, though letters to the editor were examined separately for insights into how the public responded to this news coverage—see below.)

Each article was coded for the presence or absence of particular content: (1) an explanation of the requirements for religious accommodation under Title VII; (2) an explanation of the religious observances required of practicing Muslims during Ramadan; (3) claims about hardship to the plant from providing religious accommodation to Muslim workers; (4) characterization of the accommodation agreement as inequitable to other employees; (5) characterization of the controversy as an interracial or interreligious conflict; and (6) connection of the controversy to immigration raids on the meatpacking industry.

Only one article (5%) provided an explanation of the requirements for religious accommodation under Title VII. The absence of this content from the immense majority of the articles suggests that religious accommodation for the Muslim workers was not framed as a legal obligation for the plant. The community may have been more supportive of religious accommodation for the Muslim

workers if it had been better informed of the federal law that prompted the request for accommodation from the Muslim employees and the attempted agreement negotiated by the plant management and the workers' union.

Less than one-third (32%) of the articles provided an explanation of the religious observances required of practicing Muslims during Ramadan. The community may have been more supportive of religious accommodation for the Muslim workers if they had been better informed of the religious significance of Ramadan to Muslims and of the reasons why the Muslims needed to pray and to end their fasting at sunset, rather than later in the evening at the time the dinner break was usually scheduled. By contrast, nearly two-thirds (63%) of the articles included claims about hardship to the plant from providing religious accommodation to Muslim workers. These results demonstrate that the local news coverage of the controversy was not balanced; the coverage favored reasons to oppose the accommodation over reasons to support it.

A majority (53%) of articles characterized the accommodation agreement as inequitable to other employees at the plant. This framing reinforced the idea that the religious accommodation amounted to favoritism of the Muslim employees. The value of majoritarianism was elevated over the value of religious pluralism.

Slightly less than a majority (47%) of articles framed the controversy as an interracial or interreligious conflict. It was more common for articles to identify the counterprotesters simply as "non-Muslims" rather than to describe the counterprotesters as well as the workers seeking religious accommodation in racial or religious terms. While this characterization seems defensible for the purpose of brevity, a simplifying descriptor of a group that was both racially and religiously diverse, the effect of this framing is also to elevate the value of majoritarianism. If both groups involved are described in religious and/or racial terms, then the reader is primed to evaluate the controversy in the context of pluralism. But when only one group is described in religious or racial terms, the reader is primed to evaluate the controversy in the context of majoritarianism—it's "us" versus "them."

Only one article (5%) in the *Grand Island Independent* connected the controversy at the plant to immigration raids on the meatpacking industry. And in that article, the only connection was through a claim from one of the striking workers, who was quoted as saying that plant management had used immigration status to try to silence some of the Latino counterprotesters (Overstreet 2008). In coverage that the Grand Island controversy received from news outlets *outside* the local community, the im-

migration frame was more common. An *Omaha World-Herald* article included immigration in a list of the factors complicating the controversy: "religion, culture clashes, refugee resettlement, immigration, union contracts, and factory demands in an increasingly diverse American work force" (Burbach 2008). And a *New York Times* story also gave the immigration frame prominence in its coverage, starting with its headline "A Somali Influx Unsettles Latino Meatpackers." The article's central message is encapsulated in this quotation: "But the dispute peeled back a layer of civility in this southern Nebraska city of 47,000, revealing slow-burning racial and ethnic tensions that have been an unexpected aftermath of the enforcement raids at workplaces by federal immigration authorities" (Semple 2008). Here we see that the nonlocal coverage framed the controversy as an interracial conflict between Somalis and Latinos and identified the immigration raids aimed at Latino workers as a precipitating cause.

It is uncertain why the local paper's coverage eschewed the immigration frame. But opposition to illegal immigration is prevalent in Republican-dominated areas of the country such as Nebraska: A Pew Research Center national survey from March 2006 showed that Republicans were substantially less likely than Democrats to say that illegal immigrants should be allowed to stay in the United States permanently (Pew Research Center 2006). Considering this opposition, it is likely that the use of an immigration frame would have made the public less sympathetic toward the Latinos' side in the controversy and thus possibly more sympathetic toward the Somalis' side.

We wish to be clear that the preceding analysis makes no claims about the reporters' or editors' intentions in covering this controversy. We observe the patterns in the coverage and find their messages to be skewed against religious accommodation, but this bias is likely to be unintentional. The conventions of news reporting may lead to interpretations and constructions that appear so natural that they are invisible to the reporters themselves (Edelman 1988).

Public Opinion about Muslims and Religious Accommodation

The Pew Research Center's annual Religion and Public Life Survey demonstrates that the non-Muslim public tends to see Islam as different from their own beliefs (Pew Research Center 2009). Sixty-five percent of the respondents not affiliated with Islam described Islam as very or somewhat different from their own beliefs. And those

who regarded Islam as different from their own beliefs were also more likely to say that they had an unfavorable view of Muslims. Sixty-five percent of those who thought Islam was similar to their own religion reported a favorable view of Muslims; among those who thought Islam was different from their own religion, only 37% were favorable toward Muslims.

Though the respondents were able to offer opinions as to the similarity or difference of Islam to their own religion, the public's level of knowledge about Islam is not high. Only slight majorities of respondents (53% and 52%, respectively) were able to answer correctly that Allah is the name Muslims use for God or that the Koran is the Islamic equivalent to the Bible, and less than a majority (41%) answered both questions correctly (Pew Research Center 2009). These data illustrate why it would have been important for the local news coverage to provide readers with information about Ramadan, its required observances, and its significance to practicing Muslims. It is clear that the mass public has a limited understanding of Islam.

Letters to the editor published by the local newspaper give us a systematic means of examining public perceptions of the controversy within the Grand Island community. The data reported in this section consist of content analyses of letters to the editor that were published in the *Grand Island Independent*. Three letters directly addressed the JBS Swift and Company controversy, and all three took positions opposed to the religious accommodation for Muslim workers. One characterized the Muslim workers as "trying to impose their religion" on others, and while the letter writer praised the Muslim workers for their strong beliefs, he also asserted that "Catholics, Jews, Evangelicals, Seventh Day Adventists," and any other religious groups' adherents do not expect to "just stop [their work] at a specified time to pray" (Letter 2008b). Another queried: "Didn't these people know the working hours of Swift when they accepted employment?" (Letter 2007). And he wondered whether Swift allowed its employees who are adherents of other religions "to take time off to practice their various rituals and rites." These letters reflect the framing of the *Independent's* news coverage of the controversy, emphasizing hardship to the plant and characterizing any religious accommodation as favoritism for the Muslim workers and inequitable to other workers. Another letter writer described herself as "disgusted" with the actions of the Somali protesters at JBS Swift, questioning their claims of requiring special religious accommodation ("Muslims do not have a specific time to pray"), the sincerity of their religious faith, and

their loyalty to the company (Letter 2008a). This writer praised other Muslims at the plant ("both Arabic and European") and described Islam as a "peaceful religion," but she strongly condemned the Somali workers and their requests for religious accommodation.

Perhaps this controversy did not capture the attention of the broader community enough to motivate extensive letter-writing or other widespread demonstrations of community opinion. But those few who were motivated to write were all clearly opposed to JBS Swift providing a religious accommodation to its Muslim employees. In this regard, the community opinion is consistent with the opposition expressed by the JBS Swift and Company plant employees whose counterprotests forced management to rescind its offer of religious accommodation. It is clear that they regarded religious accommodation as special treatment or favoritism toward the Muslim employees rather than a means of achieving equality in the workplace for employees who were particularly harmed by the later timing of the B-shift's dinner break.

CONSTITUTIONALISM, EFFICIENCY, AND VALUES

The tension apparent in religious accommodation cases is between economic efficiency and the protection of a fundamental right. In a simple and homogeneous community, this tension may be easily resolved. In a complicated and diverse community, matters are not so easy. As Laurence Tribe has noted, the U.S. Supreme Court has increasingly adopted a utilitarian approach that tends to favor economic efficiency (Tribe 1985). The Court's interpretations of the reasonableness and undue hardship standards under Title VII reflect this approach. But as Tribe argues, utilitarian jurisprudence effectively undermines the purpose of judicial review, a written constitution, and particularly an articulation of fundamental rights: "That purpose, of course, is to ensure that certain principles will not be sacrificed to expediency" (Tribe 1985:613). Even when a religious accommodation results, the process of attempting to weigh on a common metric the hardship on the employer in comparison to the employee's sincerity of religious belief, practice, or observance seems to slight the very idea of fundamental rights. As Tribe explains:

Being "assigned" a right on efficiency grounds, after an appraisal of the relevant cost curves, hardly satisfies the particular human need that can be met only by a shared social and legal

understanding that the right belongs to the individual because the capacity and opportunity it embodies are organically and historically a part of the person that she is, and *not* for any purely contingent and essentially managerial reason. (Tribe 1985:596, emphasis in original)

In the JBS Swift case, the responses of the other employees at the plant as well as the community (as represented by the news framing and letters to the editor) demonstrate the lack of a shared social understanding that a right to free exercise of religion is essential, a problem compounded by what Tribe terms “the inadequacy of technocratic jurisprudence” (599).

Laurence Tribe’s framework would require constitutional interpretation from judges cognizant of their constitutive role: “[C]onstitutional choices affect, and hence require consideration of, the way in which a polity wishes to *constitute* itself. In making such choices, we reaffirm and create, select and shape, the values and truths we hold sacred” (Tribe 1985:595, emphasis in original). But this role for the courts is not embraced by all. As any observer of judicial politics in the United States will recognize, constitutional scholars and judges themselves have varying perspectives on the proper approaches to constitutional interpretation and on the proper responsibilities of the courts relative to other political actors. The framework espoused by Tribe is challenged by others, notably Frank Easterbrook.

In his reply to Tribe, Frank Easterbrook argues that “we get nowhere by listing values unless we have both a metric by which to assess the claims the parties make and a legitimate rule of decision” (Easterbrook 1985:626). According to Easterbrook, the benefit of economic analysis, even when it is incomplete, is that it provides information about the likely effects of the Court’s decisions. In Easterbrook’s framework, absent clear social consensus and/or more specific directives from the political branches, the judiciary lacks the authority to decide to prioritize religious pluralism over economic efficiency. However, a utilitarian approach to jurisprudence is itself a decision to prioritize economic efficiency. Because the “costs” to employers of making an accommodation can be readily quantified and the “costs” to employees of violating their faith cannot, a quest for efficiency rigs the outcome against religious accommodation.

The debate about how to balance economic interests with the protection of liberty and diversity, sketched here in the exchange between Lawrence Tribe and Frank

Easterbrook, echoes across a range of issues. These are difficult questions, and citizens as well as lawmakers and scholars are confounded by the challenge of how best to reconcile competing goods. It is important to be cognizant of the trade-offs as the search for better public policy continues.

STATE CONSTITUTIONALISM AND RELIGIOUS LIBERTY: THE NEBRASKA EXPERIENCE

If constitutions serve as contracts for the polity to pursue its political, social, and economic rights and liberties, then it is appropriate to compare constitutions in order to determine which constitutional texts and practices may provide the polity with the greatest possible freedom and security. A.E. Dick Howard underscores the importance of comparative constitutionalism, particularly in the area of human rights:

It is hard to imagine drafters of a new constitution going about their task unconcerned about human rights standards. . . . And judges, wherever they come down on the uses of comparative data, cannot escape thinking about the question of whether they should look only to domestic sources or also to those from other countries or those based on international law. (Howard 2009:18)

While much attention focuses on national constitutions, much can also be gained by examining state constitutions. Indeed, elsewhere Howard emphasizes the theoretical importance of a state constitution: “A state constitution is a fit place for the people of a state to record their moral values, their definition of justice, and their hopes for the common good. A state constitution defines a way of life” (Howard 1998:14). Thus Howard’s description of a state constitution reflects Tribe’s argument that the *constitutive* function of constitutional interpretation must not be neglected or forgotten. Of course, it is incumbent upon public officials to ensure that a social contract so constituted includes all. One complexity of the social contract at the state level concerns the incorporation into the community of new members, particularly when those members increase the diversity of the community. As is evident in the Grand Island case, the incorporation of refugees from Somalia into the central Nebraskan community has strained tolerance for diversity. Does Nebraska’s constitution define the good life to include full membership and justice for these newest members of

its polity? We turn now to a consideration of Nebraska's state constitution.

One of the earliest constitutional cases involving religion in the state of Nebraska was *State ex rel. v. Scheve* (65 Neb. 853 [1903]). This case held that it was the duty of the state to "protect every religious denomination in the peaceable enjoyment of its own mode of public worship" (878), echoing the constitutional language on religious freedom (Neb. Const. art. I, sec. 4 [1875]). This case underscores that the Nebraska Constitution does not allow the state to discriminate among religions, and beyond a mere requirement of neutrality, the state has a duty to protect religious practices. Thus religious pluralism constituted a feature of Nebraskans' self-definition from its founding, yet subsequent decisions were not so inclusive, particularly when the religious practices of newer residents entailed worship in another language.

In the years that preceded World War I, citizens of the United States were psychologically and politically prepared to respond to international events with nationalistic enthusiasm. Many people feared that German Americans suffered from divided loyalties (Gaffney 2001). Nebraska was no exception, and the constitutional history of Nebraska's language law reveals an ongoing tension over the treatment to be extended to new residents who persisted with "foreign" ways.

In *Nebraska District of Evangelical Lutheran Synod of Missouri v. McKelvie* (104 Neb. 93 [1919]), the court upheld Nebraska's foreign language law, which prohibited the teaching of any subject in a language other than English and included private and parochial as well as public schools in the restriction (Chapter 249, Laws 1919). Foreign-language-speaking parents, certain church corporations, and private schools requested an injunction to restrain enforcement of Chapter 249, Laws 1919. The issues of the case included the rights of parents to direct the religious and educational upbringing of their children. In addressing the underlying purpose of the law, the Nebraska Supreme Court stated:

It is a matter of general public information, of which the court is entitled to take judicial knowledge, that it was disclosed that thousands of men born in this country of foreign language speaking parents and educated in schools taught in a foreign language were unable to read, write or speak the language of their country, or understand words of command given in English. It was also demonstrated that there was a local foci of alien enemy sentiment,

and that, where such instances occurred, the education given by private or parochial schools in that community was usually found to be that which had been given mainly in a foreign language. (97)

Finding that the act was intended to address these concerns, the court interpreted the language law in conjunction with the compulsory education act, Chapter 155, Laws 1919. That statute contained a specific provision stating that the act should not be construed so as to interfere with religious instruction in private or parochial schools. As a result, the court held that the purpose of the language law was to abolish instruction in foreign language in elementary schools in subjects that were required to be taught under the law. The court determined that nothing in the law prohibited religious instruction in a foreign language, provided that such instruction did not interfere with the teaching of those subjects legally required to be taught to children.

In narrowing the scope of the Nebraska language law, the court balanced the liberty interest of parents in directing the religious and educational upbringing of their children, while upholding the limitation on instruction in a foreign language. In so doing, cultural pluralism was preserved to a certain extent, while the passions of the citizenry were tempered.

Meyer v. Nebraska (107 Neb. 657 [1922]) was a second challenge to the constitutional legitimacy of the Nebraska language law. In that case, Robert T. Meyer, a parochial schoolteacher, provided instruction to a student in the German language using a book of biblical stories. Meyer asserted that German language instruction was necessary for children to understand and practice the religion of their parents. In finding Meyer guilty, the opinion of the court provides a glimpse into the popular sentiment that prevailed during the era:

The legislature had seen the baneful effects of permitting foreigners, who had taken residence in this country, to rear and educate their children in the language of their native land. The result of that condition was found to be inimical to our own safety. To allow the children of foreigners, who had emigrated here, to be taught from early childhood the language of the country of their parents was to rear them with that language as their mother tongue. It was to educate them so that . . . [their] sentiments [are] foreign to the best interests of this country. (661–62)

Drawing a distinction between religiously motivated conduct and religious beliefs, the court determined that the legislation was constitutional, finding that the burden on religious conduct was outweighed by the governmental purpose espoused by the statute.

On appeal, the U.S. Supreme Court repudiated the Nebraska legislation limiting instruction in a foreign language (*Meyer v. Nebraska*, 262 U.S. 390 [1923]). The Court noted that parental rights and religious liberty were included within the purview of the 14th Amendment. Liberty interests included within the 14th Amendment could not be infringed by legislative action that was arbitrary or without reasonable relation to a legitimate state interest. Recognizing the legislative purpose of the Nebraska language law, the Court stated:

That the state may do much, go very far, indeed, in order to improve the quality of its citizens . . . is clear; but the individual has certain fundamental rights which must be respected. . . . [A] desirable end cannot be promoted by prohibited means. . . . The desire of the legislature to foster a homogeneous people with American ideals prepared readily to understand current discussions of civic matters is easy to appreciate. . . . But the means adopted, we think, exceed the limitations upon the power of the State and conflict with rights assured to plaintiff in error. (401–2)

The state government's decisions regarding Nebraska's language law serve as a reminder that state government is not always the best venue for a jurisprudence accepting of diversity. Local passions were eventually tempered by federal institutions, consistent with the constitutional framework originally designed by the framers. Yet elements of Nebraska's constitutionalism do offer the promise of inclusivity with respect to religion.

Despite the restrictive applications of the Nebraska language law, Nebraska's constitution is unusually expansive in its protection of religion. The Nebraska Constitution states an affirmative duty to protect religion: "It shall be the duty of the Legislature to pass suitable laws to protect every religious denomination in the peaceable enjoyment of its own public worship and to encourage schools and the means of instruction" (Neb. Const. art. I, sec. 4 [1875]). This passage provides a normative dimension favorable to religious pluralism. As Calabresi and Agudo (2008:40) noted, Nebraska's state constitution (as

well as those of Texas and Ohio, which contain similar provisions) is distinctive:

These clauses are noteworthy because they provide for a positive duty on government to foster religious free exercise, rather than producing only a negative bar on government interferences with religious free exercise. These clauses also protect the freedom of worship, which may involve action, and not simply freedom of conscience or belief.

Nebraska's current constitutional structure offers a blueprint for securing religious pluralism and extending religious liberty protections even to those, such as the Muslim employees of JBS Swift and Company, whose requirements for worship do not mesh well with the established practices and routines of the majority. If public worship for Muslims during the month of Ramadan requires that worshippers daily break their fast and pray at or near sunset, and if adjusting the timing of dinner breaks to near sunset does not interfere with the religious worship of other employees, protection for the worship of Muslims may require that an accommodation be made. Since the Nebraska Constitution lays a duty on the legislature to pass legislation that protects the freedom of worship for all religions, the legislature could mandate greater religious accommodation than is available to employees under Title VII, provided that it takes care not to offend against the Lemon Test for establishment of religion. The Nebraska Constitution provides a basis to promote religious accommodation as essential to the achievement of equality within Nebraska's workplaces.

The language in article I, section 4, of Nebraska's constitution, laying a duty on the legislature to "encourage schools and the means of instruction," was used in a recent case to argue that the state constitution provides for a right to adequate education—the religious aspect of the section was not raised. In *Nebraska Coalition for Education Equity and Adequacy v. Heineman* (273 Neb. 531 [2007]), the court concluded that the question was not justiciable, because there was no clear standard for determining what an adequate education is (Miewald et al. 2009:56). Should a case be brought to argue the religious aspects of the section, the court could do likewise and find the question to be nonjusticiable as a political question, or perhaps the court would order the legislature to fulfill its constitutionally prescribed duty to protect religion.

FUTURE CONSIDERATIONS AND CONCLUSIONS

As the matter stands, the Muslim employees of JBS Swift and Company in Grand Island, NE, have not been able to secure accommodation for their religious requirement to pray and break their fast at sunset during their holy month of Ramadan. The plant management and the workers' union was willing to make the accommodation, whether motivated by a commitment to the value of religious pluralism or, more likely, a desire to retain workers in a competitive industry that suffers from labor shortages. The religious accommodation was derailed by opposition from other plant workers and by federal policies that prioritize economic efficiency and majoritarian interests.

Individual and societal acceptance of diversity is often difficult to secure, as was witnessed in this case through local news coverage that framed the issue in terms of hardship to the plant and inequitable treatment of other workers, giving its readers reasons to oppose religious accommodation, a perspective echoed in the letters to the editor on the controversy. And while local passions ought to be tempered by federal institutions, consistent with the constitutional framework originally designed by the framers, the U.S. Supreme Court's inclination toward a utilitarian approach and the absence of stronger legislative direction on religious accommodations under Title VII make relief through appeals to federal authority unlikely.

Federal institutions have often served to control potential shortcomings of state constitutionalism, as the U.S. Supreme Court did in the *Meyer* case. However, Nebraska's state constitution includes the legislative duty to protect religion, a stronger potential means of securing religious liberty than is provided by the federal constitution, subject of course to the legislature's fulfillment of this duty. Thus Muslims in Nebraska might fare better in seeking protections for their religious liberty in state venues. Although a federal structure is not a cure-all for tyranny of the majority, federalism is a structural means to limit government power and protect individual rights. At times, the protection is obtained by guaranteeing the uniformity of laws across the states, removing issues from the purview of state governments, when the states would be inclined to discriminate. At other times, the protection is obtained by devolving authority to the states and allowing the states to adopt more expansive protections for rights than are provided by the national government. Nebraska's affirmative duty to protect religion holds the promise of religious liberty for recent immigrants from

Somalia. What remains is a reaffirmation of the community's commitment to religious pluralism as a feature of the definition of Nebraska's good life. Other states could benefit from a comparison to the constitutional workings of Nebraska so as to ensure religious liberty protections for the newest residents of the Great Plains and beyond.

ADDENDUM

As this article was going to press, there was a new development in the Grand Island meatpacking plant controversy that served as our case study. On August 31, 2010, the U.S. Equal Employment Opportunity Commission (E.E.O.C.) filed lawsuits in federal court against JBS Swift & Company's Grand Island, Nebraska, meatpacking plant as well as the company's plant in Greeley, Colorado. The suits allege that JBS Swift violated Title VII and engaged in a pattern of discrimination against its Somali Muslim employees based on their religion, race, and national origin. The E.E.O.C.'s complaint asserts that JBS Swift failed to reasonably accommodate the requests of the Muslim employees to take breaks from work that would permit them to pray according to the requirements of their faith and that the company retaliated against some Muslim employees by terminating their employment when they protested the lack of religious accommodation. In a press release, the E.E.O.C. reported that it had received 85 charges filed by employees of the Grand Island plant that claimed discrimination based on religion, race, color, or national origin stemming from the 2008 controversy (retrieved from <http://www1.eeoc.gov/eeoc/newsroom/release/8-31-10.cfm>). The lawsuit filed against JBS Swift was the result of investigations of these charges conducted by the E.E.O.C. and the Nebraska Equal Opportunity Commission. The lawsuit now is pending in the U.S. District Court in Omaha. How the court will rule in the case is still uncertain. The case is *EEOC v. JBS USA, LLC d/b/a JBS Swift & Company* (D. Neb.).

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USING EURO-AMERICAN HUNTING DATA TO ASSESS WESTERN GREAT PLAINS BIOGEOGRAPHY, 1806–35

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ABSTRACT—Historic accounts from the 19th-century western Great Plains contain significant information on Plains ungulates and other animals, particularly as they relate to provisioning the Euro-American travelers. Using data derived from these accounts, a quantitative assessment of the hunting success of the Pike, Long, Glenn, and Dodge expeditions of the early 19th century is presented to ascertain the conditions of these species in the region. These data are then used to assess historiographic models of bison overhunting. This analysis indicates that the western Southern Plains and western Central Plains had differing trajectories of overhunting explained by temporally variable human and environmental impacts.

Key Words: biogeography, bison, Dodge, Glenn, hunting, Long, Pike, return rates

INTRODUCTION

Traveling up the Arkansas River in the winter of 1821 to trade and trap, a party led by Colonel Hugh Glenn encountered a substantial Indian encampment near the confluence of the Arkansas and Apishapa Rivers. Major Jacob Fowler, whose journal documents the travels of the party, estimates the encampment eventually reaches 700 lodges—composed of Kiowa, Arapaho, Kiowa-Apache (or Plains Apache), Cheyenne, Comanche, and Shoshone (Coues 1898). After camping nearby for some days, Fowler notes that “the Indeans talk of moveing the Buffelow are now drove to Some distance and this I[s] not to [be] thought Straing as about one Hundred of them are Eaten In Camp Each day Sinc our aRivel.” In a journal entry that follows, Fowler notes that the Indians “furnish [us] With Plenty of the best of buffelow meet at a low Rate bu[t] do not Wish us to Hunt them our Selves—aledgeing We Wold drive the Buffelow all off” (Coues 1898).

This description of the Indian encampment and quantity of bison being consumed provides an important window into the subsistence needs of Plains Indians. As well, the large mixed camp is an apt demonstration of the early 19th-century coalescence of Indian groups in the upper Arkansas Valley for trade and animal resources. That the trappers were discouraged from hunting bison is a remarkable facet of their interaction with the Indians.

Concern that the white hunters would drive away game with their muskets, or the desire to continue to profit from selling bison meat, could underlie this prohibition. However, a parsimonious trade in horses and mules, along with the “low rate” for which the bison meat was sold, would suggest economic opportunity was not the only motive. Perhaps there was a sense, even by that time, that overhunting was occurring in the region, and denying outsider access to the remaining bison herds was a necessity.

The near extinction of the bison that took place in the 19th century is characterized by Elliot West (1995) as “the quintessential expression of human greed and its potential to gobble up nature’s bounty.” Attempts to understand the machinations that wrought the demise of the bison have long captured the attention of scholars and writers (cf. Hornaday 1889; Roe 1951; Isenberg 2000). Yet, despite the long history of research, questions remain: When and to what degree did overhunting, as well as other cultural and ecological factors of the late 18th and early 19th century, influence the destruction of the bison?

Dan Flores (1991) argues that in the Southern Plains, the annual numbers of bison harvested by equestrian Plains Indian hunters was sustainable well into the 1830s. Environmental degradation through drought and the introduction of European livestock, along with the unmitigated access to herds afforded by the 1840 peace between the Cheyenne, Arapaho, Comanche, and Kiowa, were the

drivers that initiated the diminution of the bison in this region. In the western Central Plains, Elliott West (1995) argues that the causes were species packing and climactic fluctuations, which along with the removal of the bison-rich buffer zone between the aforementioned groups who made peace in 1840, generally corroborates the model of Flores. But, keying in on issues of timing and the significance of human overhunting, Pekka Hämäläinen presents a different model of bison destruction in the Southern Plains.

Hämäläinen (2001) argues that significant bison decline began in the 1790s rather than after 1840, and proffers a causality based on large-scale overhunting rather than environmental degradation. The crux of the difference between the models lies in the conflicting interpretations of how many bison constituted a sustainable annual harvest. As Hämäläinen (2001) rightly indicates, some problems are due to that fact that these models are “geographically focused case studies” that require “more inclusive further research.”

To test these models, this study uses data from historical accounts to develop a better understanding of bison and other Plains ungulate abundance prior to 1840. This analysis will address how human impacts created different trajectories of overhunting in the Central and Southern Plains. Information from journal accounts of Euro-American travels along the Platte and South Platte Rivers and the Arkansas River between 1806 and 1835 will be used to develop quantitative and qualitative measures of Euro-American hunting success and animal abundance as a means of demonstrating whether or not bison and other Plains ungulate species became harder to acquire through time. Quantifiable differences in the hunting success of the Euro-American expeditions should reflect the changing conditions in this region in terms of Plains ungulate numbers and provide a means of temporally testing the bison diminution models. The travel corridors used by these expeditions through the region, and the general strategy of nonspecific encounter subsistence hunting, should provide a good estimation of the abundance and distribution of these animals along the route and facilitate a better understanding of the environmental and cultural conditioning of the region.

This study will focus on a region of the western Great Plains through which four key Euro-American expeditions passed in the early 19th century. The two major waterways transecting the region—the Arkansas River and the Platte/South Platte Rivers—provide the analytical cross-sections for this study as these were the westering travel corridors for the Euro-American expeditions. The

journal accounts from the expeditions of Zebulon Pike (1806–7), Hugh Glenn (1821–22), Stephen Long (1820), and Henry Dodge (1835) comprise the primary data sets. This analysis will focus on the overlap in routes for the paired expeditions that occurred from the Grand Island on the Platte River and the Great Bend of the Arkansas River, respectively, to the mouth of Fountain Creek (Fig. 1). Of particular interest are notes on the numbers and locations of game animals and mentions of Indian groups’ location, size, and composition, along with other data that indicate game animal and/or Indian dynamics and territory. Detailed analysis of these expeditions provides two sets of comparable data illustrating the historical trajectory of Indian and game conditions based on the similarity among many characteristics of these expeditions, particularly in their timing and routes (Table 1).

The exploratory expedition led by Lieutenant Zebulon Pike in the fall and winter of 1806–7 is recounted in his own journal, which is the sole primary source used here (Jackson 1966). As one of the four expeditions tasked with exploring the recently purchased Louisiana Territory, the party of men led by Pike traveled up the Arkansas River to seek the sources of both the Arkansas and Red Rivers. The Pike party was eventually captured by the Spanish in the San Luis Valley and taken to Chihuahua (Jackson 1966; Weber 1992). His journal account provides the earliest detailed Euro-American documentation of the upper Arkansas River.

Hugh Glenn led a party of trappers and traders to the upper Arkansas in the fall and winter of 1821–22. The source of information on this expedition is the journal of the second-in-command, Jacob Fowler (Coues 1898). Issued a license to trade in the upper Arkansas region in 1821, the Glenn party represents one of the earliest trading ventures into the region made accessible by the newly opened Santa Fe Trail between the United States and Mexico (Stevens 1971:181–83). Beyond the Great Bend of the Arkansas, the journal of Fowler provides the first documented record of the upper reaches of this river since the expedition of Pike.

Two journal accounts from the scientific exploring expedition led by Major Stephen Long in 1820 provide details of a journey up the Platte River, then up the South Platte River, and down the eastern edge of the Front Range to the Arkansas River. Dr. Edwin James, the botanist and geologist for the expedition, kept a journal, and Captain John Bell was the official chronicler of the trip (James 1905; Fuller and Hafen 1957). These accounts provide the first detailed Euro-American documentation of the South Platte region and Rocky Mountain Front Range.

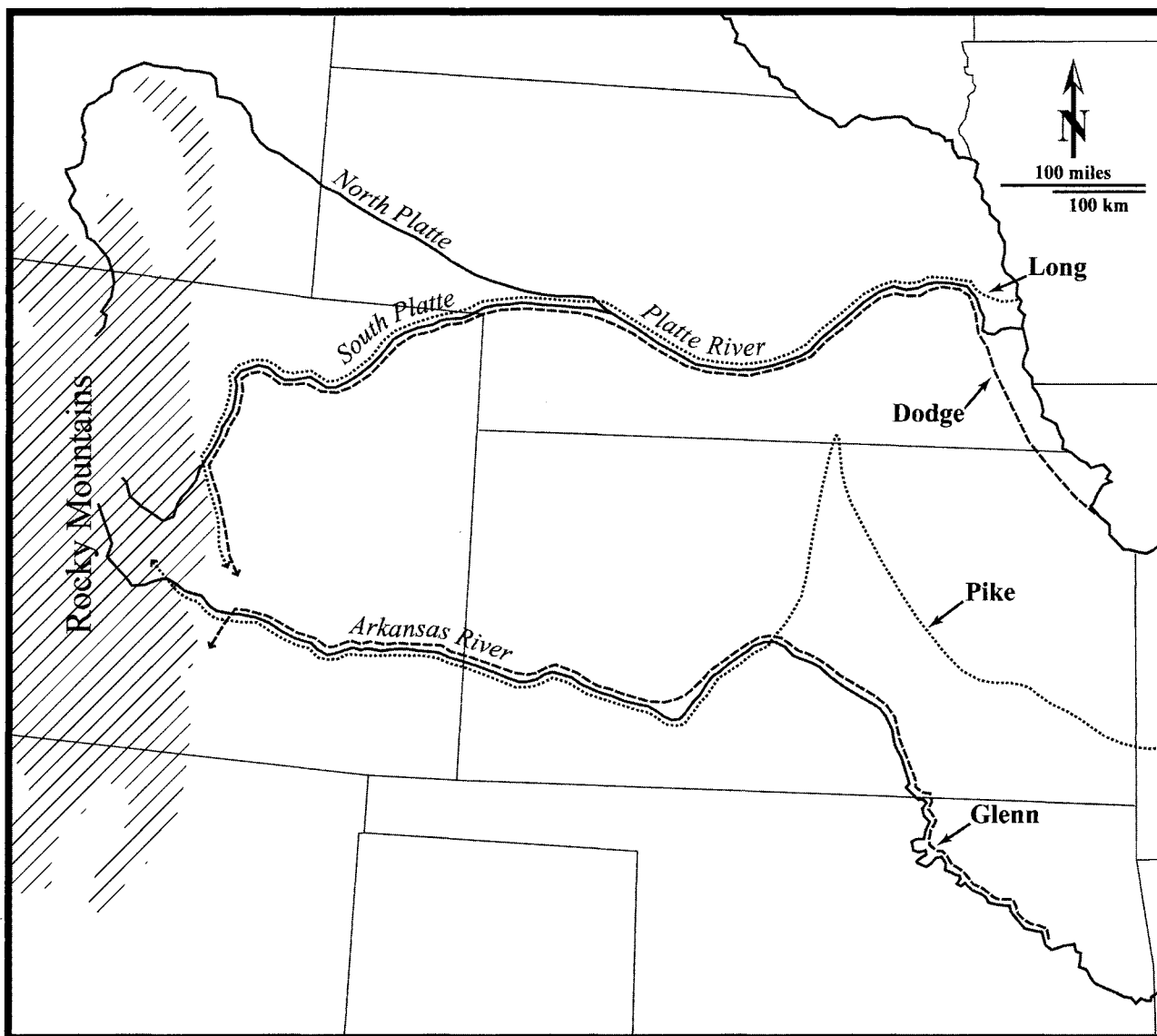


Figure 1. Western Great Plains showing portions of routes taken by Pike, Glenn, Long and Dodge expeditions.

TABLE 1
COMPARABLE DATES OF EXPEDITIONS

Expedition	Number in party ¹	Date passing by Grand Island of Platte River Longitude 98.8° W	Date passing by Great Bend of Arkansas River Longitude 99.1° W	Arrive at mouth of Fountain Creek Longitude 104.6° W
Pike	24		October 24, 1806	November 23, 1806
Glenn	20		October 19, 1821	January 1, 1822
Long	22	June 14, 1820		July 16, 1820
Dodge	127	June 27, 1835		August 1, 1835

¹ This is the initial figure at the start of journey; these numbers fluctuated.

In 1835, Colonel Henry Dodge led the First Dragoon Regiment in an expedition that duplicated much of the route traveled by Long. The official journal account of this expedition was kept by Colonel Dodge, but two journals, those of Captain Lemuel Ford and Sergeant Hugh Evans, have been published as well (Pelzer 1926; Perrine 1927; U.S. Congress 1836). This expedition, sent west to make a display of the military prowess of the United States, made numerous entreaties to the Plains Indian groups of the region.

The region through which these expeditions traveled was changing rapidly and was on the threshold of even more dramatic changes. During the time between the earlier two expeditions—Pike and Long—a nascent fur trade emerged as trappers and traders converged into this heretofore hinterland. The latter expeditions of Fowler and Dodge were the vanguard to the opening of the Santa Fe Trail and the establishment of a bison robe trade along the Front Range and the constituent trading posts, respectively, which altered the human demography and biogeography of the region drastically.

METHODS

This analysis will use the historic data to measure how the large ruminant resource base changes in the 15 years between the two Euro-American expeditions along each river. It does so by developing quantifiable measures of animal abundance and hunting success that have little precedent in the existing scholarship. Historic accounts, including the ones analyzed here, have been mined previously for the important data they contain pertaining to animal abundance, particularly large ungulate species and especially bison. Data from historic accounts compiled to determine bison herd sizes, bison ecology, range distribution, and abundances have proven essential to understanding the cultural history and prehistory of the Great Plains (e.g., Arthur 1975; Bamforth 1987, 1988; Isenberg 2000; Binnema 2001).

Two particularly innovative studies provide a methodological template for developing the quantitative and qualitative data used in this analysis. In one study, James Shaw and Martin Lee developed abundance indices for pronghorn, elk, and bison in the Southern Plains based on Euro-American accounts from 1806–57 (Shaw and Lee 1997; see also Hart 2001). These indices show statistically significant patterning through time, by species, and between the short-, mixed- and tallgrass prairie biomes. In the other study, L. Suzann Henrikson (2004) uses hunting data from journals of trappers to develop a

prey choice model for the Snake River Plain. The bison hunting success of trappers from the early 19th century is quantified in order to develop bison return rates that are incorporated into the model.

Return rates are a measure of the net caloric return derived from gathered or hunted food resources. In optimal foraging theory, these return rates are incorporated into diet breadth models or prey choice models that predict how foragers will extract resources from their environment (Kelly 1995). However, this study will develop return rates strictly as a proxy for hunting success rather than to incorporate into a model. Other than bison, return rates are calculated for the elk, pronghorn, turkey, and what are likely mule deer (see Kufield and Bowden 1995).

The main comparative analysis, however, will be restricted to the four prey species—bison, elk, mule deer, and pronghorn—primarily hunted according to the accounts. Turkeys were a resource for the Arkansas River expeditions, and enough information exists to calculate a return rate, which is presented to show the relationship between caloric return and size class. As well, prairie dogs are eaten, and badgers, wolves, and a bear are shot; however, these are limited to the accounts of Pike and Fowler and have little comparative value (James 1905; Jackson 1966).

The formulas used to calculate the return rates follow Henrikson (2004). Return rates for each expedition are calculated for each species using the formula:

$$\frac{(\text{Edible weight [kg/individual]} \times \text{Energy value [kcal/kg]})}{(\text{Edible weight [kg/individual]} \times \text{Handling time [hr/kg]})}$$

The handling time of each species for each expedition is derived from the formula:

$$\frac{(\text{Total hunter hours} + \text{Total processing hours})}{(\text{Number of animals killed} \times \text{Edible weight [kg/individual]})}$$

As this study is strictly looking at return rates in a historic context, no concessions are made for the use of guns or horses. In fact, the use of horses to transport the meat essentially equalizes the transport costs of all animals regardless of size.

In order to develop hard numbers on the return rates, constant values for a number of specific factors were formulated based on the journal information and data from other sources (Table 2; using data from Jensen 2000; Henrikson 2004; USDA 2004; Byers and Ugan 2005). The average hunting-party size was set at three for the Pike expedition based on the description in his journal of hunting

TABLE 2
DATA USED TO DETERMINE RETURN RATES

Expedition	Game animal	Scientific name	Live Weight ¹ (kg)	Edible fraction	Edible weight (kg)	Energy (kcal/kg)	Processing time (hr)	Hunting time ² (hrs/day)
All	Bison	<i>Bison bison</i>	591	0.60	354	1,220	3	
All	Elk	<i>Cervus elephus</i>	318	0.60	191	1,110	2	
All	Mule deer	<i>Odocoileus hemionus</i>	95	0.60	57	1,200	1	
All	Pronghorn	<i>Antilocapra americana</i>	58	0.60	35	1,140	1	
All	Turkey	<i>Meleagris gallopavo</i>	6	0.79	5	1,570	1	
Pike								15
Long								25
Glenn								15
Dodge								50

¹ This value is the mean of the male and female weights.

² This value is applied to each day that hunting was recorded. It is the value derived from an average hunt time of 5 hours per man multiplied by the number in an average hunting party: 3 hunters for Pike and Glenn expeditions; 5 hunters for the long expedition; and 10 hunters for the Dodge expedition.

parties that range from one to four (Jackson 1966). This number was used for the comparably sized Glenn expedition, for which we lack information on exact hunting party sizes. Although his account contains references that range from a single hunter to a time when “every man, that had any pretensions to being a good shot” went out, the Bell journal initially lists five men designated as hunters, so this figure is used as the average hunting-party size for this expedition (Fuller and Hafen 1957). These values are consistent with the two to three hunters that a party of 13 to 17 members under the guidance of Thomas Farnham used in an 1839 journey up the Arkansas River (Farnham 1843), as well as the three to six hunters generally used by the Lewis and Clark expedition (32 to 43 members) on their journey up the Missouri River in 1804–5 (Lewis et al. 2002). For the considerably larger Dodge expedition, where the journals lacked any specific information, the hunting-party size was set at 10—a slight modification of the nine hunters sent out by an 1843 dragoon detachment numbering 110 men (Connelley 1925).

The average hunter day was set at five hours, which is an intuitively median value based on mentions of evening hunts and on other accounts ranging from all-day hunts to times when game was encountered and procured in the normal course of travel, without special effort. The processing time differences take into account the much larger size of bison and elk compared to the other animals.

Overall, these times also take into account the experience of the Euro-American butchers, the use of metal tools, and the degree to which the animals were butchered. For example, on the Pike expedition, butchering intensity ranged from what was required to extract “marrow bones for breakfast” to only taking “the choice pieces of meat” (Jackson 1966).

The total allotted hunting hours per day (see Table 2) was divided evenly among each animal killed, regardless of species, if multiple animals were procured in a single day. When the hunts returned no game, the hours were given to a particular species if referenced as the object of the hunt, as when Fowler relates, “[T]hree men Went With Horses on the Hunt of Buffelov but Returned With out seeing any this day” (Coues 1898). Where unsuccessful hunts were undertaken without species specificity, the hours were evenly divided between all. The Dodge expedition journals contained no specific numbers on the amounts of bison killed, so round estimates ranging between five and 20 were assigned based on the size of the expedition and comments such as “killed them in great numbers” (Perrine 1927). Based on an estimated 4,000 calorie/day diet, these amounts would have fed the dragoons for a period ranging from four to 17 days, figures that do not reflect actual hunting periodicity recorded in the journals but possibly demonstrate the minimal processing of the bison killed. This discrepancy belies

TABLE 3
HUNTING DATA

Game animal	<i>Hunter hours</i>				<i>Number of animals killed</i>				<i>Processing/handling hours</i>				<i>Return rates (kcal/hr)</i>			
	Pike	Glenn	Long	Dodge	Pike	Glenn	Long	Dodge	Pike	Glenn	Long	Dodge	Pike	Glenn	Long	Dodge
Bison	269	202	152	350	55	24	16	75	165	72	48	225	54,709	37,771	22,976	56,221
Elk	14	29			2	5			4	10			23,567	27,206		
Mule deer	28	43	249		4	7	21		4	7	21		8,535	9,577	5,319	
Pronghorn	19		148		2		10		2		10		3,846		2,525	
Turkey	5	41			1	8			1	8			1,308	1,282		

the problem with trying to accurately gauge the amount of bison killed by this expedition, especially when it was likely that bison were killed wantonly simply for sport.

Notions of sport hunting do find their way into the journals, particularly those of the dragoons. The fascination with bison hunting in particular eventually fed into a developing sportsman ethos that became important in later conservation movements (Reiger 2001). However, the early 19th century was a time when bison as a resource was largely viewed as inexhaustible. The massive bison herds of the Great Plains gave early Europeans the impression that no amount of killing would have a lasting impact on their numbers (Gard 1959). This attitude undoubtedly manifested itself in animals being lightly butchered to completely wasted, but these particular parties were hunting for subsistence, and thus the data from these hunts are much more relevant than that from the European sport hunters who were pursuing game in the western Great Plains by the 1830s (Merritt 1985).

RESULTS AND DISCUSSION

The calculated return rates from the four expeditions are presented in Table 3. The data indicate some significant differences among the expeditions in terms of both hunting success and in the breakdown of animals killed. The return rates increase through time between the northern expeditions and conversely decrease through time between the southern expeditions. It is of note that the return rates show bison to be significantly more efficient to procure than the other animals killed by the Euro-American hunters. Understanding why bison were so much more efficient involves factoring in both their size and behavioral characteristics, along with a cultural preference for hunting and eating these animals. Bison gregariousness and poor eyesight, combined with the hunters' use of

horses and guns, made bison relatively easy to hunt. Furthermore, bison are the largest animal in the Great Plains: return rates calculated elsewhere also rank bison highly (Henrikson 2004; Byers and Ugan 2005) and demonstrate that return rates generally positively correlate with body size. Bison were the primary food source of indigenous Plains hunters, to which the Glenn party was witness.

The prodigious appetite for bison of the large Indian encampment encountered by the Glenn party negatively impacted Euro-American hunting success on the upper Arkansas River. Encamped at the mouth of Fountain Creek in proximity to the aboriginal camp, Fowler sends hunters "out to the mountains to Hunt for Buffelov" for days at a time and generally has little success—sending hunters out multiple times who return with no game (Coues 1898). As well, the procurement of turkeys, based on return rate, is indicative of the poor hunting in the periphery of the wintering Indians.

The Pike expedition hunters killed the greatest variety of animals and by far the most bison of the three smaller groups. Based on return rates, Pike's party is a close second to the Dodge expedition in terms of bison hunting success. This is despite entering the area on the heels of a severe two-year drought in 1805–6 (Cook et al. 2007). Until the party entered the mountains, the Pike party seems to have little trouble acquiring food. As well, Pike is following the weeks-old trail of a large Spanish expedition led by Facundo Melgares (Olivia 2006) and reports evidence of the Spaniards eating a horse (Jackson 1966).

The hunting success of the Pike party is surprising given the time of year, the fact that they were following (albeit weeks later) a large Spanish expedition, and that it was the end of a severe drought. This success could be attributed to animal herds concentrating in the winter shelter afforded by the Arkansas River bottoms. Furthermore, Pike does not physically encounter any Indians until the

mouth of the Apishapa River, which could also be a factor in the hunting success of his expedition through this area, especially considering the myriad Indian groups and numbers that the Glenn party later encountered on the upper Arkansas. Moreover, during the interim between Pike and Glenn, Cheyenne and Arapaho groups had moved south into the region, which increased both the human population and pressure on the resources in the area (Sherow 1992).

The Long expedition has the lowest return rates; however, this excursion took place in the midst of a severe drought (1818–20), as attested by the moniker “Great American Desert” that Long ascribed to the region (Cook et al. 2007). As Long was traveling through a region impacted by drought, his return rates may reflect the poor forage conditions. Seasonality could also be a factor in that during the spring and summer, herds are less likely to be concentrated in the riparian zones. It is telling that the hunters killed more mule deer and pronghorn than did the other expeditions, a possible reflection of resource depression and the necessary consumption of riparian zone browse by these species. On the other hand, Colonel Dodge traveled through the area in a time of much more favorable precipitation.

The First Dragoons passed through the region during a wetter-than-normal period, two years after the wettest year (1833) on record between 1500 and 1990, according to tree-ring reconstructions (Cook et al. 1999; Stahle et al. 2007). Although both Long and Dodge witness evidence of warfare along the Platte and South Platte in the form of fortified camps, neither party actually encounters Indians until reaching the Arkansas (Fuller and Hafen 1957; Pelzer 1926). Also favorable to the Dodge expedition were cultural factors that indirectly and fortuitously resulted in better bison hunting.

The region through which Dodge passed was at the time a “section of country . . . called the neutral ground, [which] extends from the forks of the Platte almost to the foot of the mountains. It will not admit of the permanent resident of any Indians. . . . The Arapahos and the Cheyenes sometimes move into this country for a short time during the summer to hunt buffalo” (U.S. Congress 1836; White 1978). Conflict among the Cheyenne and Arapaho with groups to the east over this buffalo range produced what Dan Flores (1991) describes as “an interesting type of ecological development . . . buffer zones occupied by neither side and only lightly hunted.” Animals were attracted to these liminal zones by the lack of sustained hunting pressure, and the success of the dragoons has to be attributable in some degree to this phenomenon.

A qualitative assessment of bison abundance shows patterning that reinforces the inferences from the return rate data. The assessment of numbers by the chroniclers of the expeditions varies greatly—ranging from instances of precise numeric descriptors to the generic “saw buffalo” (Jackson 1966). An ordinal index was developed from the descriptive and numeric terms used in the journals to describe the amount of bison encountered. Based on this index, the locations where bison were encountered are plotted based on longitude (Fig. 2). This spatial accounting provides a rough estimate of the east-west spread of these animals along the Platte/South Platte and Arkansas Rivers.

The Platte/South Platte expeditions show considerable overlap and demonstrate the propensity for bison in the region west of the Platte fork despite the different environmental conditions each party encountered. Dodge seems to have encountered larger numbers of bison, a product of the buffer zone. Data from the two expeditions indicate that bison were more evenly distributed along the route during the earlier expedition of Long, a possible reflection of a lack of hunting pressure or of a less constrained condition prior to the influx and conflict catalyzed by the Cheyenne and Arapaho movement into the area.

Based on the journal accounts, the wild horse distribution overlaps the bison distribution in the game-rich region west of the Platte fork, especially during 1835 when the dragoons pass through. Horses were encountered slightly farther east on the Arkansas, and the Pike expedition reports them more frequently. It has been estimated that there were tens of thousands of wild horses between the Platte and Arkansas, and that there may have been just as many pronghorn as bison inhabiting the Plains (Flores 1991; Hart 2001).

Mule deer, elk, and pronghorn are less informative for the northern expeditions because the chroniclers of the Dodge expedition make only a single mention of these species (Perrine 1927). Again, although rarely mentioned in the accounts of the Arkansas expeditions, Pike encountered ungulates other than bison generally farther east than did Glenn, perhaps an indication of animals contracting westward in the face of Euro-American expansion. Mule deer, elk, horse, and pronghorn are never mentioned in the numbers that bison are in the journals, which is not surprising as these species lacked the overall population and herding behavior of the latter.

Aside from general distributions, the journals also contain data on herd composition and movements, particularly the bison. After forming large mixed herds for the rut in July and August, bison segregate into nursery

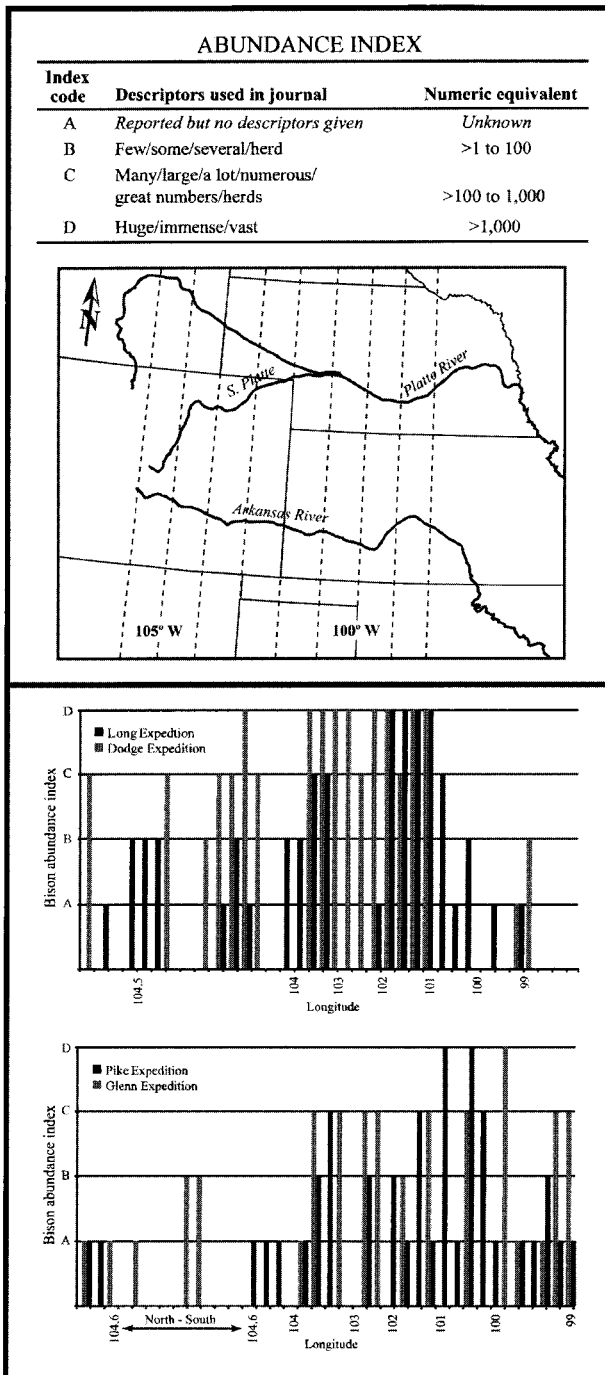


Figure 2. Bison range and abundance based on journal accounts.

herds (composed of cows/calves and juvenile animals) and bachelor herds (composed primarily of mature bulls) for the rest of the year (Bamforth 1988). This separation influences both bison distribution and human hunting strategies.

Fowler reports on October 25 that “the Hunters killed two Fatt Cows” in the vicinity slightly west of 99° longi-

tude, which are the first cows reported after several days of lamenting the lack of them to hunt (Coues 1898). Fowler was intent on attaining cows because he knew that they are in better physical condition than the bulls following the rut. On November 4, Pike reports seeing the first cows at roughly 100.7° longitude. Pike encounters nursery herds around 100 miles farther west than Glenn reports them, possibly explained by the 1805–6 drought pushing animals to the more drought-resistant grama and buffalo grasses of the shortgrass steppe (Julander 1945; Wedel 1986). To the north, Long encountered drought-impacted nursery herds even farther west in the shortgrass steppe and reports large numbers of bison moving south across the South Platte into the Colorado Piedmont area (Fuller and Hafen 1957).

CONCLUSIONS

The success of the Euro-American hunters and the biogeography of the animals they encountered in the western Great Plains are reflective of the cultural and environmental conditions of the early 19th century. Particularly along the Arkansas, the existence of a trading locus (later made permanent by the establishment of Bent’s Fort) attracted Indian groups (Hämäläinen 1998) and, as Fowler documents, impacted the game in the area. Along the Platte/South Platte, internecine aboriginal warfare over territory kept hunting pressure light in the High Plains east of the Front Range, especially in the 1830s as Dodge witnessed. However, shortly after the dragoons moved through the area, an established and lively trade develops based on extraction of bison robes from the High Plains herd.

The highly variable and seasonal Great Plains climate that can vacillate between extreme wet and dry, even annually, undoubtedly affected Euro-American hunting success. The severe droughts that impinged both the expeditions of Pike and Long appear to have affected the latter party to a much greater extent. Seasonally, water, food, and shelter constrained the movements of the hunted animals. The fall and winter seasonality of the Pike expedition, when compared to the summer expeditions, seems to have had good success acquiring game in the Plains, possibly a reflection the shelter and forage afforded by the Arkansas River riparian zone.

The consistent masses of bison just west of the Platte forks witnessed by Long and Dodge demonstrate stability not witnessed in the Arkansas Valley. The trajectories of change from the Arkansas River expeditions, vis-à-vis the return rates, generally confirm the model proposed

by Hämäläinen in that overhunting was occurring before 1840. Furthermore, the coalescence of Comanche, Kiowa, Cheyenne, and Arapaho witnessed by Fowler (Coues 1898), along with the mixed camps described by James and Bell (James 1905; Fuller and Hafen 1957), indicate that there were periods prior to the Great Peace when these groups exploited the resources of the upper Arkansas. However, the increased hunting success of the dragoons does support the Flores-West model of buffer-zone refugium into the 1830s. Overall, what these findings clearly demonstrate are the differing contexts and trajectories of change between the Arkansas and Platte/South Platte zones. The upper Arkansas was the destination for migrating Plains Indian groups in the early 19th century, and, long a trade center, its importance increased with the influx of Mexicano and Euro-American trade goods and livestock following the Mexican Revolution (Hämäläinen 1998). This influx of people and animals began earlier than in the north and was more profound, resulting in earlier negative impacts on the bison.

The Flores-West model is a more accurate reflection of the timing that is evident in the western Central Plains. Bison numbers do not appear to diminish during the period analyzed here. Rather than a result of the Great Peace of 1840, the scales were tipped against the bison in this region with the peace of the Cheyenne, Arapaho, and Lakota, who entered the forks of the Platte in the 1830s. This détente, which opened up a large game-rich buffer zone (White 1978), catalyzed the bison robe trade through the establishment of the North and South Platte trading loci in the 1830s.

The use of return rates and abundance indices represents empirical methods for looking at the early historic biogeography of the western Great Plains and provide a means to test the models developed to explain bison destruction. However, these numbers do not provide a concrete cultural and/or environmental causality for the change exhibited. Further analysis of historic accounts should bring more data to bear on this issue. Increasing the scholarly focus on the underpinnings of the early human impacts on the animals of the western Central Plains, such as that initiated by Flores, West, and Hämäläinen, will add the needed clarity and robusticity to the history of the Great Plains.

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THE POLITICAL CONSEQUENCES OF POPULATION CONSOLIDATION IN NEBRASKA

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ABSTRACT—In recent decades, the migration that has long been characteristic of life in the Great Plains has meant the steady relocation of population from rural to metropolitan counties. While much has been written about the social and economic consequences of this migration, far less is known of its political consequences. In Nebraska, the least-populated counties experience the most severe out-migration, and are the most reliably Republican. To discern a relationship between population migration and political outcomes, this study analyzes the six open-seat races for United States senator that have occurred in Nebraska since 1976. An econometric model that explains Democratic vote share at the county level demonstrates that larger growth in a county’s population exerts a positive and significant influence on the proportion of the vote won by the Democratic candidate, when partisanship and other race-specific variables are controlled for. Consolidation of more of the state’s population into fewer counties has increased the competitiveness of well-qualified Democratic candidates.

Key Words: Great Plains migration, Nebraska politics, population consolidation, Senate elections

INTRODUCTION

It only took four tries. From 1996—the first presidential election in which Nebraska law allowed the state to divide its Electoral College votes—through 2004, Nebraska voters awarded all five of their Electoral College votes to the Republican candidate for president. The 2008 presidential election represented the first time Nebraska split its Electoral College vote. Democrat Barack Obama won a majority of votes in the Second Congressional District, constituted largely by the city of Omaha and suburban Douglas and Sarpy Counties. Unique attributes of the Obama campaign may explain why the Democrat captured this electoral vote from his Republican opponent. Flush with cash and adept at grassroots and electronic organizing, Obama’s campaign organization overtly targeted its efforts in Omaha, emphasizing voter registration and, especially, early voting (Bratton 2008). An alternative explanation holds that Obama’s win in Nebraska’s Second Congressional District may be attributed to recently increasing “geographic clustering” in American politics. In analyzing the geographic distribution of votes in the 2004 and 2008 presidential elections,

Nicholas Seabrook finds a pronounced spatial component: “Republican Party support appears to be clustered in larger areas with more dispersed populations, while Democratic support is concentrated in smaller areas with higher population densities” (Seabrook 2009:4). We find the same phenomenon in Nebraska, on a smaller scale. Obama carried only four counties in the state, but they included the two most populated, Douglas (dominated by the city of Omaha) and Lancaster (dominated by the city of Lincoln).

Not to diminish the important influence of geographic clustering on election outcomes, but analysis of this sort fails to capture a dynamic element of population distribution. While support for Democratic candidates is concentrated in more densely populated areas, it is not known if, much less how, mobile populations contribute to this pattern. Nor is it understood what effect population migration exerts on other, nonpresidential political outcomes. This study explores the possibility of a causal relationship between population migration and political behavior by analyzing population change and electoral outcomes in Nebraska races for U.S. Senate over the past three decades. Like most other states in the Great Plains,

Nebraska has experienced a consolidation of more of its population into fewer of its counties. At the same time, the state has exhibited a willingness to elect Democratic candidates to statewide office while undergoing a gradual reduction in voter identification with the Democratic Party. Why Democrats continue to win statewide in Nebraska in the face of diminishing partisan loyalty is an important puzzle that is readily addressed by the candidate-centered character of congressional elections (Jacobson 1992). However, even standard explanations of Senate elections fail to account for the contributions of population dynamics to electoral results.

POPULATION CONSOLIDATION IN THE GREAT PLAINS

Migration and its effects have always been part of the culture of life in the Great Plains. E. Cotton Mather wrote in 1972 that “nomadism is a fundamental feature of the Great Plains culture” (Mather 1972:245), characteristic of every era of Plains history, from the nomadic Indian tribes, to white pioneers—those who passed through and those who settled—to the development of railroad and trucking industries, to summer tourists and local residents who think little of pulling a boat 300 miles round-trip for a weekend’s recreation on the water. If he were writing today, Mather might note the willingness of Nebraskans to drive those 300 miles to watch a football game in Lincoln or shop in Omaha or play the slots in Council Bluffs. In short, people in the Plains continue to be characterized as people on the move.

This willingness to move has resulted in a steady relocation of population from rural to metro counties in the Great Plains. Johnson and Rathge (2006) note that two-thirds of the counties in the Great Plains have lost population over the past half-century. And yet, the net population of the region had increased by 4.3 million, indicating a prolonged consolidation of residents from nonmetro to metropolitan counties. The rate of this consolidation varies according to the population of the county in question. Between 1950 and 1996, the populations of metro areas in the Great Plains grew by 152%, while the nonmetro population declined by 5%. But not all nonmetro counties shrank, nor did the declining counties decline in equal measure. Counties containing a city of at least 20,000 people grew by 39%. Counties containing a city whose population fell between 2,500 and 19,999 waxed and waned in population. While the smallest counties—those that do not have a city with at least 2,500 people—“showed the most dramatic decline,

losing more than a third of their population base between 1950 and 1996” (Rathge and Highman 1998:19). Most of the counties that lost population are rural or farm-dependent. Guttmann et al. (2005) report that between 1930 and 1990, population declined in 90% of the Great Plains counties with the most agricultural employment, while population increased in the counties with the least agricultural employment.

A substantial literature has grown up addressing the causes and consequences of this population consolidation. Economic opportunity and quality-of-life considerations appear to drive most migration. Regarding economic opportunity, technological advances in agricultural production displaced farm families (Pursell 1981), especially young adults, causing them to move to cities where they found employment opportunity (Johnson and Rathge 2006). Irrigated agriculture and access to groundwater have also contributed to population consolidation in High Plains counties (White 1992). This out-migration from rural counties also harmed small businesses in those counties, contributing to a downward spiral of population loss (Johnson and Rathge 2006). Where populations grew, the proportion of college-educated residents in a county contributed to that in-migration (Guttmann et al. 2005), suggesting that economic opportunity accounts for both growth and decline.

Regarding quality-of-life considerations, environmental factors have contributed to population consolidation. From the 1950s through the 1980s, geographic features, especially high elevations and large bodies of water, attracted migrants who sought easy access to recreation (Guttmann et al. 2005). In the 1980s, net migration patterns in the Great Plains emphasized the growth of urban areas. By the 1990s, natural amenities and suburbanization (characterized by relocation to the fringes of cities) replaced urbanization as the leading attribute of net migration (Cromartie 1998).

Turning to the consequences of population consolidation in the Plains, we see a distortion in the age structure of the declining counties. Since most of those relocating for better employment opportunities tend to be in early- or mid-career stages of life, declining counties have become skewed toward an older population. Of the counties whose populations declined continuously from 1950 through 1996, almost half had a median age older than 35. In two-thirds of the continuous-growth counties, the median age was younger than 29 (Rathge and Highman 1998). The result is a higher concentration of elderly people in economically depressed counties (Rathge and Highman 1998), threatening the future ability of these

counties to attract new development or provide for ongoing needs like infrastructure, health care, education, or public safety.

The economic byproducts of a shrinking and aging rural population are numerous. Population loss in rural areas leads to labor shortages (Pursell 1981), a decline in consumer demand, which in turn causes declines in wholesale and retail trade (Adamchak et al. 1998). A shrinking and aging rural population also make it more difficult to attract new business development: "As working-age and work-ready people leave the area, many of the people left behind are too old, underskilled, or undereducated to find work elsewhere. Consequently, they comprise a workforce that is relatively unattractive to relocating business and relatively ill-equipped to start their own businesses" (Rowley 1998:4).

Consequence builds on consequence. As populations and local economies erode, so does the capacity to govern, causing "severe dislocations in local government, education, health care, and highway construction and maintenance" (Luebke 1984:36).

In addition to the material consequences of rural depopulation in the Great Plains, we have also seen a debate over what to do about it. Offers of free land to attract new "homesteaders" and tax incentives to attract industry seem most typical of proposed solutions (Shortridge 2004), but others have recommended efforts to make the best of things as they are. The Poppers' proposal to return vast stretches of Plains grasslands into a "buffalo commons" (Popper and Popper 1987) has drawn both applause and approbation in declining rural communities.

While the causes of population consolidation in the Plains are several, only some of the consequences are well known. Still underexplored are the relationships between migration and local political phenomena.

POLITICS AND PLACE

Social scientists have long understood the relationship between politics and place. Indeed, the expectation that people in different parts of the country would have different outlooks and interests is built into the design of federalism in the U.S. Constitution. James Madison, in *Federalist* No. 10, argued that this diversity of interests would serve the republic well over time by making it difficult for particular interests, or factions of interest, to dominate political decision making. Sectional differences overshadowed most other political issues in the 19th century. Well into the 20th century, Elazar (1972) argued that states and regions possess distinct political cultures. Political scientists Earl

and Merle Black (2007) delineate the regional patterns in presidential voting, with Republicans dominating the Electoral College in the South, Great Plains, and Interior West, and Democrats polling strongly on both coasts. The Midwest is the swing region, whose states determine the outcome of modern presidential elections.

Regional patterns in presidential voting notwithstanding, political variation exists within regions as well. Writing of urbanization in the Great Plains, Rugg and Rundquist (1981) address the common perception that the region is "the domain of the farmer, hunter, Republican and conservative. Yet, this perception is misleading. In reality, the farmer is in the minority, the Democratic Party is a significant factor in politics, and golfers probably outnumber hunters" (221). This portrayal hints at an urban-rural divide in the politics of the Plains. However, this urban-rural divide, if it exists, is not static. As the Plains undergo a transition in which rural places lose population at the expense of urban and suburban places, we should reasonably expect to find political results stemming from that migration.

Bill Bishop has recently argued that population dynamics shed light on our understanding of election results. In his book *The Big Sort*, Bishop (2009) contends that people with similar value orientations and related political outlooks have begun sorting themselves into like-minded communities. When people move, they often choose to live among people who share their political views, or to escape people who do not share those views, a phenomenon contributing to political polarization in the United States. For example, Bishop documents that 79% of the people who moved away from Republican counties between 1995 and 2000 settled in counties that voted Republican in 2004, and that most of them moved to counties in which George W. Bush won in a landslide in 2004 (Bishop 2009:44). Although migration patterns such as these do not necessarily reflect political choices, Bishop argues, they nevertheless have had political consequences.

These two phenomena—historical spatial patterns in voting and a more recent big sort—suggest a causal relationship between population shifts and political outcomes. Given that migration is part and parcel of the culture of the Great Plains, it is worth asking whether, and to what extent, population change has influenced political outcomes there.

MIGRATION AND POLITICS IN NEBRASKA

Nebraska has not been immune to the population dynamics that have characterized the Great Plains over the

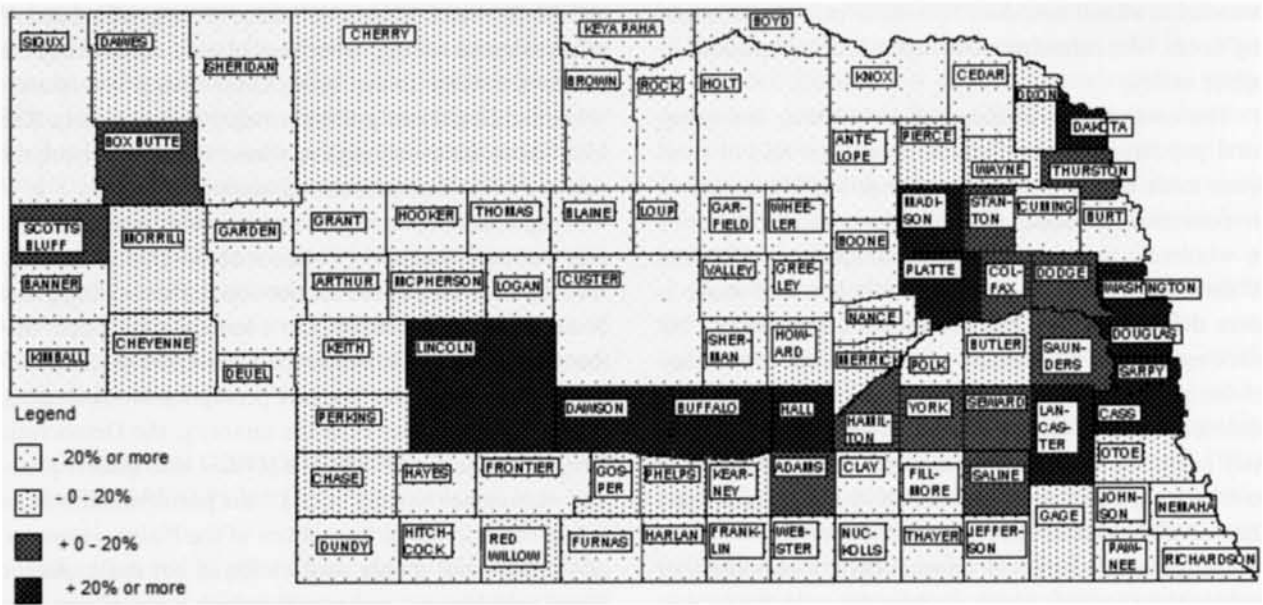


Figure 1. Population change in Nebraska counties, 1980–2008.

past 50 years. Its smallest counties have lost the greatest percentage of their populations. Figure 1 displays the pattern of population loss and gain in Nebraska's 93 counties between 1980 and 2008. The counties with the two darkest degrees of shading are those whose populations increased over those decades. Most of the counties that gained population form a pattern Nebraska officials call "the Fishhook" (Cantrell 2005). Fishhook counties lie primarily along the Interstate 80 corridor, from Lincoln County (North Platte) east to Lancaster County (Lincoln), then northeast as the interstate bends toward Omaha and its suburbs in Douglas and Sarpy Counties. From the Missouri River counties, the pattern hooks back west through Dodge, Colfax, Platte, Madison, and Stanton Counties. In 1980, these counties comprised 68% of the state's population. Combined, those same 20 counties made up 76.5% of the state's population in 2008. Figure 2 depicts the populations for all Nebraska counties, as of 2008. Although the fishhook pattern is not complete here, Figure 2 makes plain the overlap between population size and population growth in Nebraska.

Politically, observers characterize Nebraska as a "red state," owing primarily to its record of voting in presidential elections. From its first presidential election in 1868, Nebraska has distinguished itself as reliably Republican, choosing the Democratic candidate for president only five times out of 35. The most recent Democratic presidential candidate to win all of Nebraska's electoral votes was

Lyndon Johnson in 1964. Before that, it was Franklin Roosevelt in 1936.

The Republican Party's advantage among registered voters in Nebraska also gives the state much of its political coloration. The state began its system of permitting voters to register with one of the political parties (or not) in 1968, and since that time, registered Republicans have always outnumbered registered Democrats.

Figure 3 depicts the trends in voter registration from 1972 through 2008. Throughout this time, the proportion of registered voters identifying as Republican has remained fairly stable, ranging from a high of 51.18% in 1986, to a low of 48.12% in 1978. Proportions of voters identifying with the Democratic Party have fallen steadily, from a peak of 46.19% in 1976, to the low of 32.56% in 2006. The Democrats' losses have not spelled gains for the Republicans, though. As already indicated, Republican registration has changed very little. Seemingly few Democrats have switched to the Republican Party, but rather to some third party (in a few cases), or more commonly, to no party. Nebraska has witnessed a partisan dealignment, almost all of which has come at the expense of Democratic voter registration. The increase in independent registration covaries directly with the decrease in Democratic registration, with a statistical correlation (Pearson's r) between the two at $-.972$ ($p = .01$).

To begin drawing connections between population migration and political outcomes, note that the least-

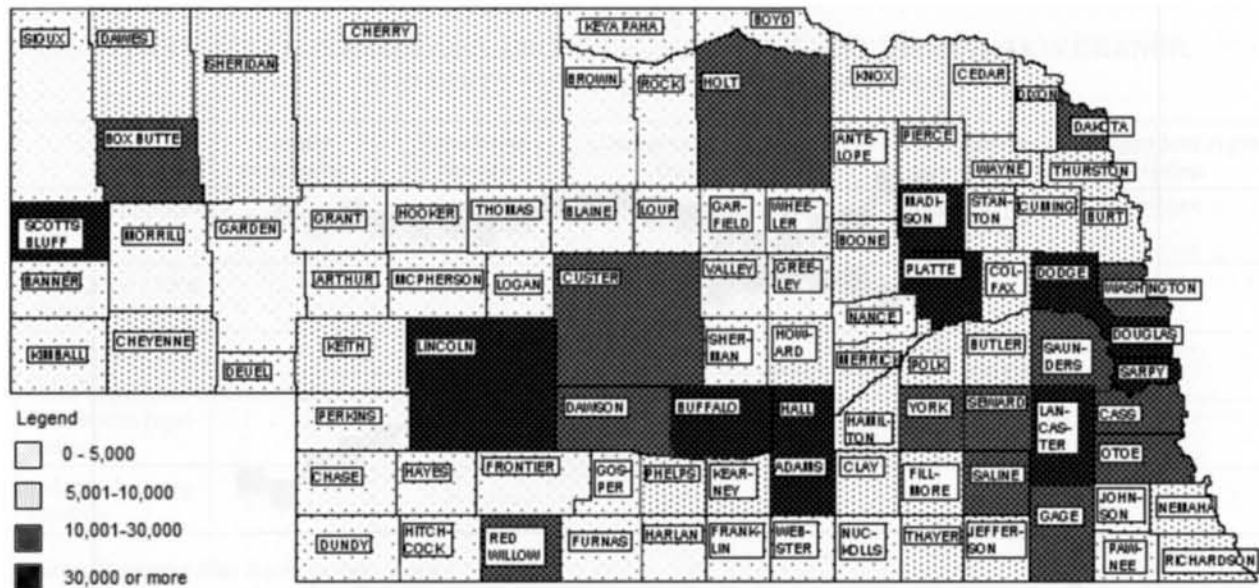


Figure 2. Nebraska population by county, 2008 estimate.

populated counties in Nebraska are also the most reliably Republican. Table 1 presents a correlation matrix showing the relationships among county population, population change, and voter registration. First, regarding county population, the matrix shows that the smaller a county's population, the stronger its affiliation with the GOP, while a larger population is more highly correlated with Independent, followed by Democratic, voter registration. Although these correlations are weak, their statistical significance nonetheless hints at a causal relationship, meriting further scrutiny.

The correlations among party registration and county population changes reinforce this pattern and tie it more directly to population migration. As the population of a county has increased, the proportion of its citizens registering with the Republican Party has decreased. When dealing with simple correlations, the inverse is also true, so that as a county's population shrinks, the remaining population shows a higher concentration of registered Republicans. In practical terms, this finding suggests that as a county's population declines, it is the Republicans who appear more likely to remain behind, while the proportions of voters registered as Democrats and Independents increase as a county's population increases. This begs an interesting question: Why? Some of those who migrate from shrinking counties toward growing counties must necessarily be Democrats and Independents (which is not to suggest that they leave for political reasons—there is no evidence that they do, while the evidence that people

migrate for economic reasons is very compelling). It is also plausible that some among the migrants change their registration upon arriving in the new community. When paired with prior knowledge of the relationships among age, migration, and party identification, this party-switching explanation makes sense. It is well established in the literature on population migration that median age in declining counties is older than in counties with growing population (Rathge and Highman 1998). It is also well established in the literature on party identification that younger voters are more likely to identify as Independents (Jennings and Niemi 1981), and that party identification becomes more stable as people age and accumulate political experience (Franklin and Jackson 1983). Thus, if those who remain behind in declining counties are older, and are also more loyal to their political party, it stands to reason that party registration (in this case, Republican) should consolidate in the counties that lose population. Likewise, if younger people are more likely to relocate, and also are more likely to change their party affiliation, then it stands to reason that party switching could take place as they migrate from declining to growing counties.

At the level of analysis presented in this study, it is unknown how many of the increased Democratic and Independent registrants in the growing counties relocated from a declining county within Nebraska, or if they have relocated from another state. Sorting out the intra- and interstate migration patterns would yield some useful

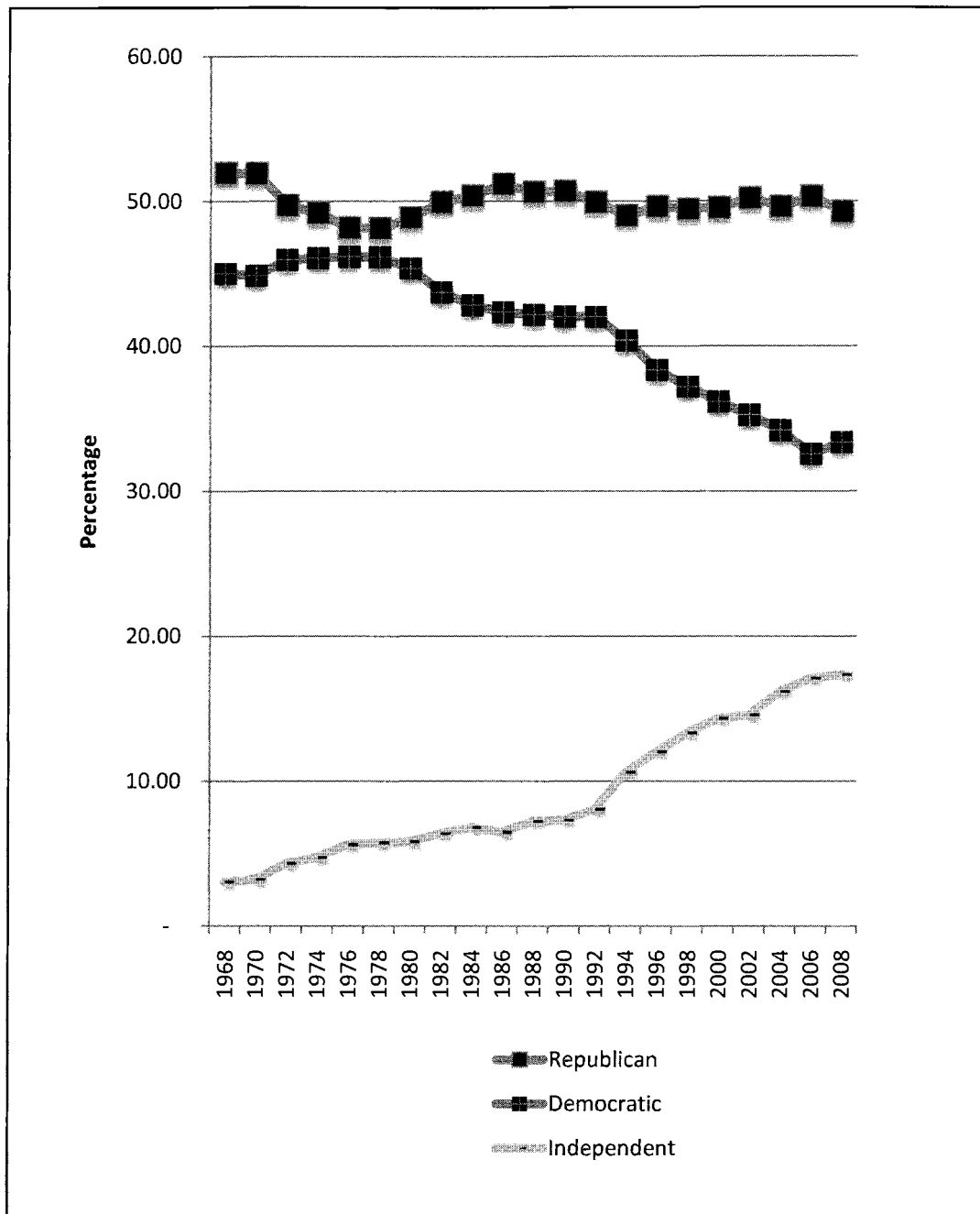


Figure 3. Trends in voter registration in Nebraska, 1968-2008.

insights on this question but would also extend this study beyond its immediate objectives. For the purpose at hand, it is enough to observe that counties losing population are more Republican, and counties gaining population are more Democratic or Independent. But are these patterns strong enough to influence election outcomes? In the next section we examine the influence of population gains and losses on U.S. Senate elections in Nebraska.

UNDERSTANDING SENATE ELECTIONS

Studies of Senate elections identify a set of factors that explain why a particular candidate has won. Candidate-specific factors, particularly the quality of his or her political experience, often prove relevant. Senate candidates who have held prior public offices, especially as governor or U.S. representative, are considered higher

TABLE 1
PEARSON'S R CORRELATIONS AMONG COUNTY POPULATION, POPULATION CHANGE,
AND PARTY VOTER REGISTRATION, 1976–2008

	County population	Population change	Democratic registration	Republican registration	Independent registration
County population	1	.303**	.182**	-.280**	.250**
Population change		1	.238**	-.315**	.200**
Democratic registration			1	-.919**	-.173**
Republican registration				1	-.315**
Independent registration					1

Source: *Nebraska Blue Book*, various years.

Notes: Entries are correlation coefficients. Population change calculated as percentage change between most recent census and election year. Voter registration calculated as percentage of voters registered Democrat, Republican, or other, aggregated at county level, for every election year between 1976 and 2008 inclusive. *N* for all entries = 558.

** $p < .01$.

quality candidates and win more frequently than political amateurs or candidates who have held lower-level state or local offices (Squire 1992). In a statistical analysis of 166 Senate races, Abramowitz and Segal (1992) find that having served as governor prior to running for the Senate increased a candidate's vote share by 5.8%.

Short-term forces are another form of influence on Senate elections that are unique to a particular race. A scandal involving one of the candidates may persuade voters to choose the other candidate, regardless of the other candidate's qualifications or political party. A particularly competitive primary race in one party may benefit the candidate of the opposing party, as disagreements or controversies from the primary continue to divide partisans in the general election (Abramowitz 1988).

Although bitter primaries are short-term forces, they are not the only factors in Senate elections that make political parties relevant. The partisan composition of the electorate matters, as citizens who think of themselves as Democrats tend to vote for Democrats, citizens who think of themselves as Republicans tend to vote Republican. In a state where one party can claim more adherents than the other, candidates from that party should be expected to win (Abramowitz and Segal 1992). National political tides also influence Senate election outcomes (Highton 2000). Whether they are caused by questions of war or peace, prosperity or deprivation, scandals, or failures of the government to govern well, some election years

strongly favor one party over the other. These trends often result from evaluations of the president and/or his party. In midterm election years, the party of the president usually loses seats in Congress, and Senate candidates can become victims of a larger national mood. During presidential election years, a Senate candidate's fate may in part be tied to the fortunes of the candidate heading his party's ticket. The evidence, however, suggests that presidential coattails are weak, where they exist at all (Campbell and Sumners 1990).

IMPACT OF POPULATION MIGRATION ON NEBRASKA SENATE ELECTIONS

In this section, a model is developed and tested which examines the influence of population migration on Senate elections in Nebraska. Since 1976, Nebraska has held six Senate races (1976, 1978, 1988, 1996, 2000, and 2008) in which neither candidate was an incumbent. The selection of open-seat races eliminates the influence of incumbency on voter choice, which tends to overwhelm most other explanations for outcomes in congressional elections (Jacobson 1992). The matchups in the six races are detailed in Table 2.

Of those six races, four were won by the Democratic candidate and two were won by the Republican, providing a fair amount of variance in the partisan result. Two of the races were very close, decided by a spread of five or fewer

TABLE 2
CANDIDATE MATCHUPS IN OPEN-SEAT SENATE RACES, NEBRASKA, 1976–2008

Year	Democratic nominee	Political experience	Two-way vote share	Republican nominee	Political experience	Two-way vote share
1976	Ed Zorinsky	Omaha mayor	52.91%	John J. McCollister	Second District, U.S. House of Representatives	47.09%
1978	J. James Exon	Governor	68.27%	Donald Shasteen	Staff of retiring Senator Carl Curtis	31.62%
1988	Bob Kerrey	Governor	57.65%	David Karnes	Senator	42.35%
1996	Ben Nelson	Governor	42.59%	Chuck Hagel	Deputy administrator, U.S. Veterans Administration	57.41%
2000	Ben Nelson	Governor	51.10%	Don Stenberg	Nebraska attorney general	48.90%
2008	Scott Kleeb	Political amateur	41.05%	Mike Johanns	Governor	58.95%

Notes: Karnes is listed as incumbent senator, but he was appointed to the seat by Governor Kay Orr after the death of Ed Zorinsky in 1987. Prior to the appointment, Karnes was a businessman who had served as the Second District chairman for Orr's gubernatorial race in 1986. Whether 1988 should qualify as an open-seat race is open to interpretation. It is included in this study because

points. One was a complete blowout, in which the winner accumulated 68% of the two-way vote. The remaining races were decisive, but not on an epic scale.

It is noteworthy that two-thirds of these races were won by the Democratic candidate, given Nebraska's reputation as a "red state." Partisanship matters, but these cases demonstrate that other electoral assets can outweigh partisan affiliation. Ed Zorinsky was a popular mayor of the most heavily populated part of the state, and even his opponent, Second District Congressman John McCollister, argued that Zorinsky ran a better campaign (Frisbie 1978). J.J. Exon, Bob Kerrey, and Ben Nelson all served as governor prior to running for the Senate, where all three developed reputations for conservative fiscal management. In Kerrey's case, this may have reflected the state's economy in the mid-1980s more than his own preferences. Nevertheless, at the midpoint of his term, in 1985, Kerrey enjoyed an approval rating among Nebraskans of 70%. At the time he left the governor's office, Exon's approval rating in the state was 89%. Ben Nelson's approval rating at the end of his term as governor was 80%. The storied nonpartisan strain in Nebraska's political culture may also contribute to these Democratic victories (Walton 2000). Whatever the reason for the individuals' victories, all of these cases make plain that the partisan composition of the electorate can be matched or exceeded by individual candidates' qualities in open-seat races.

Candidate qualities notwithstanding, the central question of this study concerns whether population gains and losses matter in explaining candidate vote share. Previously reported correlations between population change and party registration, and the correlations between the size of a county's population and its partisan voter base, suggest the possibility that both matter. That is, the size of a county's population is a good predictor of its vote, as is the rate and direction of its population change.

A measurement of population change, along with the previously described variables believed to influence voter choice in Senate elections, can be expressed in the following equation:

$$\text{Democratic vote share} = \text{Constant} + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_{6-10} X_{6-10},$$

where Democratic vote share = percentage of vote the Democratic candidate won in a given county; X_1 = percentage change in the county's population since the previous census; X_2 = population of the county; X_3 = percentage of voters in the county registered Democratic; X_4 = candidate's political experience; X_5 = margin of victory in Republican primary; and X_{6-10} = other, unmeasured effects of each election year.

The data are arranged in a pooled time series. In practical terms, this method combines six separate cross-

TABLE 3
ORDINARY LEAST SQUARES ESTIMATES: INFLUENCE OF POPULATION CHANGE ON DEMOCRATIC
VOTE SHARE IN OPEN-SEAT SENATE RACES, NEBRASKA, 1976–2008

Dependent Variable: Democratic Share of Two-Way Vote, by County

Explanatory variables	Coefficient (standard error)	t score
Change in county population since most recent census	.134 (.031)	4.278***
County population	1.02E-7 (.000)	1.804*
Percent of county voters registered Democratic	.693 (.028)	25.086***
Margin of victory for Republican primary winner in county	-.102 (.017)	-6.179***
Election effects, 1978	.203 (.009)	23.436***
Election effects, 1988	.06 (.01)	5.828***
Election effects, 1996	-.05 (.01)	-4.781***
Election effects, 2000	.047 (.009)	5.086***
Election effects, 2008	.025 (.01)	2.585**
Constant	.212 (.016)	13.495***

Notes: Table entries are regression coefficients, calculated using ordinary least squares. Parenthetic phrases in each cell indicate the standard error of the coefficient. All percentages entered in decimal form (i.e., 10% = .10). County population changed measured as difference between most recent census and population estimate for election year by U.S. Bureau of the Census. Margin of victory for Republican primary winner measured as loser's share of two-way vote subtracted from winner's share of two-way vote. Election effects coded as dummy variables, with 1 entered for each respective election year, 0 for other years. Measure of candidate quality excluded from the estimate, as it covaries precisely with election effects variables. $R^2 = .799$; $F = 241.906$ ***; Pooled Durbin-Watson $d = 1.86$; $N = 558$.

* $p < .10$; ** $p < .05$; *** $p < .01$.

sections (one for each of the elections studied) into one data set for the purpose of estimation. Estimating pooled time series with ordinary least squares (OLS) can violate the OLS assumption of homoskedasticity, however, given the unlikely situation that the error terms for each cross-section are consistent with one another (Sayrs 1989). Pooled time series is also subject to estimation error with OLS because it estimates a single constant, when it is more plausible that each cross-section has its own constant (Hanushek and Jackson 1977). Introducing dummy variables into the equation (X_{6-10} , in the present case) to capture the unique effects of each cross-section (election cycle) helps remedy both of these concerns. In theoretic terms, the variables for election-year effects capture na-

tional forces, such as presidential coattails, and race-specific considerations that are not otherwise controlled for in the model. The equation is estimated using ordinary least squares, and its results are presented in Table 3.

Population change matters in Senate elections. Over these six Senate races, growth in a county's population exerts a positive and statistically significant influence on the Democratic candidate's share of the vote. Where the population of the county has grown in recent years, the Democratic candidate wins a larger proportion of the vote. Apart from Democratic registration, to be discussed momentarily, growth in a county's population exerts the largest influence on Democratic vote share. This result provides clear evidence that larger growth

in a county's population exerts an independent effect on election results, in a way that has favored Democratic candidates in these races. Although population growth matters in explaining these election outcomes at the county level, the size of a county's actual population exerts no meaningful influence on Democratic vote share in these races. While it is true that larger counties have higher proportions of registered Democrats and Independents, county population in and of itself does not produce much in the way of Democratic vote share, when controlling for Democratic registration. The parameter estimate is so small as to be expressed by the estimation software in scientific notation, and the standard error, although rounded to zero, is large enough to fall barely within an acceptable confidence interval. Taken together, these results suggest a negligible influence of county population on Democratic vote share. The larger counties in Nebraska may be more Democratic and Independent than the smaller counties, but factors other than county population explain more variance in the election results.

Specifically, the other two variables hypothesized to influence Democratic vote share in these races—Democratic voter registration and the competitiveness of the Republican primary—produce expected results. According to the parameter estimates reported in Table 3, the percentage of voters in a county registered as Democrats exerts more influence on Democratic vote share than any other variable included in the model. This fits the results reported in national studies of Senate elections (Abramowitz and Segal 1992) and indicates that, although registered Democrats are a shrinking share of the state's voters, they remain consistently loyal to Democratic candidates.

Regarding the influence of the Republican primary on Democratic vote share, the negative sign on the coefficient lies in the expected direction. The variable is measured as the winner's margin of victory over his nearest competitor in each county, based on the two-way vote total. A larger margin of victory means a more unified Republican primary electorate. A more unified Republican primary creates less reason for Republicans to be disgruntled with their party's nominee and thus defect to the Democratic candidate in the general election. That is what happened in these races. A unified Republican Party, based on an absence of closely contested primaries, stayed unified in the general election. The absence of closely contested Republican primaries drove down Democratic vote share at the county level, reflecting a general tendency in Senate elections (Abramowitz 1988).

CONCLUSIONS

The analyses presented in this article demonstrate a relationship between population dynamics and political dynamics in Nebraska in the past three decades. Counties with more rapid rates of growth exhibit more support for Democratic candidates. Shrinking counties exhibit more support for Republican Senate candidates.

Two implications of these phenomena suggest themselves. First, the growing counties in Nebraska are attracting voters with weaker ties to the Republican Party. Although the GOP holds a sizable advantage in voter registration across the state, that advantage does not guarantee electoral wins in Senate elections (nor apparently, in gubernatorial elections, since the office regularly changes party hands between Democrats and Republicans), and the expectation of GOP wins is the weakest in the faster-growing parts of the state. If the Republicans' most loyal supporters dominate the parts of the state that are small and shrinking, and if population migration trends toward increases in the more populated counties continues, the two parties should remain competitive in statewide elections.

Second, these findings provide partial support for Bishop's argument that migrating populations alter the political landscape. As county population increases, so do the proportions of voters registered as Democrats and Independents, as does support for Democratic candidates. As counties lose population, their share of Republican identifiers and voters increases. The literature on population migration in the Plains argues that people leave small communities for economic reasons or to be closer to amenities. It is no doubt true that population shifts in Nebraska have been driven by economic necessity, and perhaps by the amenities and quality of life offered in larger communities. But it is also true that, among other consequences, these changes are contributing to a changing political environment in the state.

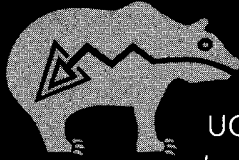
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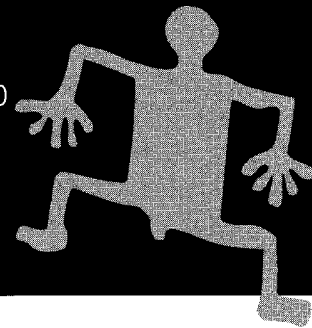


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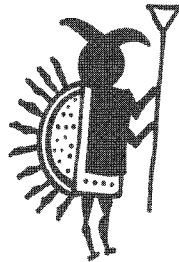
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COTTONWOOD RIPARIAN SITE SELECTION ON THE CHEYENNE RIVER SIOUX RESERVATION

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ABSTRACT—The construction of the Oahe Dam on the Missouri River eliminated thousands of acres of riparian and floodplain lands on the Cheyenne River Sioux Reservation in South Dakota. Restoration is needed to replace wildlife habitat. This study focused on site selection for native cottonwood (*Populus deltoides* Bartr. Ex Marsh. ssp. *Monilifers* (Ait.) Eckenwalde) restoration to help mitigate this loss. Geographic information systems technologies were used to develop a suitability model for cottonwood restoration. Tribal lands were extracted from a digital dataset of landownership. Those touched by or included in a 46 m border of the Moreau River were candidate sites. Of the 182 candidates, 50 sites were randomly selected for model development. Slope, aspect, stream length and number, soil properties, and land cover criteria were given a numeric score and these were summed; the lowest total score possible was -7 and the highest score possible was 33. The sample sites were evaluated and ranked as high (21 to 33, 7 sites), medium (7 to 20, 35 sites), or low (-7 to 6, 8 sites) for growth and maintenance of riparian cottonwood forests. Five sites were selected for cottonwood restoration using the model developed. Bare root trees were planted mechanically and by hand. Drought conditions limited survival and 50% of the area was replanted. Further data collection may increase the use of geographic information system (GIS) technology and facilitate site selection for cottonwood restoration in the northern Great Plains.

Key Words: GIS, *Populus*, riparian restoration

INTRODUCTION

In 1944 the Flood Control Act was passed authorizing the U.S. Army Corps of Engineers to construct water development projects, including five Missouri River main-stem dams (Oahe, Big Bend, Gavins Point,

Fort Randall, and Garrison). These reservoirs were constructed to facilitate flood control, hydroelectric power generation, irrigation, and navigation, and to improve municipal and industrial water supply, recreation, and fish and wildlife habitat (Johnson 1998; Cheyenne River Sioux Tribe 1999). The Cheyenne River Sioux Tribe lost 42,290 ha (104,420 ac) of land to the construction of the

Oahe Dam, including lands not flooded but determined to be potential erodible areas; approximately 28,815 ha (71,148 ac) of wildlife habitats were inundated. In August of 1999 legislation passed to reclaim lands taken by the Corps of Engineers during the construction of two dams on the Missouri River. Public Law 106-53 provided for the transfer of lands back to the three entities and for the establishment of terrestrial wildlife habitat restoration trust funds upon the completion of restoration plans. The Cheyenne River Sioux Tribe submitted their terrestrial wildlife habitat restoration plan in October 1999.

The tribal plan describes three main goals, one of which is to mitigate for the loss of wildlife habitat. On the Cheyenne River Sioux Reservation, the flooding of the Missouri River resulted in the loss of 9,778 ha (24,143 ac) of riparian habitats (Cheyenne River Sioux Tribe 1999) with 5,708 ha (14,095 ac) being cottonwood/ash and cottonwood/willow habitats. Due to the large loss of riparian areas, the Cheyenne River Sioux Tribe gave riparian restoration the highest priority of all habitat mitigation activities.

The journals of Lewis and Clark (1804–1806; Coues 1893) indicate that along the Missouri River in Montana, cottonwood were scattered, being dense in some areas and absent in others. Native American Indians used cottonwood for fuel and for horse forage (Winship 1904). The cottonwood also serves an important role in Lakota ceremonies (<http://angelfire.com/co/MedicineWolf/Lakota/sundance.html>). Cottonwoods dominated the unregulated Missouri River floodplain with almost half of the original forest along the upper Missouri River being early-successional cottonwood-willow forest less than 40 years old (Johnson 1998). Severson and Boldt (1978) described the cottonwood-dominated floodplain with the dominant species from Canada to Texas being the plains cottonwood with subordinates of willows (*Salix* L.) and silver sagebrush (*Artemisia cana* Pursh). The dominant species lost in the inundated riparian areas on the Cheyenne River Sioux Reservation were cottonwood, green ash (*Fraxinus pennsylvanica* Marsh.), and willow trees (U.S. Army Corps of Engineers 1982).

Natural establishment of cottonwood seedlings occurs on bare moist sites. Bradley and Smith (1986) found cottonwood stands on portions of point bars that remained moist, but also safe from extended flooding and ice flows in the river. Mature cottonwood seeds must reach a moist seedbed and germinate in a very short period. The timing of seed release and flooding is critical (Borman and Larson 2002). Vegetative reproduction can occur from sprouts, root suckers, broken branches, and shed branch-

lets (Borman and Larson 2002) depending on species and environmental conditions. Natural establishment is hindered by changes in flooding patterns. An understanding of local fluvial processes is necessary for effective management (Scott et al. 1997).

Among the objectives of the tribal plan's riparian restoration goals are restoration and management of 3,240 ha (8,000 ac) of native cottonwood riparian habitat and the establishment of ranking criteria for evaluation of site need and monitoring of project accomplishments. Geographic information systems are proving to be a useful management tool in many fields of natural resource management. The ability of GIS tools to store and integrate many abiotic and biotic criteria makes it increasingly popular as a means to assist habitat targeting in restoration projects (Bailey et al. 2003). Store and Kangas (2001) used a GIS as a platform for managing, combining, and displaying criterion data and for producing new data by using spatial analysis functions in a habitat suitability model. The Cheyenne River Sioux Tribe uses GIS for wildlife management, habitat restoration monitoring, law enforcement, and range management, using existing data and creating new data with global positioning systems (GPS).

Currently the Game, Fish, and Parks Department of the Cheyenne River Sioux Tribe has been identifying riparian restoration sites on a producer interest basis. In order to increase long-term success of the riparian restoration projects, a more systematic method is needed. The objective of this project was to establish a site-ranking method for native cottonwood riparian habitat restoration utilizing GIS technology.

METHODS

The reservation is often broken into four quadrants for wildlife management due to the large land base; the study was conducted only in the northeastern quadrant, Dewey County, of the reservation (Fig. 1).

The reservation is a mosaic of landownership and jurisdictions. Within the reservation there are tribal, federal and state land jurisdictions. The Cheyenne River Sioux Tribe is responsible for wildlife management on all tribal lands, approximately 567,000 ha (1.4 million acres). Therefore, the first step for this project was to select lands under tribal jurisdiction, 3,640 tracts.

The study focused on the Moreau River which runs through the entire northeast quadrant of the reservation and is the primary stream in this region. Typically the Moreau River consists of sand bars and gently sloping

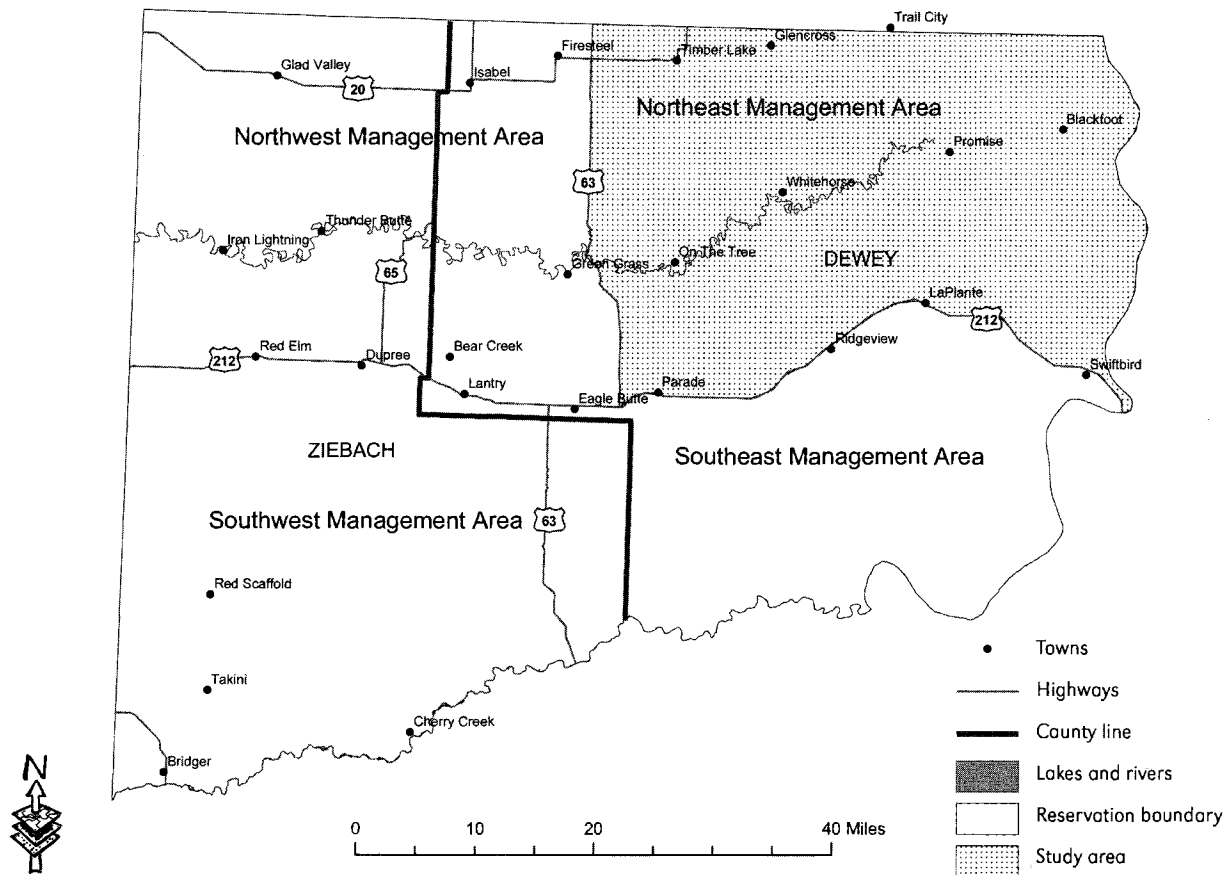


Figure 1. The study area in the northeast quadrant of the Cheyenne River Sioux Reservation, South Dakota. Map created by Julie Thorstenson, 2005.

floodplains with steep, sparsely vegetated cut banks occurring throughout the river system. Land tracts that were partially or wholly within 46 m (150 ft) of the Moreau River were selected from the new layer containing the 3,640 tracts. These 182 tracts were numbered to keep their identity confidential and these numbers were exported into a Microsoft Excel spreadsheet for random selection of 50 tracts to build the model (Fig. 2). Various selection criteria were applied to these 50 tracts. The tract size ranged from 8.1 ha (20 ac) to 258.8 ha (639.2 ac).

Restoration project success depends partly on how closely the site characteristics match the needs of the ecosystem being restored (Baird 1989). In order to rank potential riparian restoration sites, we assigned positive values to Moreau River presence, stream number and length, slope, aspect, soil properties, and land cover. Negative values were assigned for excessive mean slope and excessive grasslands.

GIS software was used to clip the Moreau River layer for each of the sample tracts, and the total length of the

Moreau River in each sample site was calculated. Presence of the Moreau River within the sample site was given a value of 5 to emphasize the importance of water to cottonwood restoration. Riparian restoration sites on the Cheyenne River Sioux Reservation are fenced and have been kept to a maximum of 1.6 km (1 mile) to avoid denying water access and grazing. Five categories were assigned for length of the Moreau River; these categories and their respective values are shown in Table 1. Lengths less than 201 m (660 ft) were considered too small to be cost effective and were assigned a value of zero.

Small stream channels and their riparian zones provide unique habitats (Meyers and Wallace 2001), but there is no clear definition or agreement of what constitutes a small stream (Moore and Richardson 2003). Various intermittent and ephemeral streams drain into the Moreau River. A Dewey County stream layer was sized, using ArcGIS, to the study area (Fig. 2). This new stream layer was clipped to each of the sample sites. These streams are very important as potential restoration sites because

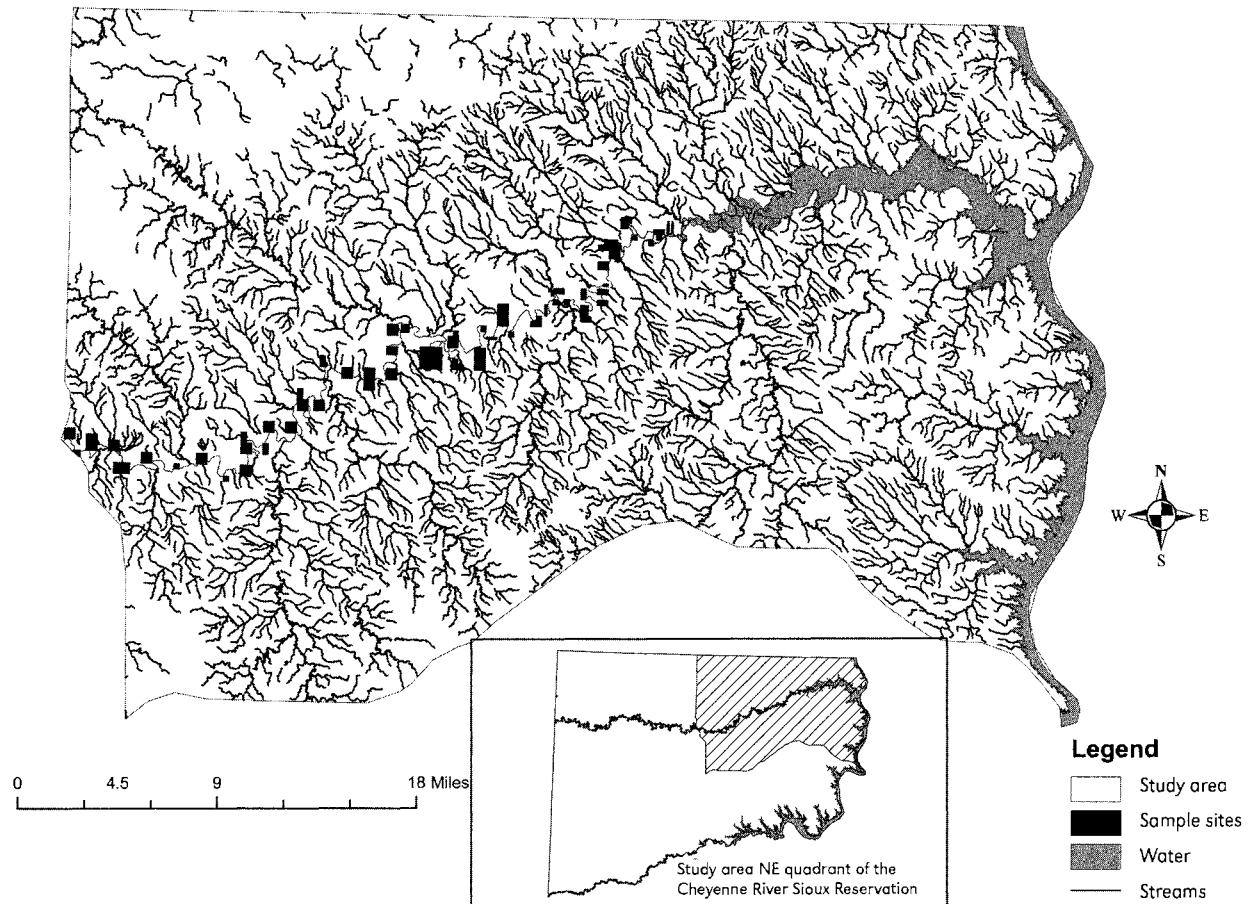


Figure 2. Streams and sample sites within the study area. Map created by Julie Thorstenson, 2005.

they provide seasonal flooding needed for cottonwood establishment. Their importance is defined in the stream factors category. The total number of streams was broken into six categories (Table 1) and values were assigned for each. Total length of all streams within each sample site was also calculated. The total stream length was considered, with categories ranging from 0 to 1520+ m (5,001+ ft) (Table 1).

Slope of the land often dictates the vegetation and land use. Hodorff et al. (1988) found that topography influenced woodlands stand structure and that steep slopes of closed stands discouraged livestock use. To analyze slope factors, a slope raster was derived from a digital elevation model (DEM) of Dewey County using ArcGIS Spatial Analyst. Slope was analyzed for each of the 50 sample sites using the zonal statistics option in Spatial Analyst. Ormsby and Alvi (1999) define zones as sets of cells with the same value. This resulted in a slope statistics table detailing such factors as minimum, mean, and maximum for each of the sample sites. Mean slope, expressed as a percentage, was used for evaluation purposes. Mean slope

was divided into four categories and values assigned for each of the four (Table 1). The lower the percentage of mean slope, the greater the value assigned. Putnam et al. (1960) reported that eastern cottonwood occurs natively on well-drained flats and that where it occurs on slopes, it is confined to the lower ones. Any slope over 15% was considered excessive for cottonwood growth and maintenance and a value of 5 was deducted from the total score. A negative value was assigned to steep slopes because they are poorly suited to establishment and survival and are difficult to plant and maintain.

Aspect was obtained from the Dewey County digital elevation model. It depicts the direction in which the land is sloping as measured in degrees (0° to 360°). Most of the approximately 810 ha (2,000 ac) of native trees and shrubs in Dewey County are on bottomland, in natural draws, and on steep, north-facing slopes (Kalvels and Boden 1979). A new grid dataset depicting aspect for the study area was created using the Surface Analyst component of Spatial Analyst. Aspect was analyzed for each of the 50 sample sites using the zonal statistics component of

TABLE 1
SITE EVALUATION FORM AND NUMBER OF SAMPLE SITES
(FROM 50) RECEIVING EACH SCORE

Criteria	Characterization	Value/Score	No. of sample sites
Moreau River present	Yes	5	44
	No	0	6
Moreau River length (m)	>1,605	4	4
	803–1,605	3	11
	402–802	2	15
	201–401	1	7
	<201	0	7
Total stream length (m)	>1,520	4	3
	761–1,520	3	4
	305–760	2	13
	31–304	1	6
	<31	0	24
Number of streams	5	5	2
	4	4	1
	3	3	3
	2	2	7
	1	1	14
	0	0	23
Mean slope (%)	0–5	3	2
	5.1–10	2	10
	10.1–15	1	11
	>15 (excessive)	–5	27
Mean aspect (°)	179–269	3	23
	89–178	2	27
	270–360	1	0
	0–88	0	0
Presence of excellent or good soil (≥ 0.4 ha)	Excellent	2	44
	Good	1	6
	Neither	0	5
Total hectares of good and/or excellent soil	>41	4	13
	21–41	3	11
	5–20	2	17
	0.4–4	1	4
	0	0	5
Deciduous forest present (≥ 0.4 ha)	Yes	1	25
	No	0	25
Wetland vegetation present (≥ 0.4 ha)	Yes	1	30
	No	0	20
Excessive grassland (%)	>75	–2	26

Spatial Analyst. This resulted in an aspect statistics table detailing such factors as minimum, mean, and maximum for each of the sample sites. Mean aspect, expressed in degrees, was used for evaluation purposes. Aspect was divided into four categories and values assigned for each, with northeast facing slopes (179° to 269°) receiving the highest score (Table 1). Southwest-facing slopes were not considered suitable for cottonwood growth and received a score of zero.

Soil type is accepted as an important abiotic factor in determining a site's suitability for a particular habitat (Tansley 1939, cited in Bailey et al. 2003). Friedman et al. (1995) found that a site with coarse soil texture and low organic matter should be chosen to increase cottonwood seedling survival. A Dewey County soil map layer was clipped to the study area using ArcGIS. The sample sites were overlaid on the study area soil layer and the soil layer was clipped using the intersect function in ArcGIS. In this case the input layers were the sample sites and the soil layer, which resulted in soils for each sample site. The soil composite of each of the 50 sample sites was then summarized. An acre percentage field was created and calculations made to yield a percentage of each soil type for the sample site. Next, all of the soils present in the 50 sample sites were recorded and examined. A ranking system was created to rank each soil series for suitability to grow and maintain native cottonwoods. The following factors were used to determine the suitability ranking of the soil: available water holding capacity, windbreak suitability (soil characteristics and plant species), fertility, runoff, permeability, erosion potential, and organic material (Dewey County soil survey). Values were summed and the soils were broken into one of four suitability indexes: poor, fair, good, and excellent. To receive a score for the soil rating, the sample site had to contain a minimum of 0.4 ha (1 acre) of excellent and/or good soil. Presence of excellent soil yielded a value of 2 and presence of good soil, a value of 1 (Table 1). Total acreage of good and excellent soil was also considered. Five categories were established for total acreage and values assigned to each (Table 1).

The 1992 National Land Cover Data (NLCD) was obtained through the U.S. Geological Survey (USGS) Seamless Data Distribution System for the eastern half of the reservation. This 30-m raster dataset was then clipped using ArcInfo to an area that included all 50 sample sites. ArcGIS Spatial Analyst was used to analyze acreage and percentage of land-cover classes represented for each of the 50 sample sites. NLCD is a 21-class land-cover classification scheme applied consistently over the United States (U.S. Geological Survey 2003). Land-cover classes

include water, developed (areas with a high percentage of constructed materials), barren, forested upland, shrubland, non-natural woody, herbaceous upland natural/seminatural vegetation, herbaceous planted/cultivated and wetlands. The U.S. Geological Survey (2003) defines deciduous forests as areas dominated by trees where 75% or more of the tree species present shed foliage simultaneously in response to seasonal change. Wetlands are described by the U.S. Geological Survey (2003) as areas where the soil or substrate is periodically saturated with or covered with water. Wetland vegetation and deciduous forests are often common in riparian areas. Therefore, presence of each was examined and scored (Table 1). At least 0.4 ha (1 acre) needed to be present to receive a value. A value of -2 was applied if an area was greater than 75% grassland (Table 1). Grasslands are defined as "areas dominated by upland grasses and forbs" (U.S. Geological Survey 2003). It was assumed that greater than 75% grassland indicated an upland area, not favorable for growing and maintaining cottonwood trees.

Once the ranking criteria were examined and weighted, an evaluation form was created (Table 1). Each of the 50 sample sites was evaluated based on this form, and scores were totaled and recorded. The lowest possible value any site could receive was a -7 and the highest possible score was 33. Threshold levels were determined for a suitability index. Low sites were sites with a score of -7 to 6, medium, 7 to 20; and high, 21 to 33. For the model, low sites were assumed to be unsuitable for cottonwood restoration. Medium sites were sites that might be able to grow and maintain cottonwoods, but might require various degrees of additional site work. High scores indicated the best sites for cottonwood restoration. Future work will be conducted to "ground truth" the model and test these assumptions.

RESULTS

The 50 tracts included in the study totaled 2,829 ha (6,986 ac) with a minimum size of 8 ha (20 ac), maximum of 259 ha (640 ac) and an mean of 57 ha (140 ac).

In 44 of the 50 sample sites, the Moreau River was present. Of these, 7 sites contained lengths less than 201 m (660 ft), 7 contained between 201 m and 401 m (660 and 1,319 ft), 15 contained 402 m to 802 m (1,320 to 2,639 ft), 11 contained between 803 m and 1,605 m (2,640 and 5,279 ft) and 4 sites contained more than 1,605 m (5,279 ft) (Table 1). Most of the riparian restoration projects presently on the reservation are at least 1,605 m (5,280 ft) in length. However, length does not influence

the overall quality of a site for restoration. The minimum reach to receive a positive value was 201 m (660 ft). Several factors contributed to the selection of this minimum. It is not cost efficient for the tribe to execute extremely small restoration sites due to the distance traveled and the labor and supplies required. However, the allowance of a shorter length gives landowners with less access to the Moreau River a chance to improve riparian habitat. Most of the land in the study area is rangeland used for livestock production. The Moreau River provides a water source and much-needed winter protection to these producers. The shorter reach allows a producer to restore cottonwood habitat without restricting complete access to a much-needed resource.

A large portion of the sites ($n = 23$) did not contain small streams. Fourteen of the remaining sites contained 1 stream, seven contained 2, three contained 3, one contained 4, and two sites contained 5 streams. The mean length of a small stream was 419 m (1,377 ft). Although 23 sites did not contain small streams, this did not correspond directly with a low suitability index. The evaluation results of the Moreau River and stream factors categories for the 50 sample sites can be seen in Table 1.

The minimum slope within the 50 sample sites was 3.1 with a maximum of 57.5. The mean slope of the 50 sample sites was 20.1. Scoring for slope was based on four categories. Only 2 sites fit the 0% to 5% category, with 10 in the 5.1% to 10% category and 11 sites in the 10.1% to 15% category. Twenty-seven of the sites had mean slopes in excess of 15% (Table 1). The Moreau River usually consists of a broad floodplain on one side and a steep cutbank on the other. Since mean slope was calculated for the entire sample site, this may not have been an accurate method for analysis of slope. It might have been more accurate to determine a percentage of each of the three categories to assess an area.

The analysis of aspect showed that the majority of the sites were in the 89° to 178° northwest-facing category ($n = 27$). The remaining 23 were in the 179° to 269°, northeast-facing category (Table 1). Sites were relatively similar in aspect. This factor seemed to have little influence on the overall site suitability for cottonwood restoration in our selected samples. While aspect may not have an effect on the choice of locations for cottonwood restoration, it may be important in site selection for other woody species. For example, woody type habitats that are not riparian exist on steep north-facing slopes (Severson and Boldt 1978).

Many soil factors contribute to the success of cottonwood restoration. There were 10 soil associations within

the study area. Friedman et al. (1995) recommended choosing sites with coarse soil texture and low organic matter to minimize competition. Of the 31 different soil types in the study area, 5 were rated excellent, 5 were good, 4 were fair, and 17 were poor in terms of their suitability for cottonwood restoration. Soils that ranked in the fair and poor categories required too much additional site preparation such as additional irrigation and site manipulation to increase runoff and flooding or fertilization to provide suitable cottonwood restoration, and overall site success was anticipated to be low (Dewey County soil survey). Five of the 50 sample sites lacked either good or excellent soils (Table 1). All of these sites received a low overall ranking. This method represents the significance of soil on cottonwood restoration. The total acreage of good and excellent soils was also calculated and scored (Table 1; Fig. 3).

Half of the sample sites ($n = 25$) had the presence of deciduous forests. The presence of wetland vegetation was slightly higher with 30 sample sites (Table 1). Twenty-six of the 50 sample sites had excessive grasslands and received a negative score (Table 1). As much as 88% of the land in the study area is in native grass and is grazed (Kalvels and Boden 1979). The sample sites that contained deciduous forests and wetland vegetation directly corresponded with the presence of the Moreau River or streams. The study area was predominantly rural and contained no major urban areas. Therefore, land classified as developed was not considered in the evaluation. The NCLD provides a broad generalization for land use in an area; however, one must consider the age of the data and that land use may have changed. Therefore, the NCLD data were used only as supplemental information and caution was taken not to place too much emphasis on it. This was accomplished by weighting the criteria at a lesser value than other criterion.

An index was developed having three classes of suitability for cottonwood restoration (based on criteria scores). The three classes were scores of -7 to 6 assumed to be low suitability, scores ranging from 7 to 20 assumed to be medium suitability, and scores between 21 and 33 assumed to be high suitability. A suitability map was created based on the suitability indexes (Fig. 4). Of the 50 samples, 8 were low suitability, 35 were medium suitability, and 7 were high suitability (Fig. 5).

Cottonwood restoration sites were selected on a small scale in 2006 based on the developed GIS model. To test the validity of the model, sites were selected from all classes of suitability. A total of five sites were selected: one low suitability, one medium suitability, and three

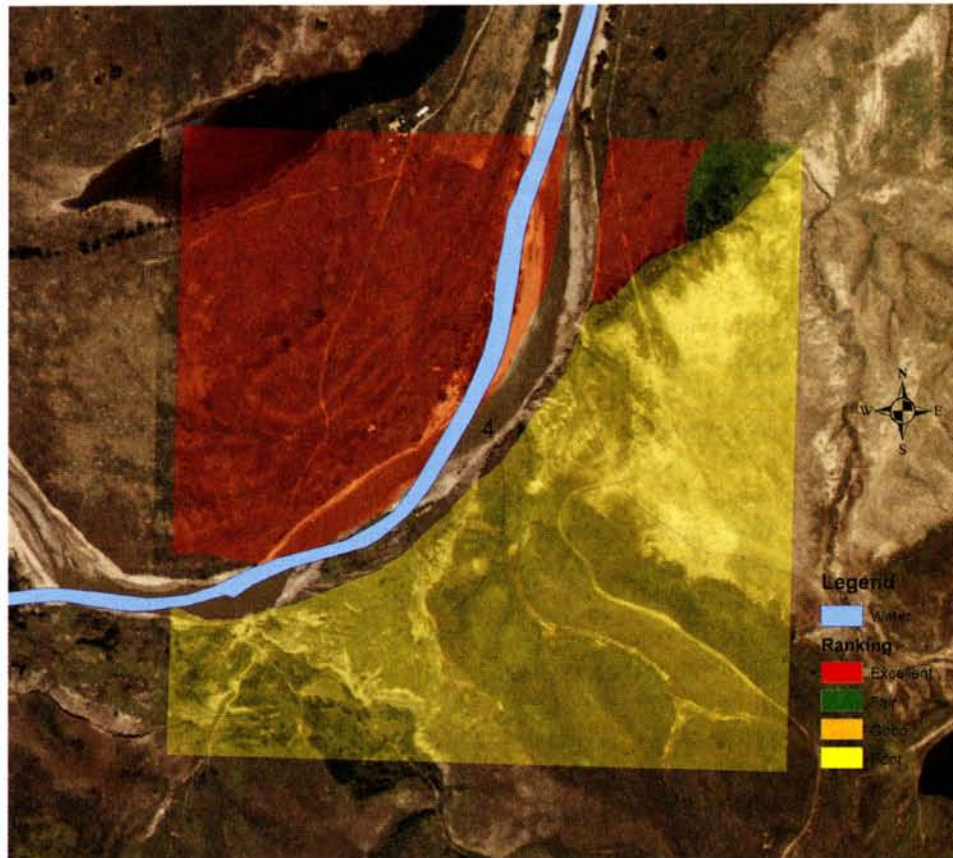


Figure 3. Aerial photo of sample site 4, showing a mix of excellent and poor soils, resulting in medium suitability for cottonwood trees. Map created by Julie Thorstenson, 2005.

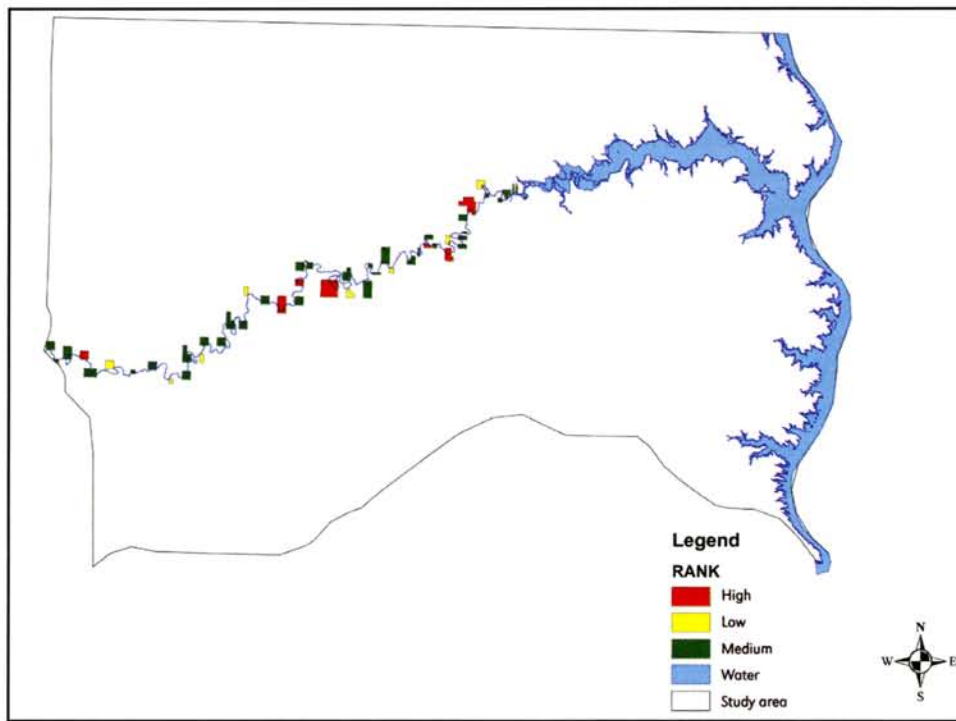


Figure 4. Sample sites by suitability for native cottonwood tree restoration in the northeast quadrant of the Cheyenne River Sioux Reservation, South Dakota. Map created by Julie Thorstenson, 2006.

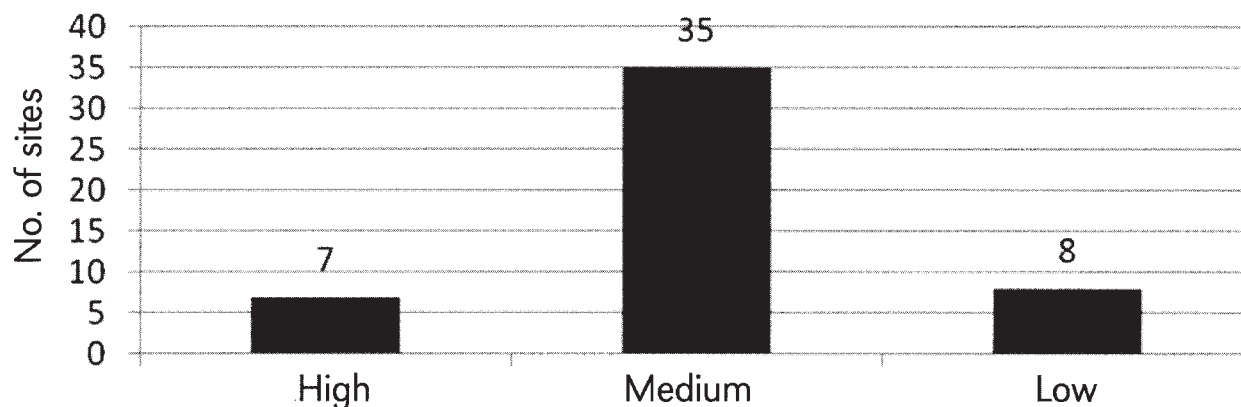


Figure 5. Cottonwood suitability index ranking of 50 sample sites in the northwest quadrant of the Cheyenne River Sioux Reservation, South Dakota.

high suitability. Each of the five sites was randomly hand planted with 3,000 (total) bare root trees. In addition, two L-shaped areas were mechanically planted with bare root trees within the medium suitability site and one of the high suitability sites (1,915 trees total). The growing season in 2006 was droughty, and 50% of the mechanically planted areas were replanted in 2007. Ware and Penfound (1949) found that cottonwood seedlings were vulnerable to drought during their first year, prior to extensive root development. Because of a change in employment, it was not possible to collect further data on survival and growth.

CONCLUSIONS

This study demonstrates how GIS technologies can be used to select sites for native cottonwood restoration on the Cheyenne River Sioux Reservation. It provides a scientific method for cottonwood restoration site selection and can serve as a model for site selection for other conservation and restoration practices.

The most important criterion for selection of sites for cottonwood restoration was presence of the Moreau River. Sample sites that did not contain the Moreau River had a negative rating for this criterion and, overall, were given a low suitability ranking. This is to be expected when dealing with riparian restoration; the proximity of a stream or river is a requirement. Riparian sites bare and moist enough for cottonwood establishment are usually close to the channel and subject to disturbance by the stream (Friedman et al. 1997). The success of cottonwood restoration on the Cheyenne River Sioux Reservation is contingent on locating sites along the Moreau River.

The second critical consideration was soil. The overall results of this study support the findings of Store and Kangas (2001) that permanent factors such as soil characteristics define the habitat potential or, in the case of this study, the site suitability.

The ultimate measure of success of this study would be actual fieldwork. Sites were selected based on the model, and bare root trees were planted. Unfortunately it was not possible to continue data collection to determine survival and growth. In the future, success of restoration efforts could be determined by annual monitoring and comparison with wildlife population surveys that are already being conducted on a yearly basis. This is a lengthy process that was outside the scope of this study. Although the effects of the Pick-Sloan Plan cannot be corrected completely, the restoration of a vital natural resource will help to offset some portion of the overall damage inflicted on riparian habitats.

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DO INVASIVE RIPARIAN WOODY PLANTS AFFECT HYDROLOGY AND ECOSYSTEM PROCESSES?

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ABSTRACT—Political and socioeconomic pressures on riparian areas in semiarid regions of the Great Plains are growing as water resources become more limited. Management along waterways has altered stream ecology and hydrology in ways that encourage the invasion and expansion of native (e.g., *Juniperus virginiana*) and non-native (e.g., *Tamarix* sp. and *Elaeagnus angustifolia*) woody species. One management tool currently implemented to restore the hydrology or increase water yields along waterways in semiarid areas is the removal of vegetation or invasive species. How managers should respond to invasive woody plants to optimize hydrological functions without compromising other riparian ecosystem functions is still debatable. In this manuscript, we provide an overview of the ecological status and hydrological role of riparian vegetation in the northern Great Plains, with examples drawn from the region and other semiarid areas. Additionally, we present information compiled from published studies on water consumption of native and non-native species at both tree and stand levels, and we evaluate the ecohydrological outcomes from removal of invasive woody vegetation. Lastly, we consider the economic costs and benefits of woody species removal, and suggest considerations to help managers make decisions regarding woody species removal.

Key Words: ecohydrology, evapotranspiration, *Juniperus*, phreatophytes, *Populus*, riparian forests, *Tamarix*, woody species encroachment

INTRODUCTION

The word “riparian” is derived from the Latin word “riparious” which means “bank” of a stream, and refers to the land, flora, and fauna adjacent to or on the bank of a body of water (Ilhardt et al. 2000). Ilhardt et al. (2000) defined riparian areas functionally as “three-dimensional ecotones of interaction that include terrestrial and aquatic ecosystems, that extend down into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain to the water, laterally into the terrestrial ecosystem, and along the water course at a variable width.” Thus, riparian areas encompass plant communities that are growing inside as well as outside the hydrological zones (Naiman and Décamps 1997). Such communities exert direct and indirect biological, physical, and chemical influence on, and are influenced by, an adjacent water body through both above- and below-ground interactions (Odum 1971). The ecosystem functions played by riparian areas as species conduit, barrier, energy source, energy sink, and habitat are well documented. These services result in terrestrial and aquatic biodiversity, corridors and habitats for wildlife, stream-bank stabilization, soil protection, water storage, groundwater recharge, mediation of seasonal water-level fluctuations, improved water quality, nutrient cycling, carbon sequestration, climate regulation, nonpoint pollution control, aesthetic, educational opportunities, as well as economically important products, biofuels, and water production (Haycock et al. 1997; Lynch and Tjaden 2000; Lee et al. 2003; Núñez et al. 2006; Sun et al. 2006; Rahel and Olden 2008).

In recent decades riparian areas have experienced changes in vegetative cover as invasive nonriparian woody species spread at the expense of ecologically important native riparian species (Cleverly et al. 2006). These changes reflect factors like natural species migration, altered management practices, damming, fire and flood control, climate change, and nitrogen depositions (Tabacchi et al. 2000). Ecological changes resulting from nonriparian woody species encroachment have substantially affected the hydrological cycle and water yields in several ecosystems. These ecohydrological changes are of particular concern in semiarid areas like the Great Plains (Stromberg et al. 1996; Warren et al. 1996; Heilman et al. 2009), where water for human use is in high demand, and where managers have been required to use water budgets as well as quantifying ecosystem responses to various water management scenarios (Dahm et al. 2002). Competing demands for water resources

and the role of riparian evapotranspiration in depleting watershed-level water budgets are prompting land managers and policy makers to seek better understanding of the ecological and socioeconomic roles of riparian systems so that water resource management can be improved. The objectives of this paper are therefore (1) to provide an overview on the current ecological status and hydrological role of riparian vegetation in the northern Great Plains, drawing examples from the region and other semi-arid areas; (2) to present published studies on water consumption in native and invasive woody species in various regions of the Great Plains and other semiarid areas; and (3) to assess the possible ecohydrological environmental effects and economic cost of the removal of invasive woody vegetation.

RIPARIAN VEGETATION IN THE NORTHERN GREAT PLAINS

Woody riparian vegetation in the Great Plains is dominated by the cottonwood species complexes that inhabit floodplain regions of sizeable rivers and streams, subirrigated valleys, and minor drainages as small groves or scattered individuals (Barker and Whitman 1988). Cottonwoods are pioneer species that produce short-lived seeds, which are carried over long distances by wind and require exposed sediments for seed germination and establishment (Taylor 2001). As rivers flood and meander, newly exposed moist substrate becomes available for cottonwood to colonize (Johnson et al. 1976; Friedman et al. 2006). In areas suitable for their establishment, cottonwoods can outcompete saltcedar simply by growing more quickly (Sher et al. 2000). Mature cottonwood trees depend on groundwater access to survive and are thus largely restricted to riparian areas supplied with alluvial groundwater originating from streamflow (Busch et al. 1992). In the northern Great Plains, cottonwood (*Populus deltoides*) usually dominates young stands. Over time, other, more shade-tolerant species such as green ash (*Fraxinus pennsylvanica*), boxelder (*Acer negundo*), American elm (*Ulmus americana*), hackberry (*Celtis occidentalis*), and peach-leaf willow (*Salix amygdaloides*), and occasionally bur oak (*Quercus macrocarpa*), catalpa (*Catalpa speciosa*), and walnut (*Juglans* spp.) regenerate beneath the cottonwoods as understory associates. Islands and stream banks in riparian areas are known to contain dense thickets of sandbar willow (*Salix exigua*) (Barker and Whitman 1988) and black willow (*Salix nigra*). The latter is often present in moist forest regions like those found in the southeastern portion of Nebraska (Rothenberger 1987). Roughleaf dogwood (*Cornus*

drummondii) is common in many lowland wooded areas, and honeylocust (*Gleditsia triacanthos*), which is adapted to a variety of environments, is especially tolerant of arid banks with southern exposures. Eastern redcedar (*Juniperus virginiana*) and chokecherry (*Prunus virginiana*) are widespread throughout the floodplain (Rothenberger 1987).

Cottonwood forest types along riparian areas are particularly vulnerable to floodplain degradation due to activities such as damming, livestock production, clearing land for agriculture, and human settlement and transportation corridors (Rood et al. 2003). An example of these changes took place along the Platte River in Nebraska, where, by 1900, pioneers, homesteaders, and Native Americans harvested large areas of woody vegetation along these riparian corridors, shifting this ecosystem from a broad region of heavily forested riparian woodlands to areas of herbaceous vegetative cover and agricultural fields (Johnson and Boettcher 2000; West and Ruark 2004).

Human activities have created conflict among stakeholders interested in the different environmental benefits and have impacted services provided by riparian areas (Auble et al. 1994). Damming, channelization, irrigation, and agricultural expansion along these waterways have aggravated the effects of other human disturbances by constraining natural water flow, abbreviating flooding and subsequent scouring, and augmenting water table variability. For example, damming in the upper Missouri River in North Dakota led to 77% and 98% reductions in average annual area eroded and deposited, respectively. Reduced river meandering decreased sediment loads, resulting in narrower and shallower channels. As a consequence, riparian forests composition along the Missouri River changed from being 47% dominated by young pioneer species of cottonwoods and willows prior to European settlement, to a forest where pioneer species accounted for only 6% of the species composition, an 87% drop, in 1979 (Johnson 1992). Intensive agricultural production during the 20th century developed in the Great Plains with little understanding of its impacts on natural resources including native grasslands, water, wildlife, and woodlands (Hughes 1994; Johnson 1997). Productive soils next to waterways were often cleared for row crop production, thus reducing buffer zones, and livestock overgrazing resulted in considerable losses in forest cover, increased soil erosion, and damage to linked plant, animal, soil, and water assets.

As human activities have altered river hydrology and reduced native riparian vegetation, many studies have

documented increases in non-native woody invasive species, such as Russian olive (*Elaeagnus angustifolia*) and saltcedar (*Tamarix chinensis*), and native aggressive woody species, such as eastern redcedar (Carmen and Brotherson 1982; Barker and Whitman 1988; Johnson 1994, 1997; Glenn et al. 1998; Lesica and Miles 1999; Friedman et al. 2005, 2006). As invasive species have spread, ecohydrologic consequences, such as drops in the water table and reduced water yields, have been observed in riparian systems (Sala et al. 1996; Huxman et al. 2005; Pataki et al. 2005; Scott et al. 2006; Wilcox and Thurow 2006). Woody species encroachment and their potential impacts on water resources in semiarid regions of the Great Plains are addressed in the following sections.

WOODY SPECIES ENCROACHMENT

Altered hydrological regimes have been shown to change riparian community composition, structure, and function, and in many cases, to increase encroachment of native (nonriparian) aggressive and non-native woody species (Tabacchi et al. 1996; Graf 2001). In Arizona, Horton et al. (2001a, 2001b) observed that native riparian species like western cottonwood (*Populus fremontii*) and Goodding's willow (*Salix gooddingii*) died when they could no longer access groundwater because river modification and climatic factors reduced water availability and thus facilitated the expansion of saltcedar into these riparian areas. Similarly, western cottonwood stands were replaced by saltcedar in the absence of flood disturbance along the Lower Escalante River in Utah as cottonwood clones matured, thinned, and died (Irvine and West 1979). Along the Verde River in Arizona, saltcedar stand density was greater in reaches where water flow was regulated compared with reaches where water flow was unregulated; the opposite trend held true for mature (11–40 year) and old-growth (>40 year) cottonwood stands (Beauchamp and Stromberg 2007). Saltcedar and Russian olive replaced cottonwood stands as well along the Rio Grande in New Mexico and along the Marias River in Montana due to changes in river hydrology (Howe and Knopf 1991; Lesica and Miles 1999). Vegetation surveyed along the San Pedro River in Arizona was dominated by *T. ramosissima* where flow frequencies ranged between 40% and 60%, groundwater depth was between 3.2 m and 3.8 m, and groundwater depths fluctuated between 0.59 m and 0.75 m (Lite and Stromberg 2003). In contrast, *Populus fremontii* dominated sites where flow frequencies ranged between 73% and 78%, groundwater depth was between 2.4 m and 2.9 m, and groundwater depths fluctuations

lower than 0.48 m and 0.56 m. Along 20 reaches in four southwestern states (AZ, NM, UT, and CO), saltcedar is more abundant in reaches where hydrology has changed (Mortenson and Weisberg 2010). However, Russian olive abundance was uncorrelated with hydrologic changes.

Russian olive, saltcedar, and eastern redcedar have been widely planted throughout the United States since the 1900s. Both Russian olive and saltcedar produce large amounts of small seeds capable of germinating under a wide range of environmental conditions (Sala et al. 1996; Katz and Shafroth 2003). Eastern redcedar seeds are eaten and dispersed by birds (Lawson 1990). Friedman et al. (2005), in a study that examined non-native riparian tree species in the western United States, reported that saltcedar and Russian olive have become the third and fourth most frequently occurring woody riparian species in the region, with saltcedar dominating low elevation sites in the southwestern United States and Russian olive being abundant in the northern Great Plains. Saltcedar introduced in central Wyoming between 1936 and 1953 spread northward into the Yellowstone and Missouri rivers in Montana by 1951 and 1967 (Pearce and Smith 2007). The spread of *Tamarix* in the western United States is limited by its sensitivity to frost (Friedman et al. 2005), suggesting that its future spread could be impacted by changes in minimum temperatures. A mid- to late successional species, the native eastern redcedar (McKinley and Blair 2008) has also invaded as disturbance regimes and stream hydrology have changed. The expansion of invasive woody species is predicted to further alter the ecohydrology of streams with potentially adverse consequences on water budgets.

RIPARIAN VEGETATION AND WATER RESOURCES

Tabacchi et al. (2000) describe how riparian vegetation influences water availability in three ways. First, the physical structure of riparian vegetation largely determines the fate of sediment and nutrients from adjacent terrestrial ecosystems carried by runoff by altering overland flow rates. Second, both sediment retention and nutrient cycling within the riparian ecosystem control both the amount of nutrients that can reach the aquatic ecosystem and the stream water temperature due to shading. Organic debris from riparian vegetation can provide food and habitat for aquatic species. Thus, riparian ecosystems exert both physical and biological influences over the water quality of aquatic ecosystems. Third, processes such as soil evaporation, plant water consumption, and

foliage interception of precipitation affect the hydraulic conductivity between the terrestrial ecosystem and the aquatic ecosystem. In this review, we briefly address the physical and chemical roles of vegetation in riparian areas, emphasizing how vegetation affects hydrology through water consumption.

Water Flow and Physical Structure of Vegetation

The physical structure of vegetation has been shown to obstruct, facilitate, or divert water flow and therefore impact hydraulic connectivity and other large-scale water properties (Tabacchi et al. 2000), with vegetation responses and impacts varying between and within geographic regions and stream types. For example, Guillemette et al. (2005) in a review of 50 watershed basin studies concluded that the removal of over 50% of basin vegetation will result in flooding and erosion. On the other hand, pioneer species that colonize immediately following disturbance may increase heterogeneity of the water flow pattern while dense herbaceous cover may limit surface water infiltration and trap fine sediments that sustain moisture levels in the upper soil profile during dry periods. Johnson (1994) reported that flow reductions due to hydrological alterations along the braided Platte River in Nebraska initially favored the spread of cottonwood-willow forests. As cottonwood-willow forests spread, they transformed the river from a wide channel characterized by scattered patches of woody vegetation to a narrow, tree-lined channel that further altered water movement and yields.

Water Quality and Riparian Vegetation

It is well known that riparian vegetation filters and retains sediment and limits nonpoint source pollution from agricultural fertilizers and pesticides in cropland and rangeland areas, thus improving water quality in streams (Schultz et al. 1994; Schmitt et al. 1999; Doskey et al. 2002; Richardson et al. 2007). Riparian vegetation also produces subsurface organic matter that fuels microbial denitrification and results in nitrogen losses from plant litter released into the atmosphere (Schade et al. 2001). However, litter of the invasive Russian olive or saltcedar contains a higher nitrogen content compared with that of cottonwood (Tibbets and Molles 2005). Elevated nitrogen levels in litter increase nitrification rates and change soil chemistry (Ehrenfeld 2003). Such alterations to the biogeochemical cycle are thought to limit the capacity of riparian vegetation to

absorb nutrients from neighboring agricultural land and to increase leaching, although the relationship between filtering capacity and leaching needs to be better tested in natural environments (Dosskey 2002). Ordination analysis of vegetation composition in rangelands located within 4 km of Utah Lake in Utah indicates that sites infested with saltcedar occur on dry saline sites dominated by annual species compared with uninfested sites (Carman and Brotherson 1982). Other studies indicate that high floodplain salinity levels can prevent restoration of riparian vegetation such as cottonwood forests in some river reaches (Shafroth et al. 2008). At the Bosque del Apache National Wildlife Refuge, species selected to restore sites after saltcedar removal are based on salinity levels, and cottonwood is planted when the soil salinity is low, ranging between 1.0 and 2.0 deciSiemen m^{-1} (Taylor and McDaniel 1998). Increased salt levels observed along the Colorado River in Mexico, associated with lack of overbank flooding, favors replacement of native forests with invasive species (Glenn et al. 1998). Thus, changes in soil biochemistry caused by leaching, vegetation changes, and nutrient cycling could have long-lasting effects on future riparian vegetation composition.

Water Consumption by Riparian Vegetation

Evapotranspiration, comprised of both transpiration (water loss) by plants and evaporation from the surfaces, is significantly influenced by vegetation structure, function, and composition, with subsequent impacts on the water balance and yields and on streamflow in riparian areas (Richardson et al. 2007). On a watershed scale, changes to vegetative cover can significantly alter the balance between evapotranspiration and streamflow (Hornbeck et al. 1993; Huxman et al. 2005). These alterations result from changes in (1) species composition and therefore transpiration rates (Table 1); (2) vegetation structure and architecture, thus the ratio of precipitation intercepted by vegetation and lost to evaporation (e.g., interception losses in temperate regions vary between 12% and 50% depending on species; Tabacchi et al. 2000); and (3) soil permeability (Huxman et al. 2005) and the resulting water infiltration due to root and litter characteristics. For example, the litter of species such as juniper and pine can trap moisture above the soil while leachates can create a hydrophobic soil layer that blocks water movement through dry soil (Madsen et al. 2008). Compared with upland sites, riparian phreatophytes use more water on an area basis. Although riparian vegetation covered about

8% of the Middle Rio Grande watershed in 1999 (Dahm et al. 2002), a water budget indicated that riparian evapotranspiration accounted for roughly 29% ($5.3 m^3 s^{-1}$ out of $18.5 m^3 s^{-1}$) of the water lost (Cleverly et al. 2002).

Vegetation water balance depends on soil water availability, plant water uptake and storage, and evapotranspiration rates. Plants in riparian areas derive their water from rainfall, rivers and streams, groundwater, or a combination thereof. For example, in Utah, Dawson and Ehleringer (1991) reported that as *Populus angustifolia* trees mature they shift from using surface stream water to using deeper water feeding into the stream. Other species, like the Fremont cottonwood (*Populus fremontii*), utilize groundwater and stream water except during periods of low streamflow when they rely on growing-season rainfall (Busch et al. 1992; Leffler and Evans 1999). In contrast, perennial grassland communities and riparian shrubs were found to generally rely on a combination of current rainfall and water from the unsaturated soil profile.

As woody species invade and alter species composition, the source and amount of water uptake by plants are altered, affecting not only the site water balance but also the water available to native trees. For instance, phreatophyte trees that rely solely on groundwater in the semiarid areas of the Great Plains are highly susceptible to groundwater fluctuations caused by physical factors such as precipitation or biological factors such as competition from other species (Scott et al. 2000). Invasive woody species like saltcedar, Russian olive, and eastern redcedar, which use multiple water sources including the groundwater and the unsaturated soil profile, have been shown to have the capability to reduce the amount of water available for native species (Busch et al. 1992; Snyder and Williams 2000). The ability of native species in this case to display plasticity in water uptake becomes essential for survival as groundwater levels drop. Such plasticity is observed in western cottonwood, the dominant riparian species in the semiarid ecosystem along the San Pedro River in Arizona, which primarily uses groundwater as a source but was found to derive up to 33% of its transpiration water from precipitation during the rainy season (Snyder and Williams 2000). An associate of the western cottonwood, Goodding's willow, does not possess this plasticity and has been reported to exclusively use groundwater despite available water in unsaturated soils, thus restricting its ability to compete for water resources (Snyder and Williams 2000).

The temporal, spatial, and amount of water uptake by riparian vegetation is dependent on species, ecotype, and age and is influenced by biotic and abiotic factors.

TABLE 1
WATER USE OF MAJOR RIPARIAN TREE SPECIES IN THE GREAT PLAINS AS A FUNCTION OF PRECIPITATION, LEAF AREA INDEX, DEPTH TO GROUNDWATER (DGW m), VOLUMETRIC SOIL MOISTURE (%), OR VAPOR PRESSURE DEFICIT (VPD kPa)

Species	Location	Precipitation (mm)	Water use rates	Method	Reference
<i>Elaeagnus angustifolia</i>	Middle Rio Grande, NM		1,230 mm yr ⁻¹	Eddy covariance	Dahm et al. 2002
<i>Juniperus ashei</i>	Uvalde County, TX 1991–1995	676 mm Mar.–Oct. 945 mm total yr	1.90 mm day ⁻¹ (Mar.–Oct.) (520 mm season ⁻¹)	Bowen ratio energy balance	Dugas et al. 1998
<i>J. deppeana</i>	Beaver Creek, AZ	553 mm yr ⁻¹	432 mm yr ⁻¹ (1.21 mm day ⁻¹)	Water balance	Lane and Barnes 1987
<i>J. osteosperma</i>	Beaver Creek, AZ	441 mm yr ⁻¹	414 mm yr ⁻¹ (1.13 mm day ⁻¹)	Water balance	Lane and Barnes 1987
<i>J. osteosperma</i>	Rush Valley, UT	239 mm yr ⁻¹	0.85 mm day ⁻¹	Eddy covariance Mar.–Oct. 2001	Leffler et al. 2002
<i>J. osteosperma</i> / <i>Pinus monophylla</i>	Los Alamos, NM Juniper leaf area index (LAI): 0.70 Pine LAI: 3.07	216 mm yr ⁻¹	121 mm yr ⁻¹ <i>J. osteosperma</i> (0.33 mm day ⁻¹) 95 mm yr ⁻¹ <i>P. monophylla</i>	Water balance	Lane and Barnes 1987
<i>J. osteosperma</i> / <i>Pinus monophylla</i>	Los Alamos, NM Juniper LAI: 1.31 Pine LAI: 0.41	203 mm yr ⁻¹	193 mm yr ⁻¹ <i>J. osteosperma</i> (0.53 mm day ⁻¹) 10 mm yr ⁻¹ <i>P. monophylla</i>	Water balance	Lane and Barnes 1987
<i>J. osteosperma</i> / <i>Pinus monophylla</i>	Los Alamos, NM Juniper LAI: 1.92 Pine LAI: 0.76	170 mm yr ⁻¹	125 mm yr ⁻¹ <i>J. osteosperma</i> (0.34 mm day ⁻¹) 45 mm yr ⁻¹ <i>P. monophylla</i>	Water balance	Lane and Barnes 1987
<i>J. virginiana</i> One 15.2-cm-diameter tree	Odessa, NE 2004	844 mm yr ⁻¹	1.0 mm day ⁻¹ April (62.3 L day ⁻¹ tree ⁻¹) 0.8 mm day ⁻¹ May–August (48.4 L day ⁻¹ tree ⁻¹)	3 cm Granier sap flow probes	Landon et al. 2009
<i>P. deltoides</i> var. <i>wis-lizenii</i>	Middle Rio Grande, NM, Belen	Flooded site	980 mm yr ⁻¹ 2000 (2.70 mm day ⁻¹)	Eddy covariance	Dahm et al. 2002
<i>P. deltoides</i> 27 trees/ha with 80 trees/ha 9.0 m average distance between trees	Odessa, NE 2004	844 mm yr ⁻¹	61-cm-diameter tree 0.26 mm day ⁻¹ April (16.5 kg day ⁻¹ tree ⁻¹) 3.78 mm day ⁻¹ May–August (240.5 kg day ⁻¹ tree ⁻¹) 22.9 cm diameter, tree 0.05 mm day ⁻¹ April (3.2 kg day ⁻¹ tree ⁻¹) 1.44 mm day ⁻¹ May–August (91.6 kg day ⁻¹ tree ⁻¹)	Granier sap flow 5 cm long probes	Landon et al. 2009
<i>P. deltoides</i> 3-year-old cuttings, 1,333 trees/ha	USDE Savanna River site, Aiken, SC	7.4 % soil water content	ST66: 24.0 mm mo ⁻¹ (0.80 mm day ⁻¹) S7C15: 33.4 mm mo ⁻¹ (1.13 mm day ⁻¹)	Granier sap flow 2 cm long probes	Samuelson et al. 2007
<i>P. deltoides</i> 2,019 trees/ha 1-yr-old seedlings	Carswell Air Force Base, TX	800 mm yr ⁻¹ 2–3.4 m DGW 153 day season	255 mm yr ⁻¹ (0.70 mm day ⁻¹) (8.2 kg day ⁻¹ tree ⁻¹)	Granier sap flow	Vose et al. 2000
<i>P. fremontii</i>	Bill Williams and Colorado rivers, northwest Arizona Monthly measurements, 1989 and 1990	130 mm yr ⁻¹	0.5 to 3.8 mmol m ⁻² s ⁻¹ , composite diurnal curve (360 mm yr ⁻¹) (1.0 mm day ⁻¹) (89 kg day ⁻¹ tree ⁻¹)	Licor 1600 steady state porometer	Busch and Smith 1995
<i>P. fremontii</i> 3-year-old poles planted 4 m apart	Lower Colorado River, California, Cibola National Wildlife Refuge		1,200 mm yr ⁻¹ (3.3 mm day ⁻¹)	Time series MODIS satellite	Nagler et al. 2007
<i>P. fremontii</i>	Matheson Wetlands Reserve, Moab, UT 220 mm yr ⁻¹ annual ppt	Control site 0.1–2.5 m DGW Saline site 0.7–2.7 m DGW	9.3 ± 0.2 mm day ⁻¹ 4.8 ± 0.1 mm day ⁻¹	Granier sap flux 2 cm long probes 17 July–21 September	Pataki et al. 2005
<i>P. fremontii</i>	San Pedro River	247 mm yr ⁻¹	1,271 mm yr ⁻¹ (3.5 mm day ⁻¹)	Bowens ratio	Scott et al. 2000
<i>P. grandidentata</i> 90-year-old trees in mixed forest	Michigan Biological Station, Pellston, MI July–August 1999 10:30–13:30 774 mm yr ⁻¹	Soil moisture < 10% Soil moisture > 15%	0.09 mm hr ⁻¹ (3.12 kg hr ⁻¹ tree ⁻¹) 0.11 mm hr ⁻¹ (3.57 kg hr ⁻¹ tree ⁻¹)	Granier sap flux, 3 cm long probes, 4 trees	Bovard et al. 2005

TABLE 1 continued

Species	Location	Precipitation (mm)	Water use rates	Method	Reference
<i>P. tremuloides</i> 70-year-old stand	Prince Albert National Park, Saskatchewan, Canada	450 mm in 1994	280 mm yr ⁻¹ poplar trees (0.77 mm day ⁻¹)	Eddy flux tower	Black et al. 2006
<i>P. tremuloides</i> >80-year-old stand 21 cm dbh 980 trees/ha	Saskatchewan, Canada 123-day growing season	235 mm yr ⁻¹ 2001 286 mm yr ⁻¹ 2002	441 mm yr ⁻¹ (1.21 mm day ⁻¹) (281 kg day ⁻¹ tree ⁻¹) 323 mm yr ⁻¹ (0.88 mm day ⁻¹) (206 kg day ⁻¹ tree ⁻¹)	Eddy flux tower	Amiro et al. 2006
<i>Populus tremuloides</i> 70-year-old stand	Saskatchewan, Canada	488 mm yr ⁻¹	120 mm yr ⁻¹ above hazelnut (0.33 mm day ⁻¹)	Eddy flux tower Late May-Oct.	Blanken and Black 2004
<i>P. tremuloides</i> , 150-year-old mixed stand wildfire chrono- sequence	Central Manitoba, Canada 439 mm mean annual precipitation	12-year-old, 6,800 trees/ha, 1.2 cm dbh	70% of surface conductance 8 mm yr ⁻¹ (0.53 kg day ⁻¹ tree ⁻¹ , growing season)	Kucera-type sap flow sensors for trees <4 cm dbh and Granier sap flow sensors for trees >4 cm dbh	Ewers et al. 2005
<i>P. tremuloides</i> , 9.0-17.8 m tall Comprised 13% total basal areal; <i>Abies bal- samea</i> understory, 2.9- 5.9 m tall	Chequamegon Ecosystem Atmosphere Study, Park Falls, WI	20-year-old, 3,500 trees/ha, 3.5 cm dbh 37-year-old, 4,200 trees/ha, 7.7 cm dbh	8 mm yr ⁻¹ (0.51 kg day ⁻¹ tree ⁻¹ , growing season) 37 mm yr ⁻¹ (2.6 kg day ⁻¹ tree ⁻¹ , growing season)	Kucera-type sap flow sensors for trees <4 cm dbh and Granier sap flow sensors for trees >4 cm dbh	Ewers et al. 2007
<i>P. tremuloides</i>	Central Saskatchewan, Canada VPD >1 kPa >100 W m ⁻² light	Parkland site 375 mm yr ⁻¹ Boreal site 462 mm yr ⁻¹	4.8 mm day ⁻¹ 9.6 mm day ⁻¹	Heat pulse sap flow	Hogg and Hurdle 1997
<i>Populus/Salix</i>	Middle Rio Grande, NM Upper San Pedro, AZ Lower Colorado, AZ		1,100–1,300 mm yr ⁻¹ (3.0–3.6 mm day ⁻¹)	MODIS and EVI data calibrated with eddy covariance	Nagler et al. 2005b
<i>Prosopis velutina</i>	Bosque del Apache National Wildlife Refuge, NM		400–1,100 mm yr ⁻¹ (1.1–3.0 mm day ⁻¹)	Scaled P-M for C/W and Bowen ratio MODIS and EVI	Goodrich et al. 2000; Nagler et al. 2005b
<i>P. velutina</i>	San Pedro Basin, south- eastern Arizona	247 mm yr ⁻¹	375 mm yr ⁻¹ (1.02 mm day ⁻¹)	Eddy covariance	Nagler et al. 2005
<i>P. velutina</i>	Upper San Pedro River, Arizona <i>P. velutina</i> savanna	6.4 m DGW 234 mm yr ⁻¹	450 mm yr ⁻¹ (1.23 mm day ⁻¹)	Bowen ratio energy balance (May–September)	Scott et al. 2000
<i>P. velutina</i>	Upper San Pedro River, Arizona <i>P. velutina</i> savanna	253 mm yr ⁻¹ 2001 293 mm yr ⁻¹ 2000	485 mm yr ⁻¹ (2.3 mm day ⁻¹) 401 mm yr ⁻¹ (1.23 mm day ⁻¹)	Eddy covariance (May–November)	Scott et al. 2004
<i>P. velutina</i> Semiarid lands	Floodplain terraces San Pedro River with <i>Sporobolus wrightii</i>	2.6 m DGW 343 mm yr ⁻¹	407 mm yr ⁻¹ (1.11 mm day ⁻¹)	Eddy covariance, MODIS	Scott et al. 2006
<i>Tamarix elongata</i> 8-year-old stands	Shiyang River basin, northwest China	134 mm yr ⁻¹	740 mm yr ⁻¹ (2.0 mm day ⁻¹)	Heat pulse sap flow	Qu et al. 2007
<i>T. ramosissima</i>	Bill Williams and Co- lorado rivers, northwest Arizona		1,220 mm yr ⁻¹ (3.34 mm day ⁻¹)	Steady state porometer, composite 1989–1990 diurnal curve	Busch and Smith 1995
<i>T. ramosissima</i> Nonflooded site	Middle Rio Grande, NM Sevilleta National Wild- life Refuge	3.4–3.7 m DGW	740 mm yr ⁻¹ 1999 (2.0 mm day ⁻¹) 760 mm yr ⁻¹ 2000 (2.1 mm day ⁻¹)	Eddy covariance	Cleverly et al. 2002; Dahm et al. 2002
<i>T. ramosissima</i> Flooded site	Middle Rio Grande, NM Bosque del Apache Na- tional Wildlife Refuge	3.7–4.0 m DGW	1,220 mm yr ⁻¹ 1999 (3.3 mm day ⁻¹) 1,100 mm yr ⁻¹ 2000 (3.0 mm day ⁻¹)	Eddy covariance	Cleverly et al. 2002; Dahm et al. 2002
<i>T. ramosissima</i>	Middle Rio Grande, NM Upper San Pedro, AZ Lower Colorado, AZ		300–1,300 mm yr ⁻¹ (0.8–3.6 mm day ⁻¹)	MODIS and EVI data calibrated with covari- ance flux towers	Nagler et al. 2005b
<i>Tamarix</i> spp.	Chibola National Wildlife Refuge, AZ	2.7–3.4 m DGW	1,100 mm yr ⁻¹ (3.0 mm day ⁻¹)	MODIS vegetation indices	Nagler et al. 2008
<i>T. ramosissima</i>	Chibola National Wildlife Refuge, AZ	<100 mm yr ⁻¹ 2.5–3.3 m DGW	3.7–9.5 mm day ⁻¹	Granier sap flow	Nagler et al. 2009

Obligate phreatophytes, such as many species from the *Populus* genus, generally extend their roots downward into the water table to support high transpiration rates and depend on access to groundwater for growth and survival. These species are generally pioneers that maximize growth and transpiration rates at the expense of drought and shade tolerance. For example, Fremont cottonwood (*Populus fremontii*) transpiration rates were higher in individuals growing along perennial streams where roots had access to the permanent water table than in those growing along intermittent streams (1.0–5.7 vs. 1.3–3.1 mm day⁻¹, respectively; Schaeffer et al. 2000; Gazal et al. 2006). Stand age also affects the amount of water consumed (Willms et al. 2006), which usually peaks after a stand has gone through self-thinning and competition has removed weaker trees from the stands.

Ewers et al. (2005) examined water use of upland trembling aspen (*Populus tremuloides*) along a chronosequence after fire disturbance. Aspen dominated the overstory at 12 to 37 years after fire. Over the chronosequence, growing-season canopy transpiration in this species rose from 8 mm observed in 12- and 20-year-old stands, to 37 mm in 37-year-old stands. This trend was explained by the increase in the ratio of sapwood area supporting a unit of leaf area with height, suggesting that taller, more dominant trees can support higher transpiration rates than shorter, generally suppressed trees. As the pioneer *Populus* trees matured, individual trees declined in health, growth, and transpiration rates as more shade-tolerant species like black spruce (*Picea mariana*) assumed complete dominance of the stands at age 70.

The ability of the riparian vegetation to resist environmental stresses like drought, the most common limiting factor in these systems, depends in large part on the species and ecotype. Species such as eastern cottonwood (*P. deltoides*) of the *Aigeiros* section of the *Populus* genus are faster growing and less drought-tolerant than species such as black cottonwood (*P. trichocarpa*) of the *Tacamahaca* section of *Populus* (Dickmann 1979). Anatomically, *Aigeiros* cottonwood species, including *P. fremontii*, *P. angustifolia*, *P. acuminata*, and *P. deltoides*, tend to have larger earlywood vessels than the *Tacamahaca* aspen species (e.g., *P. tremuloides*; Tennessen et al. 2002). While these larger vessels can support faster transpiration rates, they are more vulnerable to lose water-conducting capacity under drought due to xylem cavitation that occurs when air breaks the vertical columns of water, thus reducing the number of xylem elements that carry water up the stem (Hacke et al. 2006). Resisting xylem cavitation and maintaining hydraulic conductivity, therefore, become

crucial for species survival under drought stress in riparian areas. Several of the *Aigeiros* section *Populus* species respond to water stress first by xylem cavitation in twigs and branches, next by early leaf senescence, and then by branch dieback (Rood et al. 2000). Xylem air-entry point, the start of cavitation, in black cottonwood was reported to be at water potentials of -0.71 to -1.32 MPa (a measure of water status in leaves) in trees from wet sites and at -1.55 to -1.67 in trees from dry sites (Sparks and Black 1999). Cochard et al. (2007), in an evaluation of five interspecific poplar clones, confirmed both soil water requirements and cavitation thresholds (-1.5 MPa) and low drought resistance in these species. Recovery from drought depends on the severity and length of water stress (Amlin and Rood 2003). If water stress leads to death of twigs and branches, then cottonwood photosynthesis and evapotranspiration on a tree- and stand-level basis will decline, ultimately leading to cottonwood mortality. Coupled with the fact that cottonwood cannot regenerate under shade (Farmer and Bonner 1967), increased cottonwood mortality could speed up successional replacement of cottonwood by more drought- and shade-tolerant species, such as eastern redcedar, Russian olive, and saltcedar, unless flooding occurs at sufficient frequency (Johnson 1992; Lytle and Merritt 2004).

Eastern redcedar (*Juniperus virginiana*), an evergreen species, has the capability to grow under high (Holthuijzen and Sharik 1985) as well as low levels of irradiance (maintain positive carbon gain at around 5% of full light; Lassoie et al. 1983), photosynthesize under a wide range of temperatures (0°–40°C), and tolerate drought conditions (Eggemeyer et al. 2006, 2009; Bihmidine et al. 2010). Although xylem cavitation in eastern redcedar is reported to begin at water potentials below -4 MPa, the species is able to maintain 50% xylem conductivity at -5.8 MPa, and 10% conductivity at water potentials as low as -9 MPa (Sperry and Tyree 1990; Wilson et al. 2008). These characteristics, together with its long growing season and ability to extract water from both the saturated and unsaturated soil profiles, make eastern redcedar a significant competitor and component in many riparian and upland communities in the Great Plains (Ormsbee et al. 1976; Eggemeyer et al. 2006, 2009; Bihmidine et al. 2010). Data on tree-level water consumption in eastern redcedar are few. At a site located by the Platte River near Odessa, NE, one mature 22.9-cm-diameter eastern redcedar tree was reported to use an average of 62.3 L day⁻¹ in April and 48.4 L day⁻¹ during a five-month period between May and August (Landon et al. 2009). Our preliminary data indicate that water use of eastern redcedar trees ranging

in size from 4 cm to 28 cm in diameter averaged 5 to 50 L day⁻¹ at two sites located along the Republican River, Nebraska, depending on tree size in late summer.

Saltcedar (*Tamarix ramosissima*) is the most commonly occurring *Tamarix* species out of the 8 to 10 species that have been introduced in North America (Smeins 2003). Like eastern redcedar, drought-tolerant saltcedar (facultative phreatophyte; Busch et al. 1992; Glenn and Nagler 2005) and Russian olive can significantly alter the water balance in riparian areas by consuming water from both the unsaturated and saturated soil profiles (Truman 1996; Zhao et al. 2007). Researchers have observed Russian olive displacing native woody species in droughty and shady environments in the seedling stage (Shafroth et al. 1995). Saltcedar trees during the record 2006 drought in Kansas adapted by shifting from using water from the unsaturated soil profile when water was available to using groundwater during seasonal drought (Nippert et al. 2010). How well saltcedars avoid cavitation depends on site conditions and ecotype. At the Cienga Creek Natural Preserve in Arizona, where annual precipitation averages 310 mm, cavitation of xylem water conducting elements of *Tamarix ramosissima* did not occur until water potential dropped below -7 to -8 MPa (Pockman and Sperry 2000). In contrast, the same species growing at sites located adjacent to rivers or in a seasonal swamp in five states throughout the United States (Idaho, Washington, Florida, Georgia, and South Carolina) lost 75% of their xylem or water-conducting capacity at -0.86 MPa (Pratt and Black 2006). Saltcedar transpiration rates were also found to reflect site conditions, ranging from 13.4 mm day⁻¹ on relatively dry sites (depth to groundwater [DGW] 2–3 m), to 23.5 mm day⁻¹ in wet areas (DGW 0.5–1 m), along the lower Virgin River, Nevada (Sala et al. 1996). Higher transpiration rates in wet areas corresponded with the ability of saltcedar to (1) extract water from the various zones in the soil profile; and (2) regulate water use during the growing season by adjusting leaf production (Sala et al. 1996; Cleverly et al. 2002; Dahm et al. 2002). Therefore, control of saltcedar in areas that are flooded or have a shallow water table has greater potential of increasing water yields than control efforts in drier areas. Saltcedar's tolerance to a number of disturbances such as salinity, fire, flooding, and herbivory, and its ability to resprout after topkill, have facilitated its spread throughout the western United States and have made it difficult to control (Smeins 2003).

Although few studies have examined the ecophysiology of Russian olive (*Elaeagnus angustifolia*), work conducted in the Canyon de Chelly National Monument by Reynolds and Cooper (2010) indicates that its ability

to survive low light and droughty conditions as a seedling may enable it to increase its range. In a survey of stands in the region, Russian olive seedlings were found at light levels of $1,233 \pm 46.3 \mu\text{mol m}^{-2} \text{s}^{-1}$ under a mean canopy cover of $55.6\% \pm 18.4\%$ up to 8 m above the stream channel. In experiments monitoring the growth and survival of seedlings, about 75% of the Russian olive seedlings were able to survive under 99% shade when they had access to a shallow water table and some (10%–35%) were able to survive when subjected to water stress. In contrast, only 10% of the cottonwood (*Populus fremontii*) seedlings survived under 99% shade when they had access to shallow water, and none of the tamarisk (*Tamarix ramosissima*) seedlings survived under 99% shade. Analysis of oxygen isotopes indicated that Russian olives less than 15 years old utilized water from a shallow soil (10–30 cm depth) compared with trees 15 years or older, which utilized both shallow and deeper (40–70 cm depth) water. Thus, Russian olive can spread in densely shaded stands, replacing cottonwood and later successional native species in the absence of disturbances.

STAND-LEVEL WATER USE

Evapotranspiration accounts for much of the water lost from riparian zones in semiarid ecosystems, and precise estimates of riparian evapotranspiration are essential to accurately allocate river water for environmental and human needs (Nagler et al. 2005a, 2005b). Estimates of evapotranspirational losses suggest that 20%–50% of water depletion can be attributed to riparian vegetation in semiarid systems (Dahm et al. 2002). In Nebraska, if a phreatophyte cover of 1,289 km² is assumed (0.64% of the total state land area), Szilagyi et al. (2005) calculated, using water balance equations and an automated base flow separation, a mean groundwater phreatophyte evapotranspiration of 887 mm yr⁻¹. Estimates increase significantly as woody species density increases and invasive species spread. For example, evapotranspiration rates were 20% higher in cottonwood stands with saltcedar and Russian olive understory (1,230 mm yr⁻¹), and in saltcedar stands (1,110 to 1,220 mm yr⁻¹), compared to closed canopy cottonwood stands with an understory of coyote willow (*Salix exigua*), seep willow (*Baccharis glutinosa*), and false indigo bush (*Amorpha fruticosa*) (980 mm yr⁻¹) in New Mexico (Dahm et al. 2002). Likewise, a study in the Pecos River of New Mexico found that removing saltcedar and Russian olive from the understory of *Populus* stands reduced groundwater fluctuations by 6.7% and 18.1%, respectively (Martinet et al. 2009).

Within the *Populus* genus, riparian cottonwood trees of the warm arid southwestern region of the United States were found to transpire more water than upland poplar trees of the cooler northern regions and in Canada. The reported riparian stand-level transpiration rates are 0.7–3.4 mm day⁻¹ in *P. deltoides* (New Mexico and Texas, *Aegeros* section) and 1.0–9.3 mm day⁻¹ in *P. fremontii* (Arizona and California, *Aegeros* section) (Table 1). In comparison, in Canadian upland forest sites *P. tremuloides* stands transpired 0.3–1.2 mm day⁻¹. When contrasting stand-level water use of poplar with those reported for *Juniperus* sp., Table 1 shows that, generally, rates reported in the literature were lower for *Juniperus* than those for *Populus* species, ranging from 0.23–1.21 mm day⁻¹ in Utah juniper (*J. osteosperma*, Arizona and New Mexico) and alligator juniper (*J. deppeana*, Arizona), to 1.90 mm day⁻¹ in ash juniper (*J. ashei*, Texas; Table 1). Although, these comparatively low transpiration rates reflect the *Juniperus* conservative water use, which allow for survival in dry areas, the evergreen nature and longer growing season of *Juniperus* may offset the relatively low water daily uptake.

ECOHYDROLOGICAL RESPONSES TO WOODY PLANT REMOVAL

Reducing woody plant cover, particularly within an entire watershed, has been hypothesized to increase water yields in riparian ecosystems by reducing transpirational demands. Studies examining this hypothesis have been conducted by removing trees over an entire watershed or catchment area rather than within selected reaches. Gains in water yields, reported in the literature, have been found to vary greatly. In a review of 39 catchments, Hibbert (1967) found that, although the reduction of forest cover generally increased water yield and the establishment of forest cover on sparsely vegetated land decreased water yield, responses to removing woody vegetation were highly variable and unpredictable. In another study that examined the average streamflow water yield rather than the maximum increase in yield, Sahin and Hall (1996) found that a small (10%) reduction in conifers and deciduous hardwoods significantly increased annual water yield by an average of 22.5 and 18 mm, respectively, while reduction in scrub vegetation increased yield by only 5 mm. Variations in water yield response to thinning and cutting forest vegetation can be largely explained from differences in the interannual variability in water input, in vegetation regrowth, between riparian and stream types, and among geographic

and climatic regions (Zhang et al. 2001; Sun et al. 2005; Adams and Fowler 2006).

As precipitation increases, stream yield responses to tree harvesting increases until a maximum response is reached (Zhang et al. 2001; Wilcox et al. 2005). Analysis of published studies indicate that annual stream-water yield following tree removal in areas receiving 450 to 600 mm of precipitation showed either no response (i.e., 0 increase), or increased up to 90 mm after watershed-wide clear-cutting (mostly in areas with higher precipitations), a variation attributed to regional climatic conditions and topographic features (Table 2; Sun et al. 2005; Adams and Fowler 2006). In the southeastern United States, Sun et al. (2005) modeled potential water yields based on regional variability in climate and topography and found that in general, mountainous areas with cool summer temperatures and high rainfall showed the most increase in water yields in response to vegetation removal, while coastal wetland areas with moderate rainfall and high potential evapotranspiration exhibited the least response. In studies where clear-cutting was conducted on a portion of the watershed, the increased water yield reflected the portion of land where forest cover had been removed. Bosch and Hewlett (1982) in a review of 94 catchments found that water yield response following plant removal depended on reduction levels and type of vegetation. Water yield increases were not detectable following forest cover reductions of less than 20% of the catchment (similar observations were reported by Stednick 1996), while maximum streamflow water yield increased by 400 mm yr⁻¹ when coniferous trees were completely removed from the watershed, compared to an increase of 250 and 10 mm yr⁻¹ following the complete removal of deciduous hardwood trees and grasses, respectively, from the watershed.

In general, forest treatments conducted in riparian forests where trees can use groundwater affect stream yields more than those conducted in upland forests where trees cannot access groundwater. Nagler et al. (2010) reported that of the 637,000 km² Colorado River basin, the 180 km² area covered by saltcedar monocultures (0.03% of the total basin area) growing along the Lower Colorado River consumes between 0.75 and 1.45 m yr⁻¹ of water (1 m yr⁻¹ average) and accounts for a loss of 1% of all river flow. Wilcox (2002) reviewed experiments examining water yields response to removing honey mesquite (*Prosopis glandulosa*) and juniper (*J. ashei* and *J. pinchotii*) from nonriparian rangelands in Texas. He concluded that mesquite control in upland regions is unlikely to significantly increase water yields because (1) the typical herbaceous regrowth and tree sprouting on sites utilized most of

TABLE 2
 PREDICTED CHANGES IN ANNUAL WATER YIELD AFTER REMOVAL OF CONIFER OR HARDWOOD TREES IN A WATERSHED AS A FUNCTION OF AVERAGE ANNUAL PRECIPITATION OBSERVED IN THE GREAT PLAINS BASED ON WATERSHED-LEVEL MODELS

Average annual precipitation (mm)	----- Change in water yield (mm) -----				
	Adams and Fowler (2006) regressions on conifer removal		Brown et al. (2005)		
	Bosch and Hewlett (1982) data	New Zealand	Conifers	Hardwoods	
300	128	88	100	100	
400	151	115	140	130	
500	174	143	175	160	
600	197	170	200	190	
700	220	197	240	220	
800	243	225	280	250	
900	266	252	340	275	
1,000	289	280	360	300	
1,200	335	334	400	350	

Note: Adapted from Brown et al. (2005) and Adams and Fowler (2006).

the available soil moisture; (2) deep soils isolated the groundwater from the surface; (3) much of the increased soil water flows horizontally over the land when soils become saturated; and (4) flood-producing rainfall events produced massive runoff. Conversely, Wilcox (2002) suggested juniper control can be used to effectively increase streamflow.

The majority of paired catchment studies reviewed above and others listed in the literature (Table 2) are based on water yield changes within one to five years of vegetation removal (Brown et al. 2005). Ffolliott et al. (2003) studied dryland oak transpiration in the southwestern United States and found that mature trees in unharvested upland stands transpired about 45% of the annual regional precipitation, leaving 55% of the rain available for groundwater recharge, streamflow input, and evaporation. However, mature trees and numerous stump sprouts in harvested stands transpired 80% of the annual precipitation, leaving only 20% available for site water use. These results highlight the impact of harvest events on the water budget in semiarid regions. Consideration thus should be given to postharvest vegetation response when managing riparian forests for water use (Ffolliott et al. 2003). Several studies have demonstrated that sustained increases in water yield depend not only on vegetation response but also on site management following initial vegetation removal. Hornbeck et al. (1993) in a study of the long-term impacts of vegetation change

found that increases in water yield immediately after tree removal could only be sustained if regrowth was controlled. Similarly, studies on deforestation conducted by Ruprecht and Schofield (1989) and Silberstein et al. (2003) demonstrated increased water yields in cleared catchments in the first year after treatment, with steady yield decreases observed thereafter until a new vegetation equilibrium was established. Brown et al. (2005) generalized that transpiration rates, vegetation age, and soil storage changes to treated systems required at least five years for establishing an equilibrium following catchment alteration.

Inconsistencies in models predicting water yields as a function of vegetation type and cover caused by precipitation variations could be significantly reduced by including climatic variables, such as annual precipitation in the year of maximum change in annual yield, as explanatory variables (Brown et al. 2005; Adams and Fowler 2006). If these results are mapped out according to precipitation isocline across the Great Plains, potential water savings from clearing areas entirely covered with deciduous woody vegetation from the Platte River would range between 130 mm yr⁻¹ in the west to 250 mm yr⁻¹ in the east, and potential water savings from clearing areas with a 100% cover of eastern redcedar from the Platte River would range from 140 mm yr⁻¹ in the west to 280 mm yr⁻¹ in the east (Fig. 1). Wilcox et al. (2006) urge caution when projecting results from small catchments to larger scales.

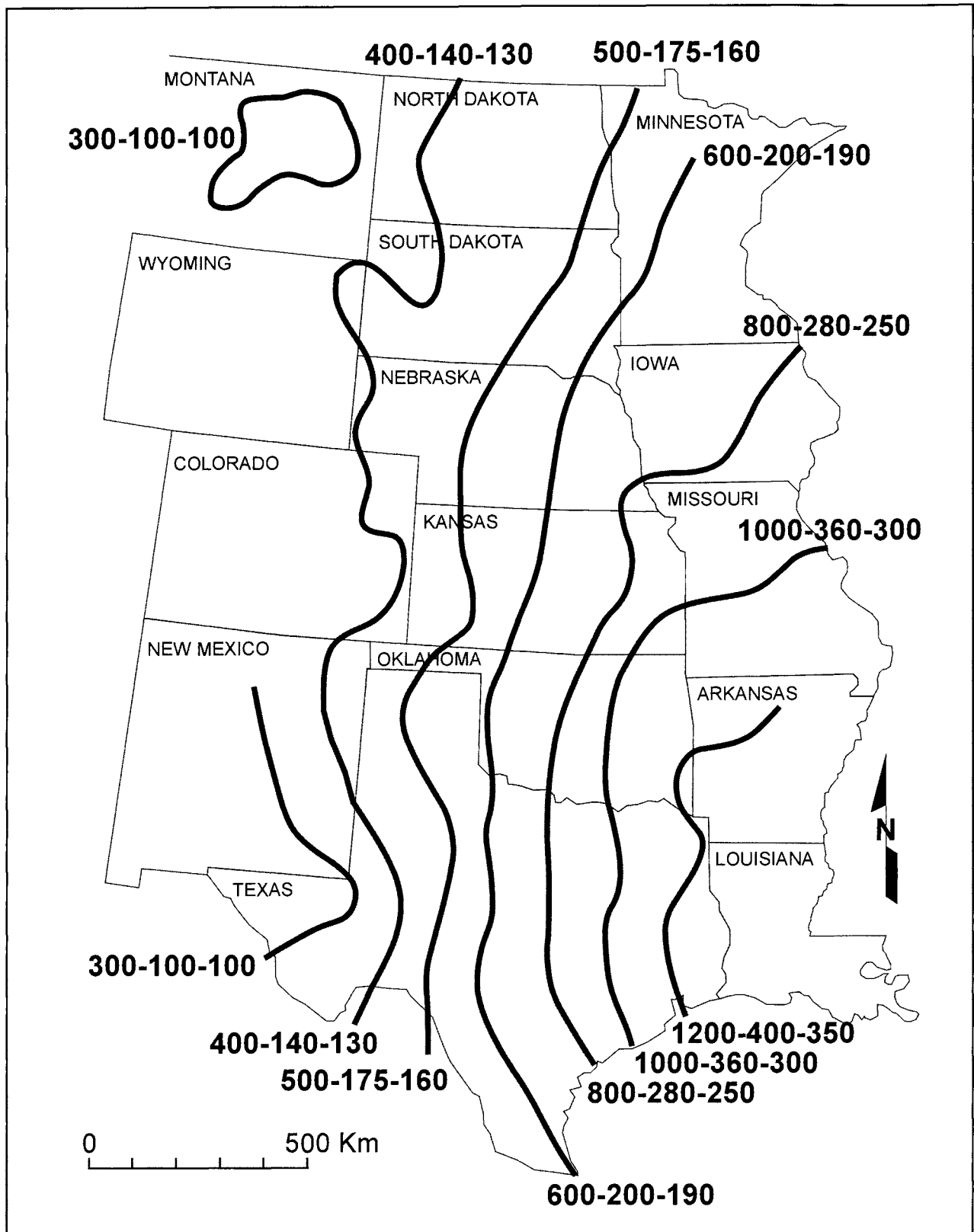


Figure 1. Precipitation isoclines in the Great Plains and adjacent areas. Numbers from left to right: the isoclines of the Great Plains according to average annual precipitation (mm, modified from Schimel et al. 1990), the predicted increase in water yields after the complete (100%) removal of conifer trees (mm yr^{-1}), and the predicted increase in water yield after the complete (100%) removal of deciduous trees (mm yr^{-1} , after Brown et al. 2005).

Models that estimate the evapotranspiration rates based on plant functional type (e.g., obligate wetland, shallow-rooted riparian, deep-rooted riparian, transitional riparian, and upland) and water table depth can potentially integrate physiological measurements across larger scales (Baird and Maddock 2005).

On a landscape scale, occurrence of trees within grasslands or agricultural systems can reduce evapotranspiration. Shading and mulch from trees reduce evaporative losses from soil (Stormont et al. 2009). On farm systems windbreaks, riparian forest buffers and alley-cropping systems (growing crops between rows of trees) can be used to reduce evapotranspiration by agricultural systems by reducing evaporative losses caused by wind (Brandle et al. 2003). An optimum tree density and distribution likely exists where the reductions in understory water losses by shade and wind reduction are greater than water losses from trees. Promotion by land managers of more efficient water use through improved management coupled with sound water-trading principles will help producers achieve economic goals and help society attain ecological interests such as greater water yields and streamflows (Clayton 2009).

ECONOMIC COSTS AND BENEFITS OF ECOHYDROLOGICAL MANAGEMENT

Removing woody vegetation from rangelands and forested areas has been proposed as a way to increase water yields from land in the western United States (Hibbert 1983; Wilcox and Thurow 2006). Managing riparian forests to balance social and economic needs and ecosystem capacity poses important challenges to managers and policy makers. Attaching an economic value to various services and goods provided by ecosystems can provide a benchmark principle for managing resources (Pearce and Smith 2001). For example, the direct role of forests in regulating water quantity and quality around the world provides an important argument for sustainable forest management and protection (Dudley and Stolton 2003). Whether or not forested riparian areas should be harvested must be assessed using both ecological and economic criteria.

In heavily timbered regions where harvests are conducted for income, streamside management zones (SMZs) are commonly written into management plans to protect riparian ecosystem functions. Trees are harvested only outside of these SMZs to provide economic benefits. In a literature review on the effects of timber harvest on U.S. eastern hardwood streams, LeDoux and Wilkerson

(2006) found that 45 m wide was enough for streamside management zones to provide all of the five ecological functions they assessed (woody debris, shade, sediment filtering, aquatic communities, riparian bird communities). Streamside management zones that were only 30 m wide provided 87% of these benefits as coarse woody debris and sediment filtering benefits from riparian forests declined. They calculated that streamside management zones cost landowners with yellow-poplar and mixed hardwood forests in the eastern United States between \$30.54 and \$67.02 ha⁻¹ yr⁻¹ (\$12.36 to \$27.12 per acre) depending on the stand type and logging technology used. The economic return of harvesting stands having about 300 m³ ha⁻¹ standing timber averaged \$9,200 ± \$940 ha⁻¹ (\$3,725 ± \$380 per acre) in yellow-poplar stands and \$11,500 ± \$1,270 ha⁻¹ (\$4,650 ± \$510 per acre) in mixed hardwood stands. In contrast to large expanses of eastern hardwood forests, Great Plains forests largely occur as linear gallery forests or as planted windbreaks (Barker and Whitman 1988). Biomass production of linear windbreak forests planted in Great Plains agro-ecosystems was calculated to be higher in narrow 10 m strips than in wider 30 m strips (Guo et al. 2004).

Riparian forests in the Great Plains are not generally managed for forest production. Here it is largely the ecological costs and benefits that must be weighed when considering whether or not to harvest or even plant trees within SMZs. Costs associated with Great Plains riparian forests include water lost through evapotranspiration, elevated sedimentation rates of dams and reservoirs, reduced forage for grazing, and losses in biodiversity (Zavaleta 2000). On the other hand, woody riparian buffers help stabilize eroding banks, filter dissolved pollutants, improve stream habitat for fish, provide forest habitat, provide flood protection, shelter livestock and yield economic products (Dosskey 1998).

Zavaleta (2000) estimated that increases in water losses, sedimentation rates, and in subsequent flooding damage caused by tamarisk costs \$280–\$450 ha⁻¹ yr⁻¹ in the western United States. Costs of removing this invader and restoring native vegetation could be recovered as soon as 17 years after removal efforts. Ecosystem adaptation to invading species like tamarisk complicates removal and restoration planning. Although many bird species have declined as tamarisk has spread, some species, such as the endangered southwestern willow flycatcher (*Empidonax tralii extimus*), now nest in tamarisk (Sogge et al. 2008). A threshold response of bird species to tamarisk at 40%–60% canopy cover appears to exist (Van Riper et al. 2008). Zavaleta et al. (2001) recommend

that removal of tamarisk and restoration of native habitat be done in a stepwise fashion to provide adequate habitat for woodland animal species like the southwestern willow flycatcher. In areas where woody species are invading grasslands, such as the Niobrara River valley, where eastern redcedar is invading, woodland bird species are replacing grassland bird species (Frost and Powell 2010). Restoring native grasslands following juniper removal would thus be essential to restoring the native fauna in these systems.

The cost of increased water yields depends on a number of factors including removal cost, increases in water yields, and economic direct and indirect returns from clearing. Differences in size and in increased water yields following clearing largely explained why water from juniper and mesquite brush removal from Texas rangelands cost \$320 ha⁻¹ in the Edwards Plateau and \$820 ha⁻¹ in the Twin Buttes watershed (Olenick et al. 2004). Although removing a low cover of juniper was less expensive than removing a low cover of mesquite, the reverse held true when woody cover was high (Table 3). Mechanical treatments were more expensive than chemical treatments.

The cost of tree removal is another crucial management consideration. In general, aerial removal of saltcedar is cheaper than ground methods (Table 3). A study comparing four control methods conducted between 1989 and 2001 at 20 sites located in seven states in the southwestern United States estimated the efficacy of saltcedar removal to be 89% ± 13% for helicopter herbicide application; 93% ± 10% for fixed-wing herbicide application; 78% ± 25% for cut-stump and herbicide application; and 88% ± 14% for foliar herbicide application (Sisneros 1994; U.S. Bureau of Reclamation 2009). Thus, aerial control methods are cheaper and more effective over large areas than labor-intensive ground methods. Including herbicide in control treatments helps ensure the long-term control of saltcedar (O'Meara et al. 2010). Follow-up control must be done to ensure restoration of native species in controlled areas. In the 23 states of the western United States, where tamarisk has invaded 470,000–650,000 ha of riparian zones, the total cost for eradicating tamarisk from riparian zones is estimated as high as \$7,400 ha⁻¹ (Zavaleta 2000). Cost of controlling juniper ranges from \$5 ha⁻¹ to \$508 ha⁻¹ depending on method and cover (Table 3).

In addition to the potentially improved water yield, wood removed during forest harvesting and thinning could be marketed and sold in emerging biomass energy and biofuels markets, as well as traditional forest markets. However, riparian forests support fundamental ecosystem

services such as internal nutrient cycling, soil protection, biodiversity conservation, carbon sequestration, climatic regulation, and quality water supply. Tree removal, when not done in an environmentally sound manner, can harm these ecosystem services. Tabacchi et al. (2000) warn that large-scale logging and fragmentation of floodplain forests can lower the ecosystem's buffering capacity to reduce water input and delay backwater drainage, thus altering the exchange of surface and ground water. Early successional species such as cottonwood depend on periodic flooding and scouring events to provide the moist bare mineral soil needed for regeneration (Smith and Linartz 1980). Treatments such as thinning can be used to remove competing vegetation and raise light levels, which allow cottonwood to establish. Cuttings are often used to quickly regenerate cottonwood in plantations and on open sites (Taylor 2001).

However, caution must be used in ecosystems where tree removal might stimulate the spread of nonindigenous species. Changes in ecosystem structure have been shown to increase encroachment by nonindigenous species in riparian zones (Planty-Tabacchi et al. 1996). These native and non-native invaders exhibit greater adaptability to physical disturbance in the form of tree removal, physical disturbance, and hydrological alterations than do endemic riparian species (Katz and Shafroth 2003). McIntyre and Lavorel (1994) report that riparian invaders demonstrate enhanced colonization and reproduction capabilities in disturbed habitats when compared with native pioneer species.

Clear-cutting riparian forests can degrade downstream habitat for fish and wildlife species. Channel narrowing has been documented along the braided Platte River due to upstream flow modifications following damming (Johnson 1994), but studies by Johnson (1997) report that over time these channel areas have stabilized. On the other hand, vegetation removed along a portion of the river to increase open channel area for migrating whooping (*Grus americana*) and Sandhill cranes (*Grus canadensis*) resulted in downstream channel area disequilibria. The vegetation clearing may have liberated excess sediment, which raised the channel and stimulated tree and shrub recruitment, causing a 10% channel loss (Johnson 1997). Channel area losses in unmanaged reaches may offset gains in managed areas, suggesting that management procedures should be reevaluated before further reaches are cleared (Johnson 1997). Jones et al. (1999) investigated the impact of riparian forest removal on downstream fish assemblages in southern Appalachian streams. The studies concluded that clearing

TABLE 3
WOODY VEGETATION TYPE AND LOCATION, TREATMENT, AND COST

Woody vegetation type and location	Treatment	Cost (US\$/ha)	Reference
<i>Juniperus</i> , moderate cover (10%–30%)	Various clearing methods	365 ± 87	Olenick et al. (2004)
<i>Juniperus</i> , heavy cover (>30%)	Various clearing methods	508 ± 111	Olenick et al. (2004)
<i>Juniperus virginiana</i> open (<30-year-old stand) and dense stands (30-year-old, 5 m tall), Custer County, NE	Burned	5	Ortmann et al. (1998)
	Burned and cut	40	
	Individual trees burned	15	
	Picloram	90	
	Cutting	65	
<i>Prosopis</i> , moderate cover (10%–30%)	Various clearing methods	256 ± 73	Olenick et al. (2004)
<i>Prosopis</i> , heavy cover (>30%)	Various clearing methods	438 ± 228	Olenick et al. (2004)
<i>Tamarix</i>	Helicopter herbicide application	168	U.S. Bureau of Reclamation (2009); Sisneros (1994)
<i>Tamarix</i>	Fixed-wing herbicide application	138	
<i>Tamarix</i>	Cut-stump and herbicide application	2,617	
<i>Tamarix</i>	Foliar herbicide application	849	
<i>Tamarix</i>	Cut and sprayed with imazapyr	1,250 ± 370	Taylor and McDaniel (1998)
<i>Tamarix</i>	Aerial spray of imazapyr with and without glyphosphate; burning	430 ± 140	Taylor and McDaniel (1998)
<i>Tamarix</i>	Individual cut and spray imazapyr	3,952 ± 6,175	Taylor and McDaniel (2004)
<i>Tamarix</i>	Individual herbicide application or mechanical grubbing	99 ± 741	Taylor and McDaniel (2004)
<i>Tamarix</i>	Large-scale control methods	1,010 ± 460	Taylor and McDaniel (2004)

vegetation over 1–3 km in width or reach was associated with the decreased abundance of benthic-dependent fish species, causing sediment-tolerant and often invasive species to supplant them. However, the study focused on deforested but still vegetated riparian zones in otherwise wooded landscapes, so the results may not apply to riparian buffers in other forested areas (Jones et al. 1999).

CONCLUSION

Despite their apparent small percentage of cover on a regional scale, riparian ecosystems play a major functional role in the hydrologic cycle in the Great Plains. Water crises and shortages in arid and semiarid areas of the United States and elsewhere due to climate change, drought, population growth, agriculture, and new demand for biofuels and other energy systems are driving

researchers and managers to find ways to reallocate water and increase water yields in streams and rivers. Because riparian forests use more water than upland forests on an area basis, approaches to increase water yields could include the removal of invasive and aggressive woody vegetation from riparian areas. Realistic projections of increased water yields following tree removal must consider many variables, including land use within the entire watershed, relative water use with each land-use category, climate, and pre- and post-treatment vegetation. As a first cut, relative areas and water use rates of different vegetation and land-use types can be used by managers and policy makers to identify regions where changes in management can have the most impact on water yields and streamflows. In the face of escalating political and socioeconomic pressures, it is critical to manage riparian habitats in an ecologically sustainable

manner in order to preserve their integrity, function, structure, productivity, and species composition. Otherwise, short-term gains in water yields after removing woody vegetation could be offset by long-term losses in ecosystem services, including water yields, as aggressive, more water-consumptive species spread in untreated and cleared areas. Targeted efforts to control woody plants in water-rich riparian zones can help minimize water lost by invasive facultative phreatophytes, such as saltcedar, Russian olive, and eastern redcedar, potentially increasing water yields. However, our review has shown that such increases are unpredictable in semiarid regions; they vary within geographic regions and stream types, and are most often temporary, with benefits leveling off after a few years unless continuous control of woody and weedy vegetation is adopted on these sites. More research on the ecologic, hydrologic, and economic consequences of the spread and management of invasive species in riparian areas is needed in the northern Great Plains. Quantifying these responses to invasive species is needed to plan effective large-scale invasive species control programs where efficient and sustainable use of water resources is a management priority.

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ESTIMATION OF LAND SURFACE EVAPOTRANSPIRATION WITH A SATELLITE REMOTE SENSING PROCEDURE

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ABSTRACT—There are various methods available for estimating magnitude and trends of evapotranspiration. Bowen ratio energy balance system and eddy correlation techniques offer powerful alternatives for measuring land surface evapotranspiration. In spite of the elegance, high accuracy, and theoretical attractions of these techniques for measuring evapotranspiration, their practical use over large areas can be limited due to the number of sites needed and the related expense. Application of evapotranspiration mapping from satellite measurements can overcome the limitations. The objective of this study was to utilize the METRIC™ (Mapping

Evapotranspiration at High Resolution using Internalized Calibration) model in Great Plains environmental settings to understand water use in managed ecosystems on a regional scale. We investigated spatiotemporal distribution of a fraction of reference evapotranspiration (ETrF) using eight Landsat 5 images during the 2005 and 2006 growing season for path 29, row 32. The ETrF maps generated by METRIC™ allowed us to follow the magnitude and trend in ETrF for major land-use classes during the growing season. The ETrF was lower early in the growing season for agricultural crops and gradually increased as the normalized difference vegetation index of crops increased, thus presenting more surface area over which water could transpire toward the mid-season. Comparison of predictions with Bowen ratio energy balance system measurements at Clay Center, NE, showed that METRIC™ performed well at the field scale for predicting evapotranspiration from a cornfield. If calibrated properly, the model could be a viable tool to estimate water use in managed ecosystems in subhumid climates at a large scale.

Key Words: energy balance, evapotranspiration, METRIC, SEBAL, water use

INTRODUCTION

Water is the most important constraint facing agriculture in most of the Central High Plains of the United States, including Nebraska. Nebraska's 8.2 million acres of irrigated lands are extremely vital to the state's economy. Local, state, and federal water management regulatory agencies need good-quality water-use estimates for different land surfaces to assess short- and long-term water management, planning, and allocations on a watershed scale. Evapotranspiration (ET) can be defined as the loss of water to the atmosphere from the ground, lake, pond, and vegetative surfaces due to vaporization of liquid water. Evapotranspiration is usually the largest hydrological flux through the summer months in the Great Plains. The ability to accurately estimate the magnitude of this flux will, therefore, go a long way toward computing the water balance and planning the use of available water resources. It is, however, the most difficult flux to quantify (Peacock and Hess 2004). Furthermore, quantification of this flux on a watershed or a regional scale is much more difficult than at a specific site. Evapotranspiration is highly dynamic in space and time because of the complex interaction of soil, vegetation, and climate. The Bowen ratio energy balance system (BREBS) and eddy correlation techniques offer alternatives for measuring surface energy fluxes, including evapotranspiration, at a footprint scale. Despite the high accuracy of techniques, they may not be practical when quantifying water use at regional scales due to the number of measurement sites needed and the operational expense of such a dense network.

Satellite remote sensing overcomes these issues with a broad spatial coverage and the potential exists for indirect evapotranspiration measurement. The land surface energy balance (EB) based models convert satellite sensed radiances into land surface characteristics to estimate evapotranspiration as a residual of the land

surface energy balance equation. The Surface Energy Balance Algorithm for Land (SEBAL) was developed to quantify evapotranspiration over large areas using remote sensing-based land surface energy fluxes (Bastiaanssen et al. 1998a, 1998b).

The SEBAL model uses the near-surface temperature gradient (dT) between the land surface and air, estimated as an indexed function of radiometric surface temperature (T_s), thereby eliminating the need for absolutely accurate surface temperature (T_s) or air temperature (T_{air}) measurements to estimate sensible heat flux (H). The dT varies linearly with T_s , and this relationship is based on two anchor pixels (hot and cold pixels) where a value of H can be estimated. The maximum and minimum values of dT are calculated for the hot and cold pixels in an image and ultimately anchor H while preventing outliers in H estimation (Bastiaanssen et al. 1998a). The anchoring pixels can exist anywhere within the satellite image footprint. It was hypothesized that H at the cold pixel and latent heat flux (LE) at the hot pixel are zero. It follows that the evaporative fraction (EF) of the cold pixel equals one and that of the hot pixel equals zero. The EF (Λ) defines the partitioning of the surface EB by means of the latent heat flux (LE)/net available energy ($R_n - G$), with the net available energy ($R_n - G$) being defined as the difference in net radiation (R_n) and soil heat flux (G).

The SEBAL model is gaining global attention for its successful application worldwide. The model has been used to estimate riparian evapotranspiration (Goodrich et al. 2000), basinwide evapotranspiration (Tateishi and Ahn 1996), mapping regional runoff and precipitation (Church et al. 1995), developing crop coefficients (Bausch 1995; Tasumi et al. 2005a, 2005b; Singh and Irmak 2009) and for quantifying on-demand irrigation (Irmak and Kamble 2009). A critical issue with SEBAL is, however,

defining anchor pixels. When anchor pixels are not present on the imagery, assumptions may not hold, and then the SEBAL approach has been less than satisfactory (i.e., Singh et al. 2008).

To solve this dilemma, Allen et al. (2007a, 2007b) introduced the METRIC™ (Mapping Evapotranspiration at High Resolution using Internalized Calibration) model using similar principles to those of SEBAL, but with refinements to anchor pixels and various energy balance components. They introduced a better proxy for scaling satellite overpass time evaporation (EF) to 24-hour periods for the well-watered and fully vegetated areas of the image which represent the alfalfa-based reference evapotranspiration surface (ET_r). In METRIC™, LE at the cold pixel with full canopy cover (leaf area index [LAI] > 4) is taken as $1.05 ET_r$, where ET_r is the alfalfa-based reference evapotranspiration. For the hot pixel, the LE estimate is based on a bare soil water balance using the FAO 56 approach (Allen et al. 1998).

METRIC™ estimates a so-called “fraction of reference ET (ETrF)” defined as the “ratio of instantaneous ET to the reference crop evapotranspiration (ET_r)” (Allen et al. 2007a, 2007b). The ETrF estimates from METRIC™ using remotely sensed data are instantaneous; even so, it allows estimating LE on a 24-hour basis. The daily reference crop evapotranspiration (ET_{r-24}) is multiplied with ETrF to estimate daily ET at each pixel of the Landsat scene. ETrF is similar to evaporative fraction used by Bastiaanssen et al. (1998a, 1998b). The instantaneous EF and ETrF are shown to be similar to the 24-hour EF and 24-hour ETrF, respectively (Shuttleworth et al. 1989; Verma et al. 1992; Brutsaert and Chen 1996; Trezza et al. 2003).

The demand for quantification of evapotranspiration over large areas is growing. Estimates based on satellite remote sensing offer a reasonable means for meeting this demand. The advantage of applying remote sensing-based evapotranspiration procedures is that the water used by the soil-water-vegetation system can be derived directly without the need to quantify other hydrological processes. Therefore, the remote sensing-based estimation of evapotranspiration has potential in quantification of large-scale water balances. The principal thrust of our study was to utilize the METRIC™ model to estimate water use in managed ecosystems in Great Plains environmental settings. In particular, we were interested in spatiotemporal distribution of the fraction of reference evapotranspiration (ETrF) on a regional scale. A total of eight Landsat 5 satellite images from 2005 and 2006 for path 29, row 32 were processed using METRIC™ algorithms.

MATERIAL AND METHODS

METRIC Model

Evapotranspiration estimation in METRIC™ is based on the principle of energy conservation. The model ignores minor energy components and considers only vertical fluxes (horizontal advective flux is not explicitly included) to estimate LE as a residual in the EB equation:

$$LE = R_n - G - H \quad (1)$$

where R_n is the net radiation, G is the soil heat flux, H is the sensible heat flux, and LE is the latent heat flux. The units for all the fluxes are in watts per meter square ($W m^{-2}$).

METRIC™ uses the empirical equation developed by Tasumi et al. (2003) to compute soil heat flux (G):

$$\begin{aligned} \frac{G}{R_n} &= 0.05 + 0.18 e^{-0.521LAI} \quad (\text{if } LAI \geq 0.5) \\ \frac{G}{R_n} &= (1.80 (T_s - 272.15)/R_n + 0.084) \quad (\text{if } LAI < 0.5) \end{aligned} \quad (2)$$

where T_s (K) is the surface temperature determined from a satellite. Equation 2 suggests that when Leaf area index (LAI) is less than 0.5, the G/R_n ratio increases with higher rates of T_s and decreases with increasing LAI.

Using the aerodynamic function, sensible heat flux (H) is expressed as:

$$H = \frac{\rho \cdot C_p \cdot dT}{r_{ah}} \quad (3)$$

where ρ is the air density ($kg m^{-3}$), C_p is the specific heat of air (1004 Joules [J] per kilogram [kg^{-1}] per degree Kelvin [K^{-1}]), dT is the near-surface and air-temperature difference (K), and r_{ah} is the aerodynamic resistance to heat transfer ($s m^{-1}$) over the vertical distance.

METRIC™ uses two anchor pixels (hot and cold) where values of H can be estimated. The model does not require the actual absolute values of air temperatures (T_{air}) above each pixel, but only near-surface temperature difference (dT) to solve for H . The dT is used because of the difficulties in estimating surface temperature accurately from the satellite due to uncertainties in air temperature (T_{air}), atmospheric attenuation, contamination, and radiometric calibration of the sensor (Bastiaanssen et al. 1998a, 1998b; Allen et al. 2007a, 2007b). Use of dT between two heights above the surface allows for the calculation of only one value of r_{ah} from only one value of a second

aerodynamic roughness. The dT for each pixel is calculated as:

$$dT = T_{z1} - T_{z2} \quad (4)$$

where T_{z1} and T_{z2} are the air temperatures at height $z1$ (0.1 m) and $z2$ (2.0 m) for any particular pixel.

The dT is estimated assuming a linear relationship between dT and T_s that is calibrated to each satellite image to compensate for uncertainties in aerodynamic surface T_s and air temperature (T_{air}). The linearity assumption is based on the field research demonstrated by Wang et al. (1995), Bastiaanssen (1995), Franks and Beven (1997a, 1997b), and Franks and Beven (1999). If one can assume the presence of wet and dry pixels in the remotely sensed image, then the image-derived surface temperatures can be scaled to yield EF or ETrF ranging from 0 to 1. The basis of this assumption is that evaporative fluxes across a given domain may be bounded at the extremes, that is, no or nearly zero evaporation (hot or dry pixel) and potential evaporation (cold or wet pixel).

Estimation of Latent Heat Flux and Reference Evapotranspiration Fraction

The integration of LE over time in METRIC™ was split into two steps. The first step was to convert the instantaneous value of LE into daily ET_{24} values by holding the reference ET fraction constant (Allen et al. 2007a). An instantaneous value of ET (ET_{inst}) in equivalent evaporation depth is the ratio of LE to the latent heat of vaporization (λ):

$$ET_{inst} = 3600 \frac{LE}{\rho_w \lambda} \quad (5)$$

where 3600 is the time conversion from seconds to hours, and ρ_w is the water density ($\sim 1.0 \text{ Mg m}^{-3}$).

The reference ET fraction (ETrF) is defined as the ratio of instantaneous ET (ET_{inst}) for each pixel to the alfalfa-reference ET calculated using the standardized ASCE Penman-Monteith equation for alfalfa (ET_r) following the procedures given in ASCE-EWRI (2005):

$$ETrF = \frac{ET_{inst}}{ET_r} \quad (6)$$

ETrF serves as a surrogate for K_c (basal crop coefficient) and has been used with 24-hour ET_r in order to estimate the daily ET at each Landsat pixel:

$$ET_{24} = ETrF \times ET_{r-24} \quad (7)$$

where ET_{24} is the daily value of actual ET (mm d^{-1}) and ET_{r-24} is 24-hour ET_r for the day of the image, calculated by summing hourly ET_r values over the day of image. The procedures outlined in ASCE-EWRI (2005) were used to calculate parameters in the hourly ET_r .

Although daily values of ET derived at the satellite overpass date are more helpful and practical, water regulatory agencies are interested in seasonal ET estimates to assess water management, planning, and allocation. First, to obtain seasonal ET, the reference ET fraction (ETrF) for each satellite overpass date is calculated for the considered period. The ETrF is then interpolated (i.e., linear, cubic spline) for other dates between the dates of satellite overpasses. Subsequently, the interpolated ETrF is multiplied with the corresponding calculated ET_{r-24} to obtain actual ET (ET_{24}) for the dates between satellite overpasses. Seasonal ET can be obtained by summing daily ET_{24} values for the considered period.

METRIC Model Setup

The METRIC™ model calculates actual evapotranspiration by utilizing satellite images containing both shortwave and thermal bands. The sensible heat (H) for each pixel of an image is estimated at each pixel, and equation 1 is used to find LE. Values for H are calculated across an image according to the surface temperature (T_s). This is done using a “ dT vs. T_s ” function. The dT can be estimated as a linear function of surface temperature (Bastiaanssen et al. 1998a). It is the difference between the air temperature very near the surface, at 0.1 m above the zero plane displacement height, d , and the air temperature at 2 m above the zero plane displacement height.

The linear equation for dT vs. T_s in METRIC™ is developed by using the dT values for the cold and hot pixels, which provide internal and automatic calibration. In addition, internal calibration of the EB utilizes ground-based reference ET (ET_r) to tie down the derived EB (Allen et al. 2007a, 2007b). Therefore, use of quality controlled hourly ET_r is important to improve accuracy of daily and longer period ET estimates.

In METRIC™, cold and hot pixels should be located near the weather station (\sim within 50 km). The cold pixel is used to define the amount of ET occurring from the well-watered and fully vegetated areas of the image, which represent instances where the maximum (or near maximum) amount of available energy is being consumed by evaporation. For this study, we selected a number of cold pixel candidates for each image representing an agricultural area under a center pivot irrigation

system that has vegetation at full cover (LAI is usually greater than 4.0 m^2) to estimate ET at the cold pixel. We assumed that $ET = 1.05 ET_r$ at the cold pixel. The ET_r is the rate of ET from the alfalfa reference calculated using the ASCE Standardized Penman-Monteith equation for alfalfa. H for the cold pixel was then calculated as $H = R_n - G - 1.05 ET_r$.

The selection of the hot pixel follows the same procedure as for the cold pixel. The hot pixel should be located in a dry and bare agricultural field where one can assume evaporative flux is 0. We selected the hot pixel candidates with a surface albedo similar to dry and bare fields (0.175–0.2) with very low LAI (usually less than 0.1). In south-central Nebraska, we found that the hot pixels could not be assumed to have zero evaporation because of high frequency of rain in the region. Therefore, H was estimated as $R_n - G - ET_{\text{bare soil}}$, where $ET_{\text{bare soil}}$ was obtained by running a daily soil water balance model of the surface soil using ground-based weather measurements (Allen et al. 1998). The METRIC™ model was then run for each of the cold and hot pixel candidates. The best suitable anchor pixels were determined based on the distribution of ET_rF over the image. For instance, ET_rF of well-irrigated and fully vegetated agricultural crops should have an ET_rF of 1.0, on average.

Landsat Satellite Datasets and Processing

Landsat 5 (LT5) cloud-free, systematic terrain-corrected (Level 1T) satellite images (path 29, row 32) were obtained from the Earth Explorer, USGS site (<http://www.edcns17.cr.usgs.gov/EarthExplorer/>) for the 2005 and 2006 growing season. The acquisition dates for Landsat 5 images were May 19, June 20, August 7, and September 8, 2005, while the dates for 2006 were May 22, June 23, July 25, and October 13. These images had a cloud cover of less than 10%. The METRIC™ algorithms developed by University of Idaho (Allen et al. 2007a, 2007b) were adapted and modified in Erdas Imagine® Image Processing Software (Leica Geosystems Geospatial Imaging, LLC) to achieve the objectives.

The seasonal progression of land surface conditions were characterized with a normalized difference vegetation index (NDVI). The index was computed using reflectance for the near infrared (ρ_{NIR}) and red (ρ_{RED}) bands:

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}} \quad (8)$$

Experimental Setup Description for the Study Area

The field data were collected at the University of Nebraska–Lincoln South Central Agricultural Laboratory near Clay Center, NE ($40^\circ 34'N$, $98^\circ 08'W$; elevation 552 m). The Pioneer 33B51 corn hybrid was planted for the years 2005 and 2006 at 0.76 m row spacing and a seeding density of approximately 73,000 seeds/ha and with planting depth of 0.05 m. The Pioneer 33B51 hybrid had a comparative relative maturity of 113 to 114 days. In 2005 corn was planted on April 22, emerged on May 12, reached full canopy closure on July 4, reached silking stage on July 12, matured on September 7, and was harvested on October 17. In 2006 corn was planted on May 12, emerged on May 20, reached complete canopy closure on July 8, reached silking stage on July 15, matured on September 13, and was harvested on October 5.

The soil at the experimental site is Hastings silt loam, which is a well-drained soil on uplands. It is a fine, *montmorillonitic, mesic Udic Argiustoll*, with field capacity of $0.34 \text{ m}^3 \text{ m}^{-3}$ and permanent wilting point of $0.14 \text{ m}^3 \text{ m}^{-3}$. The particle size distribution is 15% sand, 62.5% silt, and 20% clay. The soil has a 2.5% organic matter content. The experimental field (13 ha) was irrigated using a subsurface drip irrigation system. The drip laterals were spaced every 1.52 m (in the middle of every other crop row) and were installed at a depth of approximately 0.4 m from the soil surface. Irrigation was applied twice or three times a week to replenish the soil water content to approximately 90% of the field capacity in the top 0.90 m of the soil profile, which was considered to be the effective root-zone depth for corn. Detailed description of experimental field data collection methods were reported by Irmak and Irmak (2008) and Irmak et al. (2008).

Flux Measurements Using a Bowen Ratio Energy Balance System

This study used the surface energy balance flux data that were measured and reported by Irmak and Irmak (2008) and Irmak et al. (2008). The BREBS was installed in the middle of the experimental field with a fetch distance of 260 m in a north-south direction and 137 m in an east-west direction. The row orientation of the field was in an east-west direction. There were adequate fetch conditions since the prevailing wind direction in the experimental site is usually from the south during the spring and summer months. In addition, the experimental field was surrounded with large irrigated cornfields in four

directions. The BREBS measurement heights were thus considered to be within the boundary layer over the irrigated cornfield. The BREBS measurements were made daily for 2005 and 2006.

Measurements were made using a deluxe version of a BREBS (Radiation and Energy Balance Systems, REBS, Inc., Bellevue, WA). The chromel-constantan thermocouple air temperature and relative humidity (RH) probes (Model THP04015 for temperature, and THP04016 for RH; REBS, Inc., Bellevue, WA) were used to measure air temperature and RH gradients. The BREBS used an automatic exchange mechanism that physically exchanged the temperature and RH sensors at two heights above the canopy. Soil heat flux was measured using three REBS HFT-3.1 heat flux plates and three soil thermocouples. Each soil heat flux plate was placed at a depth of 0.08 m below the soil surface approximately 45 cm apart from each other. Three REBS STP-1 soil thermocouple probes were installed a few centimeters from each soil heat flux plate. Measured soil heat flux values were adjusted to soil temperature and soil water content as measured using three REBS SMP1R soil moisture probes at a depth of 0.06 m. The three sets of soil heat flux, soil temperature, and soil water content probes were installed on the crop row on the ridge, in the middle of the dry furrow where the drip lateral pipe was not present, and in the middle of the furrow where the drip lateral pipe was present (the drip laterals were installed on every other crop row in the middle of the furrow). The average soil heat flux values from three sensors were used in the calculations.

R_n was measured using a REBS Q-7.1 net radiometer installed approximately 4.5 m above the soil surface. Shortwave radiation and longwave radiation were measured simultaneously using a model REBS THRDS7.1 double-sided total hemispherical radiometer, and the hourly albedo values were calculated from the ratio of outgoing shortwave to incoming shortwave radiation. Wind speed and direction at 3 m height were monitored using a Model 034B cup anemometer (Met One Instruments, Grant Pass, OR) that had a wind speed range of 0–44.7 m s⁻¹ with a starting threshold of 0.28 m s⁻¹. All variables were sampled at 30 s intervals and averaged and recorded every hour for energy balance calculations using a Model CR10X datalogger and AM416 Relay Multiplexer (Campbell Scientific, Inc., Logan, UT). The satellite overpasses on path 29, row 32, were usually between 11:00 a.m. to 11:10 a.m. Central Standard Time. The hourly BREBS measurements from 11:00 a.m. and 12:00 p.m. Central Standard Time were converted to represent the instantaneous fluxes for each satellite overpass date.

Details of flux measurements were given by Irmak and Irmak (2008) and Irmak et al. (2008).

Meteorological Data

Weather data were acquired from the High Plains Regional Climate Center's (HPRCC) Automated Weather Data Network (AWDN). The AWDN stations record hourly data for air temperature, humidity, soil temperature, wind speed and direction, solar radiation, and precipitation. Reference ET (ET_r) values were calculated using the ASCE-EWRI (2005) standardized Penman-Monteith equation for alfalfa reference. Table 1 shows average weather conditions at South Central Agricultural Laboratory measured with BREBS for the days of Landsat overpass for 2005 and 2006 growing seasons.

RESULTS AND DISCUSSION

Mapping Spatiotemporal Distribution of Normalized Difference Vegetation Index, Available Energy, and Reference Evapotranspiration

Figure 1 shows land-use classes for path 29 and row 32. The land-use classes for a given scene have different surface roughness characteristics because of the height and density of land surface properties. Therefore, use of a land-use map in METRIC might improve parameterization of the surface roughness parameter especially if a high level of accuracy and detail are represented in the land-use map for the study area. The land-use map was developed at the Center for Advanced Land Management Information Technologies (CALMIT) using level 1T LT5 scenes for 2005 (CALMIT 2006). The scale of the map is 1:100,000 with a ground resolution of 28.5 m. There are 25 land-use classes, and agricultural crops are identified as either irrigated or dryland. The overall accuracy of the statewide classification was calculated at 80.43%. The top portion of Figure 1 covers south-central Nebraska and includes primarily agricultural crops such as corn and soybeans with some grain sorghum. Pasture (rangeland, grassland) and native vegetation are located from west to east in southern Nebraska and cover as much as one-third of the Nebraska portion of the scene. The Kansas portion, one-quarter portion of scene, includes mainly small grains (wheat) and rangeland.

To quantify the spatial distribution of seasonal ET, at least one image per month was required for an accurate and continuous characterization of the ETrF (fraction of

TABLE 1
AVERAGE WEATHER VARIABLES AT THE SOUTH CENTRAL AGRICULTURAL
LABORATORY NEAR CLAY CENTER, NEBRASKA,
FOR THE DAYS OF LANDSAT OVERPASS FOR 2005 AND 2006 GROWING SEASON

Date	T _{max} (°C)	T _{min} (°C)	RH _{max} (%)	RH _{min} (%)	U ₃ (m s ⁻¹)	R _s (W m ⁻²)	ET _r (mm d ⁻¹)	LE/(R _n - G)*
May 19, 2005	30.7	10.8	84.4	22.3	3.20	342.6	9.62	0.42
June 20, 2005	33.0	18.9	96.2	47.8	4.10	315.5	8.22	0.94
August 7, 2005	31.4	16.2	97.3	51.2	3.10	257.5	5.56	0.98
September 8, 2005**	30.5	18.2	96.1	53.3	3.58	242.7	5.24	1.45*
May 22, 2006	29.5	13.9	80.7	40.5	4.40	271.1	8.09	0.19
June 23, 2006	28.4	15.1	98.3	40.5	2.02	332.9	7.29	0.80
July 25, 2006*	32.6	21.2	90.7	51.3	4.65	246.7	6.84	1.14*
October 13, 2006	11.9	-2.9	79.5	20.0	5.48	198.5	3.99	0.44

Notes: The climate variables are T_{max} = maximum air temperature, T_{min} = minimum air temperature, RH_{max} = maximum relative humidity, RH_{min} = minimum relative humidity, U₃ = wind speed at 3 m height, R_s = incoming shortwave radiation, and ET_r = reference evapotranspiration. All the climate variables were from Bowen ratio energy balance system except the ET_r data, which were calculated using the standardized ASCE Penman-Monteith equation for alfalfa following the procedures given in ASCE-EWRI (2005) with the data from the High Plains Regional Climate Center weather station located near the study field.

*Partitioning of R_n - G to LE at the satellite day.

**Advection occurred.

reference ET or relative ET) curve for each Landsat pixel for the growing period (May 1–October 15). Only four Landsat 5 images were selected from May 19 through September 8 in 2005 to demonstrate progression of vegetation growth and corresponding fluxes on a spatial scale in the study domain. Figure 2 shows the progression of NDVI on May 19, June 20, August 7, and September 8 during the 2005 growing season while Figure 3 shows R_n - G for the same days, respectively. NDVI is a measure of vegetation amount and condition and associated with biomass, leaf area index, and percentage of vegetation cover. It can provide information about the crop stand, crop development stage, crop conditions, and water stress conditions. R_n - G shows the amount of available energy for latent heat (LE) and sensible heat (H).

The NDVI values were usually lower for agricultural lands (top portion of the image in Fig. 2) than rangeland/natural vegetation (bottom portion of Fig. 2). NDVI values were around 0.2–0.3 for agricultural crops on May 19, while they were as high as 0.6 for rangeland/natural vegetation. The NDVI increased gradually during the vegetative development stage of agricultural crops (May

through June) and reached its maximum value (~0.75 and 0.85) in August. It remained fairly constant during the reproductive stage of crops (August through September).

Similar to NDVI progression, the available energy (R_n - G) increased with the crop growth and development (Fig. 3). This increase in R_n - G is due to the increase in the vegetative ground cover. Higher ground cover as indicated by higher NDVI acts as a barrier to the conduction of solar radiation to the soil surface so that less R_n is consumed in heating of the soil (G). Results showed that R_n - G was lower when much of ground was bare soil ranging from 450 W m⁻² to 480 W m⁻² and higher (550–600 W m⁻²) when NDVI was high.

Figure 4A shows the ETrF for the LT5 satellite overpass on May 19, 2005, for path 29, row 32. As expected, the ETrF was highly variable in south-central Nebraska due to variation in soil, cropping practices, and vegetation development. The ETrF values were usually lower for agricultural lands than rangeland/natural vegetation in May. This was due to crop germination and emergence stages at this time. The grazed rangeland/natural vegetation has green vegetation in May as evidenced by

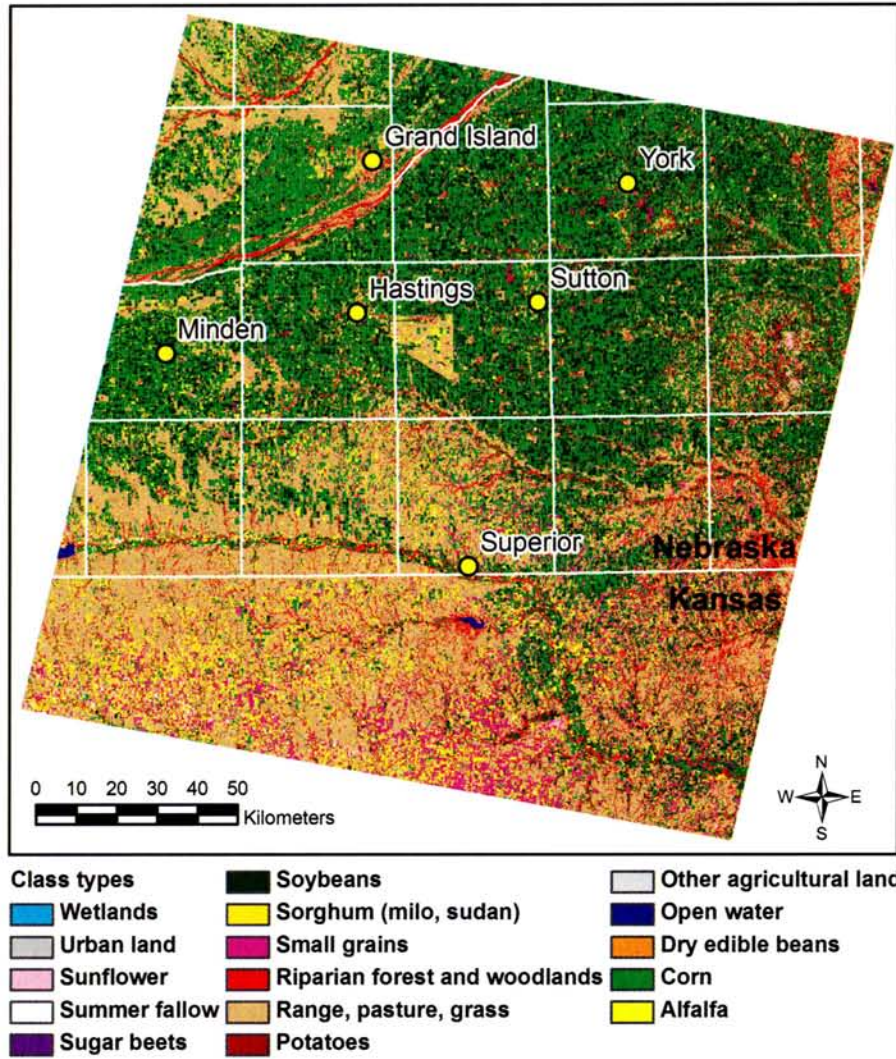


Figure 1. Land-use map of the study area (path 29, row 32) originated from 2005 Nebraska land-use map.

higher NDVI values in the scene. The corresponding ETrF values from grazed rangeland/natural vegetation pixels were quite high in May, indicating that grazed rangeland/natural vegetation is transpiring at near potential rates and most of the $R_n - G$ was used for transpiration. Daily ETrF values on May 19, 2005, were from 0.3 to 0.4 for agricultural lands and was as high as 0.9 for the natural vegetation/rangeland represented in the image (Fig. 4A).

The ETrF vales for agricultural crops generally increased on the June image (Fig. 4B) and were from 0.6 to as high as 0.9. Most of the spatial variability in ETrF was probably due to variation in management practices mainly cropping practices (soybean or corn), soil moisture, hybrids, and dates of planting for agricultural fields.

Figure 4C shows the ETrF distribution on August 7, 2005. The ETrF from agricultural land was much higher (around 1.0 or higher) than the natural vegetation/rangeland. By the end of July agricultural crops usually reach their full canopy cover and vegetative development stops. This is demonstrated by a high NDVI for agricultural crops in August, which indicates a maximum leaf area index (Fig. 2C). At this stage, well-watered crops usually transpire at their potential rates (potential ET). The agricultural crops in south-central Nebraska are irrigated with center pivot irrigation systems to supplement additional water from mid-June to mid-September and to prevent crop water stress conditions. However, most of the rangeland is not irrigated, and could now be suffering water stress consistent with lower ETrF.

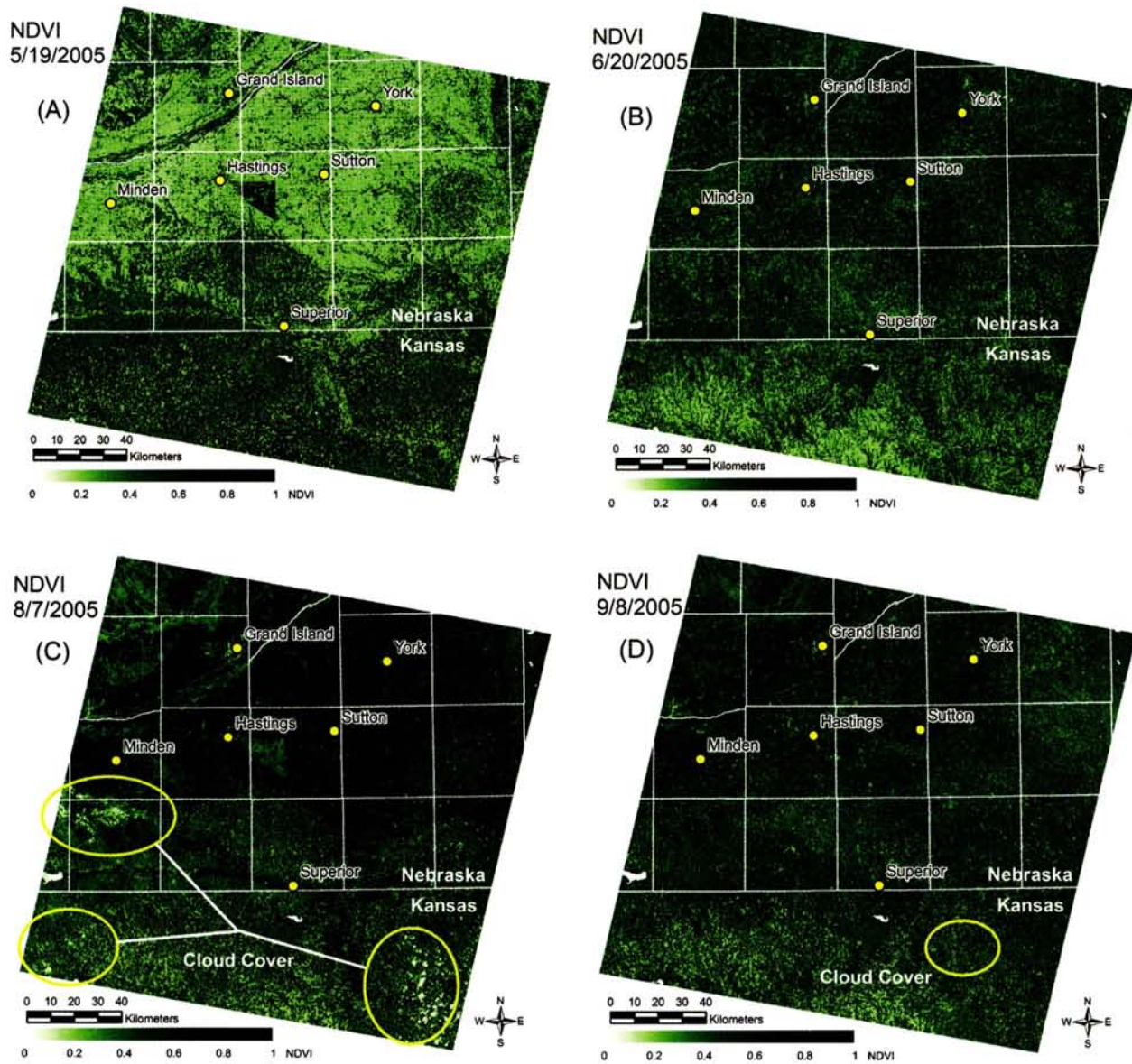


Figure 2. Landsat-derived normalized difference vegetation index (NDVI) values for path 29, row 32 on (A) May 19, 2005; (B) June 20, 2005; (C) August 7, 2005; and (D) September 8, 2005. Cloud cover is identified by yellow circles in the August 7 and September 8 images.

There was an obvious increase in ETrF for agricultural crops in the September 8 image compared to values in August 8. The ETrF values were around 1.0 and 1.1, indicating that actual evapotranspiration by agricultural crops is equal to potential ET. These values were slightly higher than expected. Higher ETrF on September 8 could be attributed to the high amount of precipitation that was received at most of the weather stations on the Landsat scene prior to the satellite pass on September 5. The ETrF of the hot pixel was 0.94 on September 8, determined by solving the daily surface-layer water-balance model of

FAO-56 (Allen et al. 1998). This indicates a significant residual evaporation at the hot pixel. Similar results were found by Singh et al. (2008), who applied SEBAL model for the same dataset.

The ETrF maps generated by the METRIC™ model showed the spatial and temporal distribution of relative ET during the growing season as land surface conditions continuously changed (Fig. 4). The information also allowed us to follow the seasonal trend in ETrF for major land-use classes on the image. The ETrF was lower early in the growing season for agricultural crops and gradually

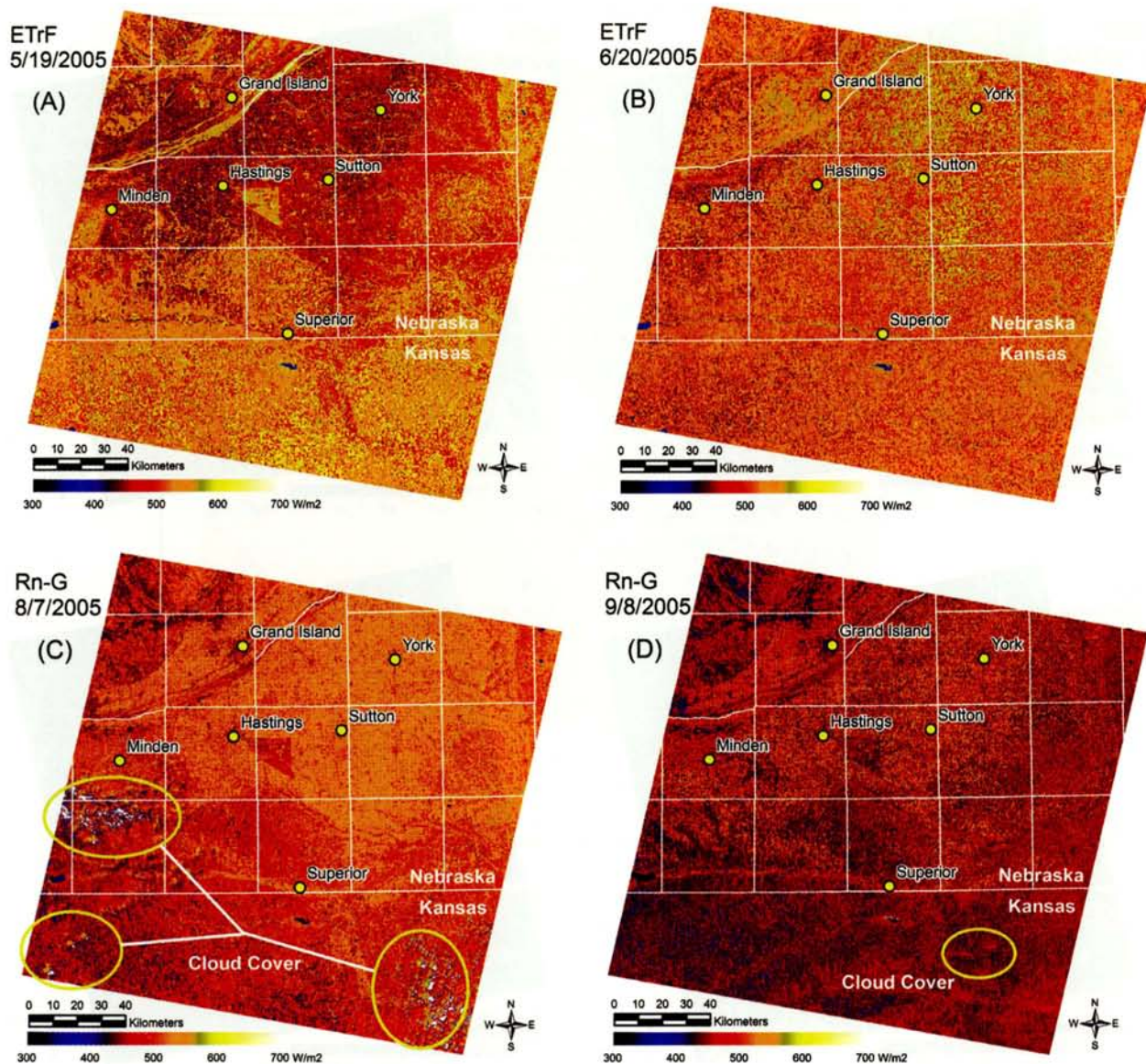


Figure 3. Landsat derived available energy ($R_n - G$) values used for path 29, row 32 on (A) May 19, 2005; (B) June 20, 2005; (C) August 7, 2005; and (D) September 8, 2005. Cloud cover is identified by yellow circles in the August 7 and September 8 images.

increased as the agricultural crops increasingly transpire water toward the midseason.

ETrF from SEBAL and METRIC™ models has been used to serve as a surrogate for K_c (basal crop coefficient) in order to estimate the daily ET from a satellite. Singh and Irmak (2009) developed locally calibrated E_T -based K_c curves for corn (*Zea mays* L.), soybeans (*Glycine max* L.), sorghum (*Sorghum bicolor* L. Moench), and alfalfa (*Medicago sativa* L.) grown under irrigated and dryland conditions in Nebraska's climate. The results indicated that single K_c data sets typically derived for specific crop

varieties for the region would lead to substantial error(s) in ET_c calculation. Similar work was done by Tasumi et al. (2005a) using ET maps created by SEBAL model. They developed the distribution of K_c curves for a large number of individual fields by crop type (alfalfa, bean, corn, peas, potato, sugar beet, spring wheat, and winter wheat in south-central Idaho. Both studies (Singh and Irmak 2009; Tasumi et al. 2005a) further developed the relationship between K_c curves and vegetation indices such as NDVI in order to obtain more rapid and simple estimates of ET based solely on the vegetation index, NDVI.

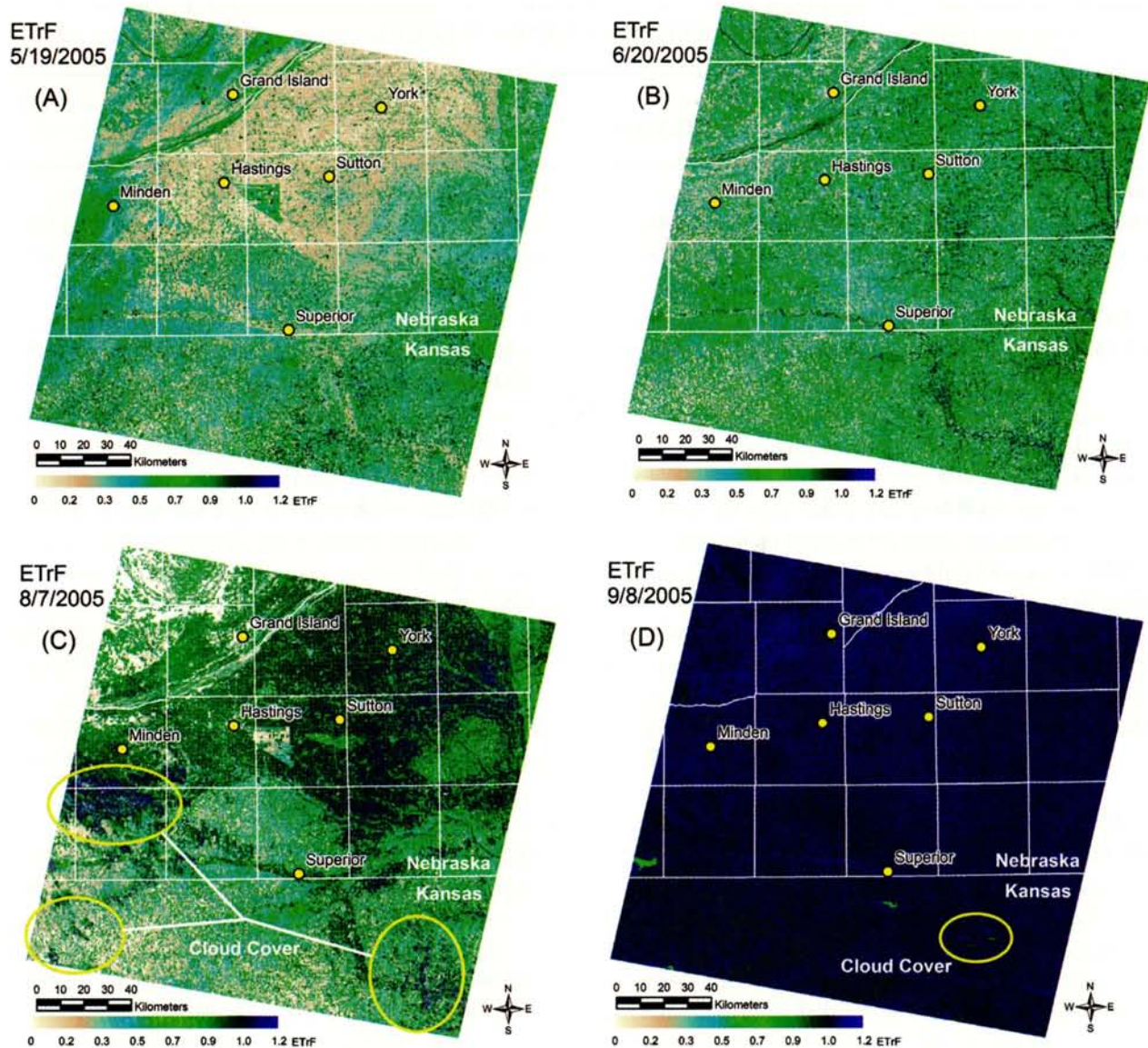


Figure 4. Landsat derived ETrF values (reference evapotranspiration fraction) for path 29, row 32 on (A) May 19, 2005; (B) June 20, 2005; (c) August 7, 2005; and (D) September 8, 2005. Cloud cover is identified by yellow circles in the August 7 and September 8 images.

Evaluation of the METRIC™ for Estimating Energy Fluxes and Daily Evapotranspiration

The comparisons of measured and METRIC™-estimated instantaneous incoming and outgoing radiation fluxes for 2005 and 2006 are presented in Table 2. The model estimated incoming solar radiation ($R_{s\downarrow}$) well for both years with root mean square of error (RMSE) of less than 20 watts per meter squared ($W m^{-2}$). The slope of regression coefficients was close to unity indicating a very strong fit and little systematic bias between estimated

and measured incoming radiant energy flux. On average, BREBS-measured $R_{s\downarrow}$ was $821 W m^{-2}$ for the combined dataset (2005 and 2006).

Table 1 shows average weather variables at the South Central Agricultural Laboratory near Clay Center, NE, for the days of Landsat overpasses for the 2005 growing season. The climate variables are T_{max} = maximum air temperature ($^{\circ}C$), T_{min} = minimum air temperature ($^{\circ}C$), RH_{max} = maximum relative humidity (%), RH_{min} = minimum relative humidity, U_3 = wind speed at 3 m height ($m s^{-1}$), R_s = incoming shortwave radiation ($W m^{-2}$), and ET_r =

TABLE 2
EVALUATION OF METRIC™ MODEL

Fluxes (units)	Year	BREBS	METRIC	Slope	RMSE	Percentage error	r ²
Rs↓ (W m ²)	2005	849	841	0.989	12.9	1.5	0.872
	2006	807	829	1.030	17.9	2.2	0.957
Rs↑ (W m ²)	2005	117	148	1.268	15.5	13.2	0.825
	2006	112	149	1.339	20.9	18.8	0.547
R1↓ (W m ²)	2005	417	373	0.889	27.0	6.5	0.210
	2006	371	355	0.940	29.8	8.0	0.198
R1↑ (W m ²)	2005	523	474	0.871	49.7	9.5	0.594
	2006	525	451	0.857	39.3	7.5	0.825
Rn (W m ²)	2005	571	575	1.004	12.7	2.2	0.840
	2006	529	530	1.002	27.6	5.2	0.683
G (W m ²)	2005	62	72	0.8991	9.4	15.0	0.667
	2006	60	73	1.254	12.1	21.6	0.463
H (W m ²)	2005	122	130	0.886	46.5	38.2	0.393
	2006	193	245	1.251	31.5	16.4	0.990
LE (W m ²)	2005	442	373	0.842	34.100	7.7	0.988
	2006	280	212	0.845	36.818	13.2	0.982
ETrF	2005	0.88	0.818	0.912	0.060	6.8	0.882
	2006	0.52	0.463	0.937	0.058	11.2	0.898
ETc (mm d ⁻¹)	2005	5.690	5.857	1.057	0.348	4.3	0.918
	2006	5.028	5.179	0.973	0.257	4.2	0.960

Notes: Instantaneous incoming shortwave (Rs↓), outgoing shortwave (Rs↑), incoming longwave (R1↓), outgoing long wave (R1↑) radiation fluxes, net radiation (Rn), soil heat flux (G), sensible heat flux (H), and latent heat flux (LE) at the BREBS flux-tower footprint at South Central Agricultural Laboratory for 2005 and 2006. BREBS-measured and METRIC predicted average flux for each year is also included. Statistics include slope of regression line (with intercept forced to zero), root mean square of error (RMSE), percentage error (RMSE/mean flux), and r² of the regression line between BREBS-measured and METRIC™-predicted values.

reference ET (mm d^{-1}). All the climate variables were from the BREBS except the ET_r , which was calculated using the standardized ASCE Penman-Monteith equation for alfalfa following the procedures given in ASCE-EWRI (2005) with the data from the HPRCC weather station located near the study field. The partitioning of available energy ($R_n - G$) to latent heat (LE) calculation for each satellite date is shown in the last column. If $LE/(R_n - G)$ is greater than 1.0, this indicates advection on that day. In this case H represents the movement of energy from the air to the canopy so that LE can exceed $R_n - G$. The higher the number, the higher the contribution of advection. BREBS data indicated that there was strong advection on September 8, 2005 ($LE/(R_n - G) = 1.45$) of the Landsat overpass days, thus, heat was transferred to the cropland area, creating additional energy to be used by the crop to meet the high ET demand on that day. This was expected since there was a large nonirrigated grassland area surrounding the experimental field at South Central Agricultural Laboratory that acted as a source for advective heat. Daily ET_r in September and October was the lowest among the satellite overpass dates for both years (Table 1).

Table 2 shows estimates of instantaneous incoming shortwave ($R_{s\downarrow}$), outgoing shortwave ($R_{s\uparrow}$), incoming longwave ($R_{l\downarrow}$) and outgoing longwave ($R_{l\uparrow}$) radiation fluxes, net radiation (R_n), soil heat flux (G), sensible heat flux (H), and latent heat flux (LE) at the BREBS flux-tower footprint at South Central Agricultural Laboratory for 2005 and 2006. Statistics include the RMSE, percentage error (RMSE/mean flux), and r^2 of the regression line between BREBS-measured and METRIC™-estimated values. The outgoing shortwave radiation ($R_{s\uparrow}$) was calculated by multiplying albedo with $R_{s\downarrow}$. On average, BREBS-measured $R_{s\uparrow}$ for the two-year dataset was 114 W m^{-2} , indicating that approximately 14% of incoming solar radiation ($R_{s\downarrow}$) was reflected back ($R_{s\uparrow}$) to the atmosphere (Table 2). METRIC™ estimated R_n well for both years. The statistics of R_n values of our study are comparable with those observed by other researchers (Crawford and Duchon 1999; Diak et al. 2000; Jacobs et al. 2004; Singh et al., 2008).

METRIC™ overestimated sensible heat flux (H) by 17% with a RMSE of 31.5 W m^{-2} in 2006. The model poorly estimated H for the September 8 image in 2005. Poor estimation of H on this date was due to a recent precipitation event. Precipitation occurring prior to the Landsat image date created wet surface conditions where LE was greater than zero for all potential hot pixel candidates.

There was a good fit between METRIC™ estimated and BREBS-measured ET_{rF} for 2005 and 2006 as evidenced by high r^2 values (Table 2; Fig. 5). Both METRIC™ and BREBS measurements demonstrated that very high ET_{rF} was obtained for the days that advection occurred in the experimental field. The ET_{rF} for the two advective dates are shown inside circles on Figure 5. We should note that BREBS-measured ET_{rF} was calculated by dividing daily values of BREBS-measured ET (mm) to daily reference ET (ET_r). However, METRIC values were obtained by dividing instantaneous ET (ET_{inst}) to daily ET_r , and extended to the full day as a constant in order to obtain daily ET for each satellite overpass date.

METRIC™ ET compared well with observations for both years as evidenced by high r^2 and low RMSE values (Fig. 6; Table 2). The RMSE was less than 0.5 mm on a daily basis for both years. The lowest ET was measured prior to harvest on October 13, 2006. The largest discrepancy in ET was on this date, with 0.88 mm underestimation by METRIC™. Overall, our validation analysis results showed that METRIC™ performed well at the field scale for estimating ET from a cornfield. Results also showed that the daily ET estimates were much closer to the measured ET than estimates of H and G fluxes to measured H and G fluxes.

CONCLUSION

In Nebraska, surface water is regulated by the Nebraska Department of Natural Resources (NDNR) and groundwater is regulated by the 23 Natural Resources Districts (NRDs). According to NDNR, water demands meet or exceed supply limits in many basins, and NDNR has designated these basins as fully appropriated or over-appropriated. The dilemma for management entities is how to maintain profitable agricultural operations that are dependent on irrigation water while protecting surface water and groundwater resources to comply with water compacts or basinwide water management goals. Nebraska is presently engaged in a water planning process in which even small errors could have serious impacts over the long term. If ET is over- or underestimated, some river basins may be needlessly closed or mistakenly left open to further development. Clearly, Nebraska has many economic factors at stake in water planning and management decisions. There is a need to develop scientifically sound methods that provide reliable assessment of water management policies.

The METRIC™ is a hybrid model that combines remotely sensed energy balance via satellite data and

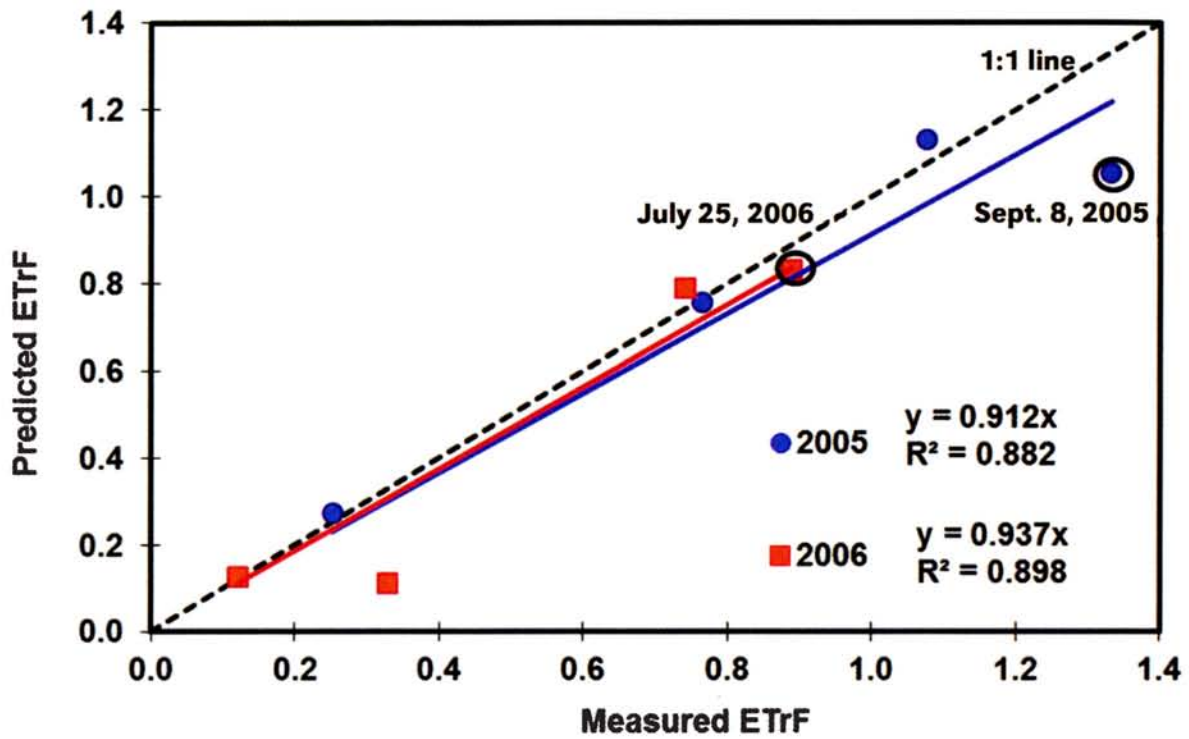


Figure 5. BREBS-measured and METRIC™-estimated evaporative fraction (ETrF) at the BREBS flux-tower footprint at South Central Agricultural Laboratory. The ETrF for the two advective dates are shown inside circles.

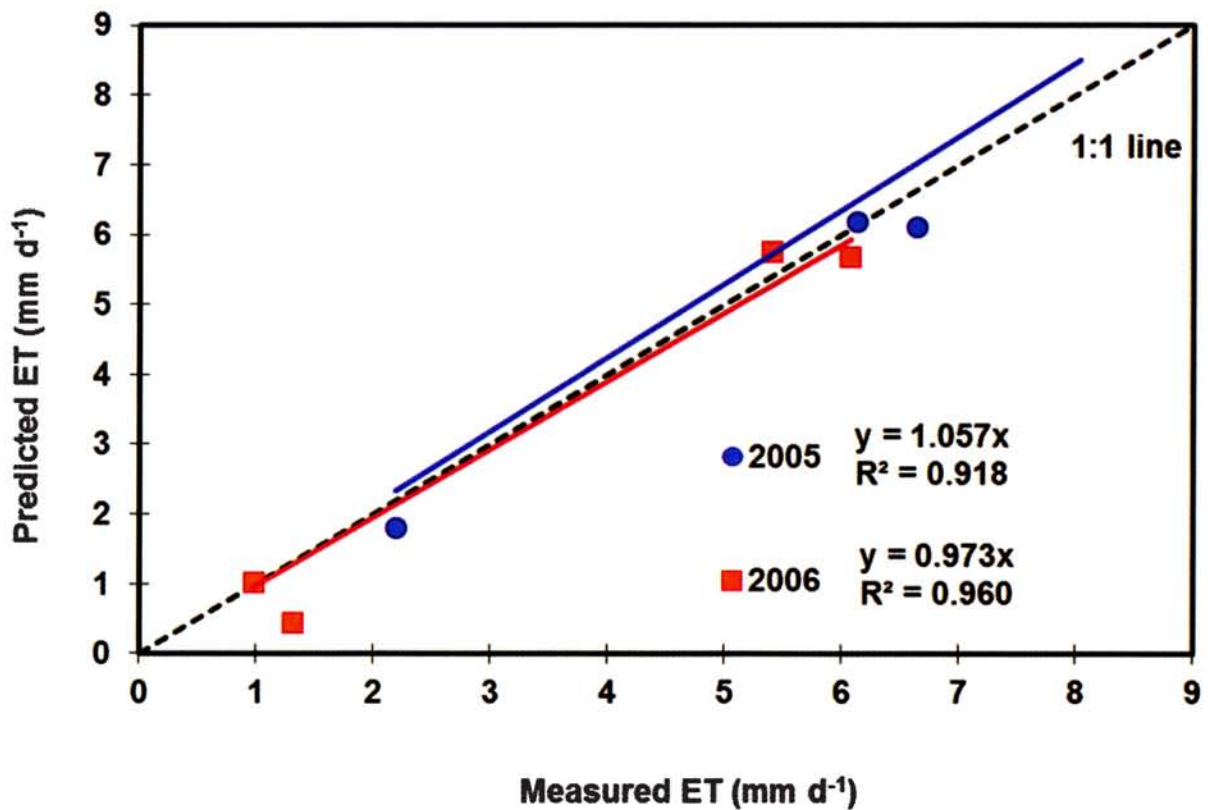


Figure 6. BREBS-measured and METRIC™-estimated daily evapotranspiration (ET, mm d⁻¹) at the BREBS flux-tower footprint at South Central Agricultural Laboratory.

ground-based evapotranspiration via in situ meteorological measurements in order to determine evapotranspiration. The application of the model gave an insight into the spatiotemporal distribution of relative ET on a landscape scale (170 × 183 km area). If calibrated properly, the model could be a viable tool to estimate water use in managed ecosystems in subhumid climates on a large scale, and particularly to assess short- and long-term water management, planning, and allocations. However, there are a few constraints with application of the model to create monthly and seasonal ET maps. Currently, a number of efforts are being made at the University of Nebraska–Lincoln to use METRIC™ in agricultural water management. Some of the efforts include (1) calibrating model algorithms against measurements over different vegetation, climate, and water regimes in the Great Plains; (2) testing submodels to estimate H, G, LAI, and other variables under various land surfaces and developing improved algorithms (or localized calibration of the model) if needed; (3) validating the model in the advective conditions; (4) developing a GIS-based soil water model to account for background evaporation; (5) automating hot and cold pixel selection; and (6) comparing pixel-by-pixel values with other remote sensing–based models.

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HEALTH AND FERTILITY IMPLICATIONS RELATED TO SEASONAL CHANGES IN KIDNEY FAT INDEX OF WHITE-TAILED JACKRABBITS IN SOUTH DAKOTA

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ABSTRACT—White-tailed jackrabbit (*Lepus townsendii*) populations in the Northern Plains have been in a general decline for the past decade or longer. A suggested reason for this population decline was reduced body condition of individual jackrabbits due to habitat changes. In order to evaluate body condition, we determined the kidney fat index of 314 white-tailed jackrabbits harvested in 44 counties throughout South Dakota. We removed and weighed kidneys and all perirenal fat associated with the kidneys from collected jackrabbits. We measured kidney weight to determine times of high metabolic activity as indicated by an increase in mass. Body condition was assessed by measuring the amount of kidney fat within each collected jackrabbit. Seasonal fluctuations were evident in average kidney weight and kidney fat for both sexes of white-tailed jackrabbits. The kidney fat index in both male and female peaked in winter and was near 0% in summer. We believe that changes in body condition as indicated by the kidney fat index were related to the onset of breeding season rather than availability of food resources.

Key Words: kidney fat index, kidney weight, South Dakota, white-tailed jackrabbit

INTRODUCTION

Estimating the nutritional status of a wildlife population by using condition indices is an important step in wildlife management. Kidney weight and related fat have frequently been used as an index of physical condition in mammals (Caughley and Sinclair 1994; Garant and Crête 1999) as fat reserves influence the probability of survival (DeCalesta et al. 1975; Garant and Crête 1999). Perirenal fat is easily accessible and measurable while producing a wide scale of values under regular environmental circumstances, and is considered to be a reliable indicator of body condition (Caughley 1970; Flux 1971). Riney (1955) proposed using a kidney fat index (KFI) as a measure of physical condition for mammals. The KFI

is based on the assumption that the amount of perirenal fat is a reliable indicator of total body fat (Van Vuren and Coblenz 1985). The KFI has been accepted as a satisfactory means of rating body condition (Caughley 1970; Monson et al. 1974), although decreased predictability of very low KFI values is recognized (Ransom 1965; Finger et al. 1981). The kidney fat index can be used as a measure of seasonal trends in condition for a variety of ungulates (Ransom 1965; Blood and Lovaas 1966; Batcheler and Clark 1970; Caughley 1970; Bear 1971; Monson et al. 1974; Dauphine 1975; Van Vuren and Coblenz 1985; Takatsuki 2000; Oosthuizen 2004; Spinage 2008), for opossums (*Didelphis virginiana*) (Bamford 1970), and for several leporids (Flux 1970, 1971; Martin 1977; Pepin 1987; Parkes 1989).

Flux (1971) found the kidney fat index to be useable in examining hares (*Lepus capensis* and *L. europaeus*), in which kidney fat deposits are the largest in the body. Henke and Demarais (1990) found that the kidney fat index was a good indicator of short-term nutritional stress in black-tailed jackrabbits (*L. californicus*). However, no data have been published regarding the kidney fat index in white-tailed jackrabbits (*L. townsendii*). While conducting an ecological study of white-tailed jackrabbits in South Dakota, we had the opportunity to examine a large number of individuals. We examined distribution, home range, reproductive information, and nutritional status. An objective of this research was to determine seasonal kidney weight and body condition of white-tailed jackrabbits using the kidney fat index, which we report on here.

MATERIAL AND METHODS

We collected white-tailed jackrabbits in 44 counties throughout South Dakota from August 2004 to September 2005 (Fig. 1). We attempted to collect 15–20 jackrabbits each month using a .22 caliber rifle in isolated areas of each county between 1600 and 2200 hours. All specimens were fitted with an individual ear tag, placed in a plastic bag, and frozen for later examination. All research conducted on jackrabbits was approved by the South Dakota State University Institution's Animal Care and Use Committee.

We estimated the ages of collected jackrabbits using the epiphyseal closure method (Hale 1949; Lechleitner 1959; James and Seabloom 1969). We used X-ray analysis (0.15 second exposure time) to determine epiphyseal closure in the left or right humerus. Jackrabbits were classified into two age classes based on the amount of closure observed on the proximal epiphysis of the humerus. In juveniles (2–12 months) the epiphyseal area had a definite groove or was at least visible. In adults (over 1 year old), there was no evidence of an epiphyseal line (Lechleitner 1959).

We removed and weighed kidneys and all perirenal fat associated with the kidneys from collected jackrabbits. We measured kidney weight to determine the average increase in mass throughout the year. If kidneys were damaged in the collection process, those jackrabbits were omitted from examination. We assessed body condition by measuring the amount of kidney fat within each collected jackrabbit. The KFI was calculated as (total kidney fat weight) / (kidney weight) \times 100, and expressed as a percentage (Riney 1955) for each specimen. We calculated the overall average KFI for both sexes for each season.



Figure 1. White-tailed jackrabbit in northeast South Dakota. Photograph courtesy of Bob Losco, Conservation Officer, Webster, SD.

We used two sample t-tests to detect any differences in kidney weight between age groups and sexes ($\alpha = 0.05$). We pooled 3 months of data for seasonal calculations and comparisons as follows: summer (June–August), fall (September–November), winter (December–February), and spring (March–May). Since the kidney fat data were not normally distributed, we transformed the data using the square root of the original data for analyses.

RESULTS

We collected 314 white-tailed jackrabbits and were able to estimate age for 264 individuals. There were 171 jackrabbits classified as adults and 93 classified as juveniles. We could not use 21 of the specimens because the kidneys were damaged during collection. We examined 243 (126 male, 117 female) white-tailed jackrabbits with undamaged kidneys to determine monthly and seasonal fluctuations in kidney weights and for calculation of the kidney fat index (Table 1).

The average female kidney weight (9.32 g; SE = 0.17) was not different from average male kidney weight (7.92 g; SE = 0.15) ($t_{241} = 1.31$, $p = 0.19$). There was no difference in average kidney weight between adult (8.04 g; SE = 0.22) and juvenile males (7.58 g; SE = 0.31) ($t_{124} = 0.35$, $p = 0.55$) or adult (9.77 g; SE = 0.28) and juvenile females (9.23 g; SE = 0.35) ($t_{115} = 0.71$, $p = 0.48$), so we pooled adult and juveniles for other data analyses.

There were seasonal differences in average kidney weight for females ($F_3 = 2.83$, $P = 0.042$). The average kidney weight was higher in spring (9.99 g; SE = 0.32) than in summer (8.76 g; SE = 0.33), but there were no differences for fall (9.58 g; SE = 0.31) or winter (9.57 g; SE = 0.27) (Table 2). There were also differences in seasonal average kidney weight in males ($F_3 = 3.58$, $P = 0.016$). Average

TABLE 1
MEAN KIDNEY WEIGHTS (g) OF WHITE-TAILED JACKRABBITS FROM SOUTH DAKOTA, 2004–2005

Month	Male			Female		
	Adult	Juvenile	Kidney wt. (SE)	Adult	Juvenile	Kidney wt. (SE)
2004						
Aug.	10	7	7.63 (0.29)	14	11	9.04 (0.5)
Sept.	2	5	8.02 (0.18)	1	4	9.28 (0.85)
Oct.	1	2	9.18 (0.6)	2	2	9.72 (0.99)
Nov.	2	4	9.06 (0.98)	2	2	10.48 (0.05)
Dec.	4	3	9.43 (0.29)	3	4	10.02 (0.39)
2005						
Jan.	6	3	7.14 (0.24)	6	1	8.76 (0.51)
Feb.	9	0	8.56 (0.41)	10	0	9.83 (0.42)
Mar.	12	0	7.23 (0.1)	11	0	9.89 (0.41)
Apr.	22	0	8.61 (0.16)	10	0	10.31 (0.51)
May	3	0	9.62 (0.26)	1	0	8.03
June	4	2	7.21 (0.57)	3	3	8.91 (0.89)
July	5	5	6.12 (0.31)	2	4	7.28 (0.62)
Aug.	4	2	7.81 (0.42)	4	6	8.85 (0.63)
Sept.	4	5	7.71 (0.54)	4	7	9.29 (0.44)

TABLE 2
SEASONAL MEANS FOR KIDNEY WEIGHT (g) AND ASSOCIATED KIDNEY FAT (g)
IN WHITE-TAILED JACKRABBITS IN SOUTH DAKOTA, 2004–2005

	Male		Female	
	Kidney wt. (SE)	Kidney fat (SE)	Kidney wt. (SE)	Kidney fat (SE)
Summer	7.20 ^a (0.21)	3.45 ^a (0.88)	8.76 ^a (0.33)	1.72 ^a (0.42)
Fall	8.30 ^b (0.32)	10.00 ^b (1.12)	9.58 (0.31)	9.81 ^b (1.22)
Winter	8.29 ^b (0.26)	27.67 ^c (2.87)	9.57 (0.27)	39.50 ^c (3.55)
Spring	8.20 ^b (0.37)	15.04 ^b (2.86)	9.99 ^b (0.32)	16.02 ^b (2.40)

Note: Within columns, *a* is significantly different than *b* or *c*; *b* is significantly different than *c*.

kidney weight was lower in summer (7.20 g; SE = 0.21) than in fall (8.30 g; SE = 0.32), winter (8.29 g; SE = 0.26), and spring (8.20 g; SE = 0.37) (Table 2).

Perirenal fat reserves fluctuated monthly and seasonally in both sexes (Table 2). Female kidney fat was seasonally different ($F_3 = 61.37$, $P < 0.001$). Winter fat deposits (39.5 g; SE = 3.55) were higher than during any other season, and summer fat deposits (1.72 g; SE = 0.42) were lower than the other seasons. There was no difference between fat deposits in fall (9.81 g; SE = 1.22) and in spring (16.02 g; SE = 2.40). Male kidney fat was

seasonally different ($F_3 = 19.10$, $P < 0.001$). Winter fat deposits (27.67 g; SE = 2.87) were higher than any other season. Summer fat deposits (3.45 g; SE = 0.88) were lower than the other seasons. There was no difference between fall fat deposits (10.00 g; SE = 1.12) and spring fat deposits (15.04 g; SE = 2.86). KFI for both sexes gradually rose from summer to fall. There was a peak in winter for both sexes. Female KFI peaked in January and male KFI peaked in February. The kidney fat index for both sexes regressed in spring and was low again in summer (Fig. 2).

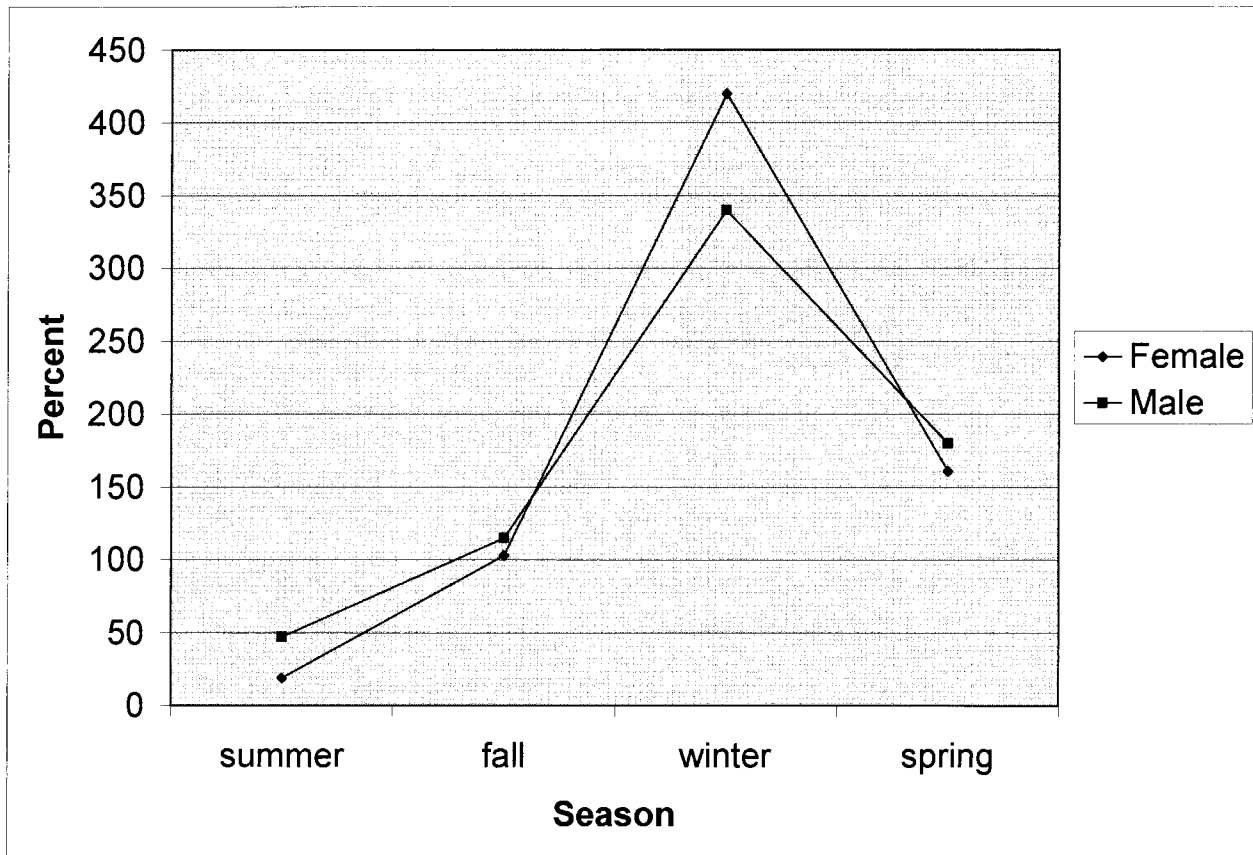


Figure 2. Seasonal differences in kidney fat index for white-tailed jackrabbits collected in South Dakota in 2004–2005.

DISCUSSION

Although sexual dimorphism occurs in white-tailed jackrabbits (Lim 1987), we found that mean kidney weight for females did not differ from mean kidney weight of males. We also found no difference in kidney weights between juveniles and adults. There was little seasonal variation of average kidney weights except during summer, when kidney weight was lowest in both sexes. Flux (1971) found a similar seasonal variation of about 10% in the kidney weight of hares in New Zealand. The extreme heat as well as the stress of reproduction occurring during summer may have inhibited normal activity, resulting in lower average kidney weights.

Jackrabbits are unlikely to carry excess fat at any time since they are subject to predation (Lim 1987). However, both sexes of white-tailed jackrabbits in South Dakota retained more perirenal fat during winter months. The KFI for both sexes steadily increased from fall to winter. The male KFI peaked in February while females peaked

in January. Individual jackrabbits had high fluctuations in seasonal fat deposition, with a KFI of 100%–270% during winters and a low of 0% during summer. Similar to our findings, the KFI of both males and female European rabbits (*Oryctolagus cuniculus*) was maximal in winter and minimal in summer (Boyd and Myhill 1987). In Scotland, the KFI of the mountain hare (*L. timidus*) peaked late in winter in both males and females (Flux 1970). In contrast, Flux (1971) found that hares in New Zealand showed little seasonal variation in fat depositions.

In South Dakota, fat in white-tailed jackrabbits started to accumulate in late autumn or early winter rather than in summer when food is plentiful, indicating that jackrabbits had sufficient nutrition. White-tailed jackrabbits in South Dakota were found to be highly productive, with 3–4 litters per year (Schaible 2007). With inadequate nutrition, white-tailed jackrabbits have decreased reproductive output (Rogowitz 1992).

It is likely that the buildup of kidney fat was related to the onset of the breeding season rather than the availability

of food resources. After peak months, regression in perirenal fat was observed for both sexes, likely due to increased activity during breeding season. As the breeding season progressed, the kidney fat index for both sexes gradually decreased and reached 0% during June, at which point it began to increase again. Throughout the year males gained and lost fat reserves about a month after females. The different patterns in male and female jackrabbits tie in closely with the breeding season, as females are reproductively active a month before males (Schaible 2007). It is clear that fat storage was important for energy during reproduction, especially where early breeding is advantageous. Body fat reserves declined throughout the reproductive season in both sexes, and the steepest decline in the KFI of females occurred during the most productive phase of the season (Schaible 2007). Reproduction in both sexes places demands on stored fat reserves. The decline of fat in late summer may be associated with a reduced capacity to meet the energy demands of reproduction, and in contrast, the onset of reproduction in late winter is associated with attaining maximal body condition.

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HISTORIC AND CONTEMPORARY TRENDS OF THE CONSERVATION RESERVE PROGRAM AND RING-NECKED PHEASANTS IN SOUTH DAKOTA

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ABSTRACT—Over the past century, the interactions between agricultural land use and government cropland retirement programs have affected pheasant population change. Two government land retirement programs that returned croplands to grasslands, Soil Bank in the 1960s and the current Conservation Reserve Program (CRP), help to illustrate these connections. From 2007 to 2010, South Dakota lost 41% of its CRP lands and experienced an 18% decline in pheasants per mile. However, because of where CRP expirations have occurred and where pheasant populations are found, some regional variability is seen. Western South Dakota (Region 1) had an 80% increase in pheasants per mile and a 51% decrease in CRP land, while central South Dakota (Region 2) had a 22% increase in pheasants per mile and a 42% decrease in CRP land. Region 3 saw a 51% decrease in pheasants per mile and a 25% decrease in CRP land, and Region 4 had a 45% decrease in both pheasants per mile and land in the CRP. These differences are explained by regional land use and land cover, the extent to which row crop agriculture dominates each region, and the variability in the abundance of pheasants found in each region.

Key Words: Conservation Reserve Program, pheasants, South Dakota

INTRODUCTION

The ring-necked pheasant (*Phasianus colchicus*), hereafter pheasant, is an economically important species and cultural symbol in South Dakota (Fig. 1). In 2009, 167,000 people hunted pheasants in South Dakota, adding over \$219 million to the state's economy (South Dakota Department of Game, Fish and Parks 2010a). Successfully introduced to the state in 1909 (Switzer 2009b), by 1945 the pheasant population reached 16 million, the highest number on record according to the South Dakota Department of Game, Fish and Parks.

Since then, population has fluctuated as a result of complex interactions between human and natural systems. The two dominant factors affecting pheasants are (1) the natural system of weather and related ecosystem or habitat response and (2) the human land management system that can provide pheasants with ample suitable habitat for nesting, food, and protection from the elements, especially the harsh winter conditions that are common in eastern South Dakota. When weather is fair and habitat abundant, pheasants thrive. When weather is fair and habitat is less abundant, populations can still

be sustained. However, when winter weather produces blizzard conditions and winter habitat is not available for protection, populations can decline precipitously.

In this article I highlight the effects on pheasant populations of weather events, habitat availability, agricultural land use, and government land retirement programs. First, I present a historical summary that details how changes in land management, coupled with weather events, have shaped pheasant numbers since the 1920s. I then focus on what is currently happening in South Dakota, specifically regarding the loss of Conservation Reserve Program habitat, and how those changes have affected pheasant populations.

CONSERVATION RESERVE PROGRAM, WILDLIFE, AND DRIVING FORCES OF CHANGE

The Food Security Act of 1985 established the Conservation Reserve Program (CRP), which has created opportunities for enhancing fish and wildlife populations on millions of private farmland acres (Miller and Bromley 1989). The CRP has been shown to increase abundance and nesting success for many grassland bird species from



Figure 1. The male ring-necked pheasant (*Phasianus colchicus*). Photo by Terry Sohl. Used with permission.

Indiana to Nebraska (Best et al. 1997). In the Prairie Pothole Region of North Dakota, the addition of 1.9 million hectares of CRP land was shown to have added 12.4 million waterfowl to the region in the early 1990s (Reynolds et al. 2001). Other species that have benefited from the increase in CRP land are white-tailed deer in South Dakota (Gould and Jenkins 1993), Henslow's sparrows in Illinois (Herkert 1997), and northern bobwhite quail in Missouri (Greenfield et al. 2002).

Over the past half-century, wildlife biologists have linked habitat changes to decreases in pheasant populations (Patterson and Best 1996; Eggebo et al. 2003; Riddle et al. 2008), while others have studied how pheasants are adversely affected by severe weather events (Nelson and Janson 1949; Kozicky et al. 1955; Martinson and Gron Dahl 1966; Gabbert et al. 1999). Some have looked specifically at the changes in the amounts of CRP lands and how those changes affected pheasants (Riley 1995), and others have investigated negative impacts of the removal of protected lands and adverse weather conditions on upland game species (Erickson and Wiebe 1973; Nielson et al. 2006). Others, taking a social science approach, have investigated changes to local agricultural and recreational (pheasant hunting) economies (Bangsund et al. 2004; Scallan 2008) in the United States and abroad.

Integrated studies of social and natural systems (Lambin et al. 2001; Rindfuss et al. 2004) have revealed new and complex patterns and processes not evident when studied by social or natural scientists *separately* (Liu et al. 2007). With the exception of site-specific studies done mostly by wildlife biologists (Leif 2005; Giudice and Haroldson 2007), little work related to pheasants has

been done in larger geographic areas over longer time frames.

Historic Summary of Pheasant Population Change

Since 1908, South Dakota pheasant populations have gone through boom and bust cycles driven by integrated changes in agricultural policy, land use, and weather. Laingen (2009) explores these population dynamics in greater detail. The following points, referenced in Figure 2, give specific, abbreviated explanations of how these changes have affected historic pheasant populations in South Dakota.

- A. During the Dust Bowl years, long-term drought and economic depression led to abandoned farmland (Trautman 1982); a new land retirement program, the Agricultural Conservation Program, increased grasslands and pheasants flourished.
- B. In 1937, subzero temperatures and 180 cm of snow killed 80% of the pheasant population, yet in only a few years' time, the population rebounded. This is an example of how a devastating weather event can be overcome if habitat in subsequent years is available.
- C. During World War II, tractor fuel was rationed and farmers were sent overseas to fight in the war. Agriculture declined and abandoned farmland and grasslands expanded. Weather conditions were also optimal. Rainfall filled prairie potholes, creating sturdy stands of wetland vegetation needed for winter cover. Pheasant population exploded to an estimated 16 million birds, the highest ever counted (South Dakota Department of Game, Fish and Parks 2010a).
- D. At the end of World War II, soldiers came home and grasslands were returned to cropland. Abnormal spring temperatures (1946) and severe winter weather (1947–48), coupled with habitat loss, increased bag limits, and the hunting of hen pheasants (which ended in 1946), led to a major decline.
- E. Under the Soil Bank Program, cropland was taken out of production and returned to perennial legumes and grasses. Populations quickly increased to an estimated 11 million birds.

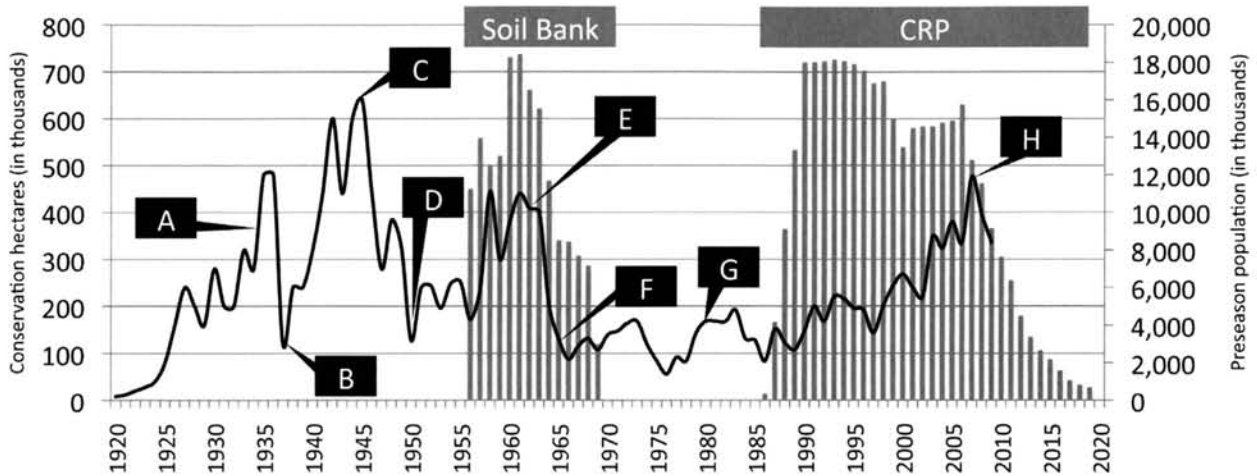


Figure 2. Preseason South Dakota pheasant population (black line) from 1920 to 2009 and total hectares per year of the Soil Bank and Conservation Reserve Program (gray bars), including projected hectares that will expire though 2020. Letters A–H are explained in the section of the text entitled “Historic Summary of Pheasant Population Change.” Sources: Berner 1988; USDA 2008; South Dakota Department of Game, Fish and Parks 2010a. Graph by author.

- F. Soil Bank grasslands were lost when droughts forced haying in the early 1960s. The severe winters of 1964–65 and a blizzard in 1966 killed an estimated 86% of the pheasant population because habitat had been returned to cropland.
- G. Grain exports due to new markets in the Soviet Union and China led to increased cropping, and the U.S. government changed its policy from conservation to production (Hart 1991). A severe blizzard struck in 1975; any headway pheasant population made was diminished due to lack of winter habitat. Fencerow-to-fencerow farming practices kept populations at or near record lows throughout the 1970s and into the early 1980s.
- H. The Conservation Reserve Program was created in 1985 as a federal program to retire highly erodible and environmentally sensitive cropland and pasture in 10- to 15-year contracts (USDA 2010a). Pheasant population rebounded as 6.5% of South Dakota’s croplands were retired. Above-normal springtime rain events in the mid-1990s filled in prairie pothole wetlands, creating habitat. Severe winters in 1997 and 2001 did kill some pheasants, but because habitat was plentiful, numbers quickly rebounded.

Over the past 90 years, pheasant population size has been a function of both human and natural systems. Some of the most devastating losses have occurred when habitat

loss was coupled with some abnormal or severe weather event. Habitat loss may be driven by numerous factors, but as of late, most factors involve reactions to agricultural policies outlined in contemporary U.S. farm bills, specifically land usage related to the CRP.

Contemporary Summary of Pheasant Population Change

Because CRP contracts are normally 10 years long, and because the program started in 1986, we have a good idea of when large tracts of retired grasslands may be coming up for contract renewal. Between 1986 and 1989, South Dakotans had enrolled just over 526,000 hectares of cropland into the CRP. Those same contracts were up for their first renewal between 1996 and 1999. As Figure 2 shows, the vast majority of those acres were renewed, mostly because government payments for CRP contracts (\$23 per hectare) were competitive with what farmers could earn by farming that same land or renting it out (\$22 per hectare) (Janssen et al. 2007; USDA 2008).

Ten years later (2006 to 2009), this is no longer the case. In 2007, farmers in eastern South Dakota could earn, on average, \$26 per hectare on land in the CRP and over \$36 per hectare in cash rental rates (Janssen et al. 2007; USDA 2008). Consequently, South Dakota lost 86,000 hectares, or 14%, of its total CRP acreage in 2007 and 2008 (USDA 2010a). Contracts that expired between 2008 and 2010 added another 214,000 hectares to that total loss. Continued losses could cause a more significant pheasant loss than the 1960s post–Soil Bank decline because today’s

agricultural landscape is much less diverse. Although the new 2008 U.S. farm bill states that it will continue to support the CRP by enrolling 13 million hectares into the program (USDA 2010b), CRP rental payments may not yet be substantial enough to compete with today's cash rental payments and high crop prices.

SUMMER BROOD SURVEYS OF 2008 AND 2009

In the few years since CRP lands have been converted back to cropland in portions of eastern South Dakota, decreases in pheasant numbers have already been seen in the annual August roadside surveys by the South Dakota Department of Game, Fish and Parks (2010b). During these surveys, which begin in late July and continue through mid-August, South Dakota Department of Game, Fish and Parks staff drive, at no greater speed than 32 km per hour, on 110 48-km routes, observing, identifying, and collecting information on all pheasants seen within 0.2 km of the roadway. The objectives of the brood surveys are to "annually determine reproductive success, population trends, and relative densities throughout the pheasant range in South Dakota" (South Dakota Department of Game, Fish and Parks 2010b).

Changes at the State Scale, 2007 to 2009

To see how the current loss of CRP habitat has begun affecting pheasant populations, I mapped the annual roadside survey data from the South Dakota Department of Game, Fish and Parks for 2007, 2008, and 2009 into two maps, one illustrating the change in pheasants per mile (PPM) from 2007 to 2008 and a second showing the change in PPM from 2008 to 2009 (Fig. 3). The circles are placed at the midpoint of each of the 48-kilometer routes driven by department employees (see Fig. 5), and the size of the circles is proportional to the amount of change that occurred.

Though South Dakota lost 146,000 hectares in the CRP in 2007, from 2007 to 2008 the statewide pheasant-per-mile index actually increased by 9% (Switzer 2009a). It was the highest PPM index since the Soil Bank years of the early 1960s. Much of the increase in pheasant abundance occurred in the region near the James River or farther west between the James and Missouri Rivers, where grasslands are common and CRP loss was less pronounced (Fig. 3). It was east of the James River, however, that South Dakota experienced most of its 2007 to 2008 CRP loss. This region of the state has more productive soils and a higher percentage of cropland in row crops.

In areas near Brookings, Watertown, Sioux Falls, and Mitchell, pheasant abundance declined between 17% and 36%, as vital nesting habitat was replaced by cropland.

Weather during 2007 to 2008 was also optimal. Winter conditions were mild, and though heavy snow and blizzard conditions did occur in late March and early April, the events were short lived and little mortality was reported (Switzer 2009a). Significant rainfall events and below-normal temperatures occurred across much of the state in May and early June. However, this only helped to create ideal summer nesting conditions, and precipitation and temperatures during the brood-rearing season were optimal.

A much different story unfolded in 2009. The 2009 statewide pheasant-per-mile index declined by 26% compared to the 2008 survey (Switzer 2010). An additional 45,000 hectares in the CRP were lost in 2008, and in their brood survey report, state wildlife biologists stated that "without a doubt, CRP has helped build and maintain high pheasant densities in South Dakota during the past years" (Switzer 2010), indicating that the current decline in CRP land was linked to pheasant loss. Northeastern South Dakota experienced the biggest impact, losing another 18% of its CRP hectares in 2008 and a total of over 89,000 hectares since 2007.

Losses in the 2009 pheasant population could be the result of lag time, as the effects of CRP losses in 2007 and 2008 were finally made evident. Coupled with habitat loss, the winter of 2008–9 brought normal winter weather conditions back into much of the northern Great Plains. Cold temperatures and persistent snow cover, coupled with a decrease in winter CRP habitat, stressed the importance of ample suitable habitat for South Dakota's pheasants (Fig. 4). Spring 2009 also brought challenges. Below-normal temperatures occurred during the nesting season and early stages of the hatch, which likely decreased chick survival, and locally heavy rainfall events likely resulted in re-nesting attempts, which typically result in smaller clutch sizes.

Changes at the Regional (Multicounty) Scale, 1986 to 2009

State-level population dynamics reveal an association between quantity of CRP lands and pheasant population. While informative, the coarseness of that analysis does not provide an adequate description of both the spatial and temporal variability associated with distribution and quantity of CRP lands or pheasants. To that end, a more detailed, regional-scale assessment is necessary. Brood

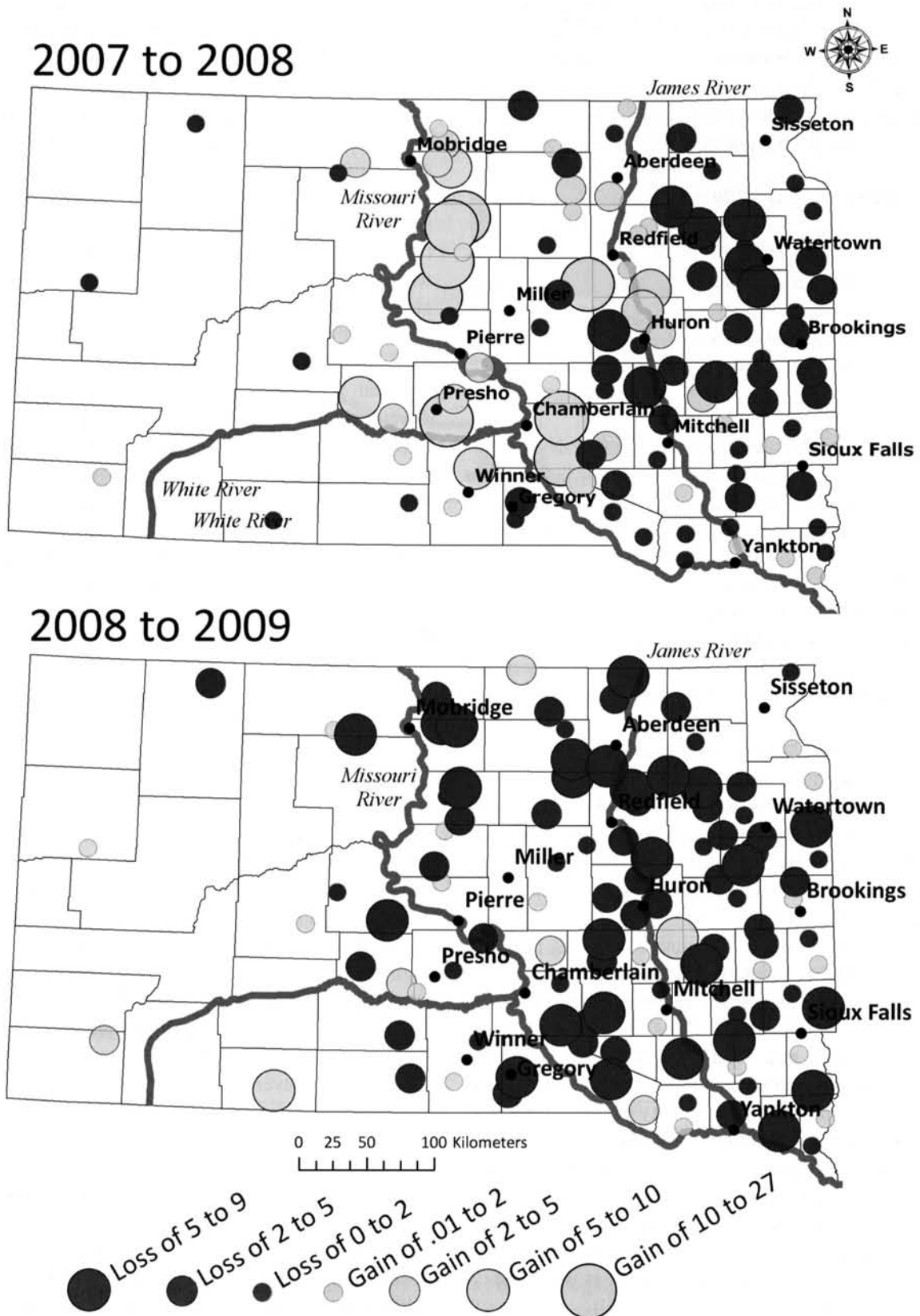


Figure 3. Change in pheasants per mile counted during the August roadside pheasant survey conducted annually by the South Dakota Department of Game, Fish and Parks. Sources: Switzer 2009a, 2010. Maps by author.



Figure 4. A pheasant attempts to seek shelter in a snow-covered harvested cornfield in Kingsbury County, SD. Photo by Wade Harkema. Used with permission.

survey routes cannot be analyzed at a county-level scale. However, according to Travis Runia, wildlife biologist for the South Dakota Department of Game, Fish and Parks, brood route data can be aggregated into the administrative region (multicounty scale) in which each route is located (Fig. 5) (T. Runia, pers. comm. 2010).

Patterns of change found in Region 1 (13 counties in western South Dakota) show that temporal changes in CRP hectares and pheasant counts do not correspond well to one another. This is because (1) Region 1 is large, (2) it contains only five survey routes, and (3) the western part of South Dakota is not and has not historically been a region where pheasants have been found in large numbers. While small pockets of suitable habitat do exist, land cover in this region consists mainly of rangeland (as well as the Black Hills) and shortgrass prairie, and lacks the mix of grassland, wetland, and agricultural land cover preferred by pheasants.

Region 2 consists of 20 counties bordering the Missouri River and its tributaries. Here, pheasants are found in higher numbers, especially in the glaciated areas east of the Missouri River and west of it in the counties of Lyman, Gregory, and Tripp in south-central South Dakota. While CRP lands are an important component of this region's land cover, the diversity of agricultural land cover that is already present (row crops, small grains, wetlands, and pasturelands) diminishes the importance of the Conservation Reserve Program and the overall effects that any loss of CRP land has on pheasants. As the CRP has declined, loss of CRP hectares in this region has not affected pheasants to the extent that it has in Regions 3 and 4.

Regions 3 and 4 are in eastern South Dakota. The physical geography of this portion of the state is unique.

Having been glaciated, these regions contain soils that are conducive to row crops—especially corn and soybeans—and the area planted to corn and soybeans has greatly increased over the past 40 years (Hart 2003:24). Since 1970, over 1.7 million hectares of new corn and soybeans have been planted. This increase in row-crop-intensive agriculture has been shown to be detrimental to pheasant populations not only in South Dakota but also in other states such as Illinois (Warner et al. 1984) and Nebraska (Taylor et al. 1978). It also stresses the importance of long-term government land retirement programs for sustaining pheasant populations.

Here, the connection between decreasing amounts of CRP land and decreasing pheasant populations is more apparent. As shown in Figures 3 and 5, Regions 3 and 4 were the first to see both the large-scale expiration of CRP contracts between 2007 and 2008 as well as the first decline in pheasants. This should not be surprising. With eastern South Dakota having some of the most productive soil in the state, as soon as landowners were able to get out of their CRP contracts in 2007, they did just that. During the following year, the trend of expiring CRP lands continued to become more widespread in Regions 3 and 4 but also continued westward into the eastern portions of Region 2, where initial declines in pheasant populations were also seen.

THE FUTURE

The Dakotas, Minnesota, and Iowa will likely see the biggest decline in CRP lands over the next five years (USDA 2008). In simple terms, as more CRP land disappears each year, all that stands between another post-Soil Bank population crash are consecutive years of increased habitat loss coupled with severe winters that produce high mortality or abnormal spring weather, which influence nesting and breeding success. Results of the 2007–9 pheasant brood surveys suggest the importance of quality habitat for maintaining robust pheasant populations.

Certainly, severe winter weather does levy a toll on pheasants regardless of habitat availability. Winter weather in the 1990s and early 2000s was relatively mild with the exceptions of the severe winters of 1996–97 and 2000–2001, when high levels of pheasant mortality occurred. However, populations rebounded rapidly because of ample breeding and nesting habitat provided by the CRP. Winter weather remained mild into 2007 and 2008, minimizing the short-term effects of the most recent habitat loss. The winter of 2009–10 was a different story. Winter arrived in early December. Arctic air, snowstorms,

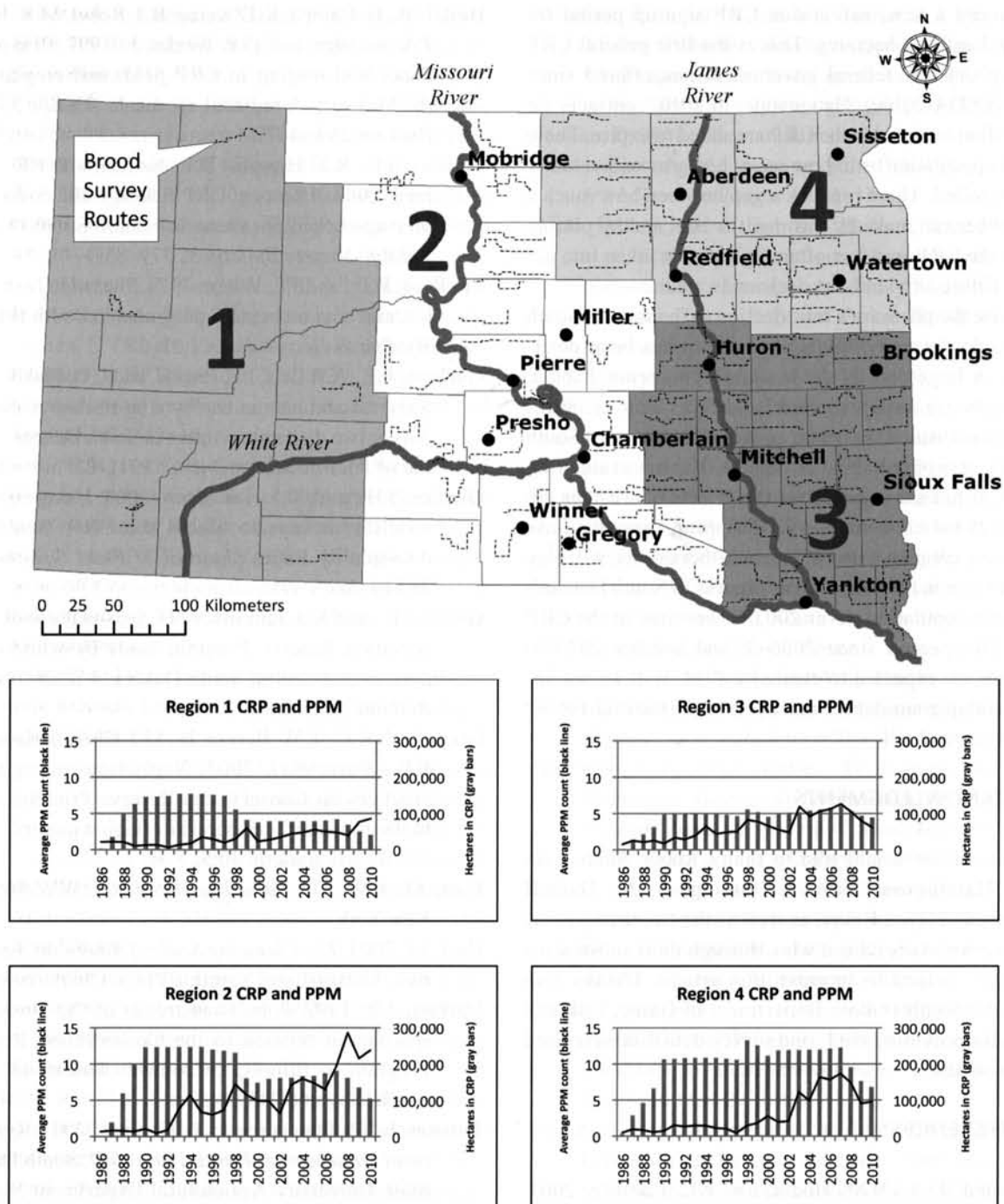


Figure 5. Brood survey routes and administrative regions of the South Dakota Department of Game, Fish and Parks (top). Variation in the relationship between Conservation Reserve Program (CRP) hectares and pheasant-per-mile (PPM) counts by administrative region (bottom). Sources: USDA 2008; South Dakota Department of Game, Fish and Parks 2010a. Maps and graphs by author.

and sleet pounded the state for most of the winter, no doubt raising winter mortality rates above normal. The effects of the winter of 2009–10 can be seen in the eastern regions of South Dakota where pheasants-per-mile numbers continue the declines that began in 2007 and 2008.

While predicted CRP loss may not be as extensive as once thought, regional variations of land use, created by agriculturally driven land-use decisions, will continue to highlight the important role the CRP plays in certain regions within the state. In July 2010 the USDA

announced a new, nationwide CRP sign-up period for nearly 2 million hectares. This is the first general CRP sign-up that the federal government has offered since 2006 (USDA 2010c). Nationwide, in 2010, contracts for 1.8 million hectares in the CRP are slated to expire. There is still speculation as to how many hectares will actually be reenrolled. There remains a gap between how much a landowner can make by farming the land and by putting it into the CRP, and it is often *the* variable taken into account before any land-use decision is made.

Since the pheasant's introduction to the state of South Dakota in the early 1900s, its success has been determined in large part by the availability of prime habitat. Pheasants are extremely hearty and resilient creatures that can withstand the brutal continental climate of South Dakota, *if* proper habitat is present. Habitat availability is key. If habitat is available, the effects of weather are muted. If habitat continues to disappear, those land-use decisions, coupled with extreme weather events, will play a larger role in the year-to-year success of South Dakota's pheasant population. Over 200,000 hectares in the CRP have disappeared since 2006–7, and another 202,000 hectares are expected to expire by 2013. Will we see another collapse similar to what occurred in the mid-1960s? Only time will tell.

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BOOK REVIEWS

Bridging the Divide: Indigenous Communities and Archaeology into the 21st Century. Edited by Caroline Phillips and Harry Allen. Walnut Creek, CA: Left Coast Press, 2010. 290 pp. Photographs, illustrations, maps, notes, reference lists, appendices, glossary, index. \$79.00 cloth.

An outgrowth of demands for ethical treatment and repatriation of their ancestral remains, Indigenous Archaeology (IA) reflects the desire of Indigenous peoples to have a say in how stories of their pasts get told. Too often, Indigenous people claim, archaeologists have discounted oral tradition in favor of scientifically derived histories, histories that may discount or contradict millennia-old beliefs. IA is different, done *for* them, sometimes *by* them, and usually in complete collaboration *with* them. Their questions are central to research agendas and interpretations. IA is controversial because some archaeologists see collaboration as infringement on academic freedom, as movement away from a hard-earned, explicitly scientific archaeology, and as essentializing Indigenous people. Nevertheless, IA has rapidly expanded internationally as part of an effort to decolonize archaeology. Many more Indigenous people have become trained as archaeologists, and those who practice IA have carefully pondered the many epistemological issues it raises.

This volume derives from the World Archaeological Congress's 2005 Inter-Congress on "The Uses and Abuses of Archaeology for Indigenous People" held in Aotearoa/New Zealand. The dozen chapters are wide ranging geographically and provide a solid overview of the status of Indigenous archaeology. In New Zealand, Australia, and North America, for example, Indigenous archaeology has seen nearly two decades of implementation, and scholars are discussing detailed epistemological issues. In most of South America, however, arguments are ongoing about whether it is even a reasonable approach. Most chapters are openly polemical, arguing in support of IA, emphasizing the ways it helps to expand our understanding of the past. The only challenge comes from George Nicholas's excellent chapter in which he argues for an end to IA. He worries that even though IA provides important insights, it is becoming marginalized when it should be seen as central to a discipline that has

experienced an increasing demand for collaboration with stakeholders.

Although none of the chapters in *Bridging the Divide* deal specifically with the Great Plains, some of the earliest IA began in the region during the late 1980s and served as exemplars for the nascent approach. Numerous Great Plains projects continue today due largely to the substantial number of Native Americans living on or near ancestral lands, so issues raised in this excellent volume have relevance for understanding both IA practice and interpretations of its results. **Larry J. Zimmerman**, *Department of Anthropology, Indiana University-Purdue University Indianapolis / Eiteljorg Museum*.

Hell Gap: A Stratified Paleoindian Campsite at the Edge of the Rockies. Edited by Mary Lou Larson, Marcel Kornfeld, and George C. Frison. Salt Lake City: University of Utah Press, 2009. xxiii + 444 pp. Maps, figures, appendices, references, index. \$60.00 cloth.

Every Plains archaeologist has heard of the Hell Gap site. But few could tell you much about it. All that changes with the publication of this needed, dense, thorough collection that chronicles the life and content of this singularly important archaeological site. With 20 papers and 13 appendices, this book takes a monumental step forward in furthering our knowledge of nearly the entire Paleoindian sequence of occupation on the western Plains. Hell Gap is the type site for three Paleoindian point styles: Goshen, Hell Gap, and Frederick, and contains at least six other cultural complexes: Folsom, Midland, Agate Basin, Alberta, Eden/Scottsbluff, and Lusk. All in a stratified and fairly well-dated sequence. There are hints of Clovis, but the jury is still out.

Located in eastern Wyoming, the Hell Gap site was discovered when amateur collector J. Duguid picked up a complete Agate Basin point in 1958 (the first appendix tells his story). Sharing that information led to years of excavation by a virtual "who's who" in the history of Plains archaeology. Previously known by a few short articles and unpublished works, this volume is the first major synthesis of one of the most studied and significant sites in the Plains.

Space does not permit review of every chapter and appendix. The volume has extensive paleoenvironmental

information, with papers on geoarchaeology (Haynes), soil development and structure (Reider; Miller and Goldberg), phytoliths and vegetation (Fredlund), snails (Jass and Mead), and climate (Bryson and Bryson). What is pleasantly surprising is the general agreement in these studies as to the environmental trends that persisted at Hell Gap between about 11,000 and 7,000 BP. The papers are detailed, technical, and challenging—a reflection of the 50+ years that have passed since the early excavations, the ambiguity of deciphering other people's (some now deceased) field notes, the complexity of site stratigraphy, and the ravages of 10,000 years.

Papers devoted to human history include two that chronicle the history of site investigations (Kornfeld and Larson; Knudson), two on faunal analysis (Rapson and Niven; Byers), two papers on microwear (Muñiz; Bamforth and Becker), a review of the Eden component (Kneel, Hill, and Izeta), Cody (Kneel), Frederick (Byrnes), a discussion of site formation (Larson), a chipped stone analysis (Kornfeld), a technological analysis of the points (Bradley) and of point damage and resharpening (Hashizume), and an excellent book summary by Larson (if starting from scratch I'd read this chapter first).

Hell Gap emerges as a repeatedly used short-term camp where game (mostly bison) was processed, tools used and discarded, and local high-quality toolstone obtained. Features seem rare (a few hearths) for a site occupied so long. Though a site of high fidelity, there is some "mixing" of point styles between levels, a situation that engenders considerable explanatory gyrations—omitting, however, the possibility that a single group of people roamed around with slightly variable styles of points, a lesson we need to remember from the Olsen-Chubbuck site.

Hell Gap is an extraordinary site, but one thing about it was quite ordinary—it had been extensively studied but poorly reported. The editors and authors are to be commended for digging into dusty bags and field records of the 1960s and bringing to light critical information on some of the earliest inhabitants of the continent. **Jack W. Brink**, *Royal Alberta Museum*.

Barnum Brown: The Man Who Discovered *Tyrannosaurus rex*. By Lowell Dingus and Mark A. Norell. Berkeley: University of California Press, 2010. xiv + 368 pp. Map, illustrations, appendices, notes, bibliography, index. \$29.95 cloth.

Barnum Brown, born in 1873, was a product of the American West and the homesteading traditions of the

mid to late 19th century. His father was an ambitious, but level-headed, Virginia-born entrepreneur-turned-Kansas farmer, and young Brown grew up on a prosperous farm that employed 31 men. Authors Dingus and Norell highlight a key event in Brown's life when, aged 16, his father took him on an epic four-month trip of three thousand miles by oxcart to see the Old West his parent had known before it passed away forever. As Brown described it, "This was Father's finest gift to me; it was of himself." It seems this trip instilled a life-long sense of wanderlust in Brown, giving him the courage to travel far away from home and the skills to look after himself in remote places. Returning, he enrolled in high school in Lawrence, Kansas, and continued on to higher education at the University of Kansas in 1893.

Originally intending to study engineering, but soon realizing that geology and palaeontology were his calling, he managed to charm his way onto a field expedition in 1894 led by Samuel W. Williston, one of the leading palaeontologists of the day. Brown made a great impression on Williston, and his exemplary field and camp skills led to his being recommended as an assistant on an American Museum of Natural History expedition in 1896. He passed muster with the AMNH field crew, and his fate with the AMNH was sealed. He would remain with the Museum well past his official retirement in 1942 until his death in 1963.

It is impossible to summarize Brown's many accomplishments and adventures in this short review. During his time with the AMNH he traveled extensively in western North America and internationally—Cuba, Mexico, Patagonia (where he survived a ship wreck near Cape Horn), France, England, Turkey, Greece, Ethiopia, Egypt, Somaliland, Arabia, India, and Burma. Fifty-seven specimens he collected now form the foundation for the exhibit halls in the AMNH, not just including dinosaurs, but fossil mammals and invertebrates as well. He returned almost yearly to western North American sites that host thousands of top-quality fossils of backboned animals from the past 280 million years.

The book itself is well written, and follows Brown's life chronologically from birth to death. Along the way, the narrative delves, sometimes quite deeply, into the people and events, both American and foreign, that would have influenced Brown's life and work at the time. The reams of facts, figures, and dates in the book are meticulously referenced using the extensive archives of the AMNH. Brown was notorious for not keeping field notes, and correspondence to and from the field with his bosses, as well as annual reports, are the sources for most of the

details of Brown's life while associated with the Museum. Despite their efforts, the authors lament that aspects of Brown's personal life and personality can really only be glimpsed from the writings of his two wives, his only daughter, and professional colleagues, leaving the man himself still a bit of a mystery. **Donald M. Henderson**, *Curator of Dinosaurs, Royal Tyrrell Museum of Palaeontology, Drumheller, Alberta.*

Paradise Found: Nature in America at the Time of Discovery. By Steve Nicholls. Chicago: University of Chicago Press, 2009. x + 524 pp. Notes, index. \$30.00 cloth.

Covering 500 years in 500 pages, *Paradise Found* details the amazing abundance of the natural world that greeted the first European arrivals to North America. Such a perspective is not wholly original; pre-Columbian biodiversity has been a popular topic of investigation for two generations of scholars. But as filmmaker, entomologist, and author Steve Nicholls explains, past catalogs of plenty have, if anything, underestimated the bounty of the precontact physical world. Explaining in full detail the transition from ecological complexity to fragile instability makes the narrative of loss all the more powerful. *Paradise Found* is short on silver linings. This account is not a celebration of what once was, but a declensionist narrative. As Nicholls explains, European mercantilists arrived on a continent rich in resources, paused for a brief moment, and then went to work. Studying this process does have value, however, as a "deep perspective" on the ecological past can, the author insists, help us better manage our "modern environmental crises."

Paradise Found is arranged by geography, opening on the Atlantic coast and marching forward to a western finish. In each locale, Nicholls begins with an accounting of early exploration and discovery and then shifts to an analysis of environmental exploitation. In all of this, readers focused on the Great Plains will find much of interest. Countering the long-accepted notion that the apparently monotonous landscape of the Plains is marked foremost by a "great stillness," *Paradise Found* reveals a regional ecological mosaic that is "incomprehensibly complicated."

This is a work of synthesis; readers familiar with environmental history, especially the work of Donald Worster, will find little unexpected in *Paradise Found*. What is more welcome is the amount of natural science that informs the narrative. Even a casual glance at his notes reveals that Nicholls has made good use of science

to reconstruct lost environmental worlds. He also does a fine job of explaining the masked connections between environmental destruction and free market capitalism. The operators of New England factories, for instance, ran machines with leather belts made from Great Plains bison, and yet they never saw the ecological or social transformations that resulted from the near extermination of these animals. Nicholls intends his book as a corrective. The idea is to reveal these linkages as a way to show readers how ecosystems really work—an important step in the creation of a balanced environmental ethic. **John Herron**, *Department of History, University of Missouri–Kansas City.*

Nature's Ghosts: Confronting Extinction from the Age of Jefferson to the Age of Ecology. By Mark V. Barrow, Jr. Chicago: University of Chicago Press, 2009. xi + 497 pp. Illustrations, notes, bibliography, index. \$35.95 cloth.

In 1886 William Temple Hornaday realized that perhaps fewer than three hundred bison roamed the Plains. As chief taxidermist for the U.S. National Museum, his reaction was to urge collecting a good series of specimens, up to a hundred if possible. Hornaday's expedition to Montana returned with "twenty-five bison skins, one head skin, sixteen fresh and dry skeletons, fifty-one dry skulls, and two bison fetuses" plus remains of a massive old bull that became the model for the buffalo nickel and the seal of the secretary of the interior. Fortunately, Hornaday also returned with a desire to breed bison and other rare wildlife in captivity. He was instrumental in founding both the U.S. National Zoo and the Bronx Zoo. After some setbacks, he managed to establish a breeding herd at the Bronx Zoo and to send bison back to the wild starting in 1905.

The saving of bison occupies a central place in *Nature's Ghosts*, but Mark Barrow's chronicle extends over a century both before and after. The story starts with Thomas Jefferson and fossils that came to be recognized as mastodons, mammoths, and giant ground sloths. "Jefferson and most of his contemporaries were certain that the natural world was orderly, static, and new." In such a worldview, extinction was unthinkable. Fossil evidence plus the historical extinctions of dodos, moas, and great auks forced reconsideration. Unfortunately, extinction was subsequently viewed as perhaps inevitable for species "past their time." As Hornaday's initial reaction illustrates, collecting rare species frequently happened ahead of efforts to preserve those species. Bison preservation followed immediately, but passenger pigeons and Carolina

parakeets slipped away without any serious attempts at captive breeding.

Extending through the 20th century, *Nature's Ghosts* follows the rise of ecology and conservation biology as disciplines and the construction of institutions to prevent extinction. Science allowed extreme interventions to save California condors and whooping cranes, but was not enough to save heath hens or preserve the Singer Tract for ivory-billed woodpeckers. The book documents that the science of saving species is often complicated, and that the politics is substantially more difficult.

This book ranges across centuries and continents, and only a few parts of it are explicitly about the Great Plains. Nonetheless, it contains valuable lessons for anyone concerned with extinction in the Great Plains and elsewhere. First, the book is a tour de force with nuggets for everyone (e.g., slaves were the first to recognize that teeth dug up in South Carolina resembled those from elephants). Second, the long perspective frames the tasks of the present to be both daunting and doable. The book is full of tales of persistence by both endangered species and dogged individuals. The short view remembers that the Endangered Species Act passed by overwhelming margins in 1973. The book extends our perspective back through two weaker previous Acts and the many occasions of failing to act. Confronting extinction has never been easy, and we should not expect it to become any easier soon. **Peter A. Bednekoff**, *Department of Biology, Eastern Michigan University*.

The Vanishing Face of Gaia: A Final Warning. By James Lovelock. Foreword by Martin Rees. New York: Basic Books, 2009. ix + 278 pp. Figures, references, index. \$27.00 cloth, \$15.00 paper.

I must have been deeply impressed by the fable of *The Ant and the Grasshopper* as a child because I still remember it decades later. The lessons from that tale clearly have been missed by many people these days. Had they been learned and heeded we might not find ourselves in so many environmental and economic messes. Similarly, if we in the U.S. had not seen the so-called Fairness Doctrine manipulated by a few scientists attempting to discredit proven science in the eyes of the public, as documented in Oreskes and Conway's *Merchants of Doubt* (2010), we would seriously be trying with other nations to solve these problems instead of largely ignoring them. Few of us give any thought to how what we are doing to despoil the Earth now will affect humans generations beyond the lives of our grand-

children, if humans happen to be around then. We all are products of our upbringing, and because of that, as Arthur Schopenhauer said, "Every man takes the limits of his own field of vision for the limits of the world." It's so easy to deny there's a problem and ignore all the evidence that there is.

In his latest book, *The Vanishing Face of Gaia*, James Lovelock writes a clear narrative about the major impacts humans are having on the tightly coupled biotic/abiotica system we call the Earth and that Lovelock refers to as Gaia in his many scholarly works. He tells us that this coupled system acts in concert to maintain the Earth's environment at an optimal condition for the organisms that live together here, modifying, for example, the atmosphere so that its composition stays at about 21% oxygen and 78% nitrogen (in the tale of *Goldilocks and the Three Bears* this would be "just right"), with some—but not too much—carbon dioxide, methane, and other greenhouse gases present in the mixture. He points out that part of the problem of recognizing our negative impacts on the system is that, while the data of human-induced increases in greenhouse gases can not be seriously challenged, many of us feel the data are meaningless and should be dismissed without due consideration. He notes that the reports of the Intergovernmental Panel on Climate Change (IPCC) in 2001 and 2007 documented the changes being induced by human activities, but that a demand for a consensus with international political leaders led to the report's being watered down. Seeking consensus instead of accepting the facts and moving to solve problems now is part of the reason we are in this fix.

Lovelock tells us that global warming is a fact supported by data taken from all over the world. He says that even if we accepted this and tried to stop adding greenhouse gases to the atmosphere we would not be able to reverse the trend in the foreseeable future. He evaluates the ideas of green energy and writes that they are unlikely to help decrease warming and may even add to the problem. He comes out strongly for nuclear energy because it does not produce greenhouse gases and expresses his opinion that we were manipulated by opponents of this energy source to prevent its use. Our discovery of fire may have been our "original sin," he asserts, because much of the environmental damage to the Earth's atmosphere can be linked to its use.

If the scenario laid out by Lovelock proves true, what will its probable impact on the Great Plains be? Lovelock tells us that the climate of the lower 48 states will become much more arid than it is today for a prolonged period.

This will have a profound impact on our quality of life and our food production, particularly in those areas of the Plains where very long-term irrigation is not possible. That conclusion does not give those of us who live here now or who will live here in the future much joy, but Lovelock writes that there will be areas where climate change will not be quite so negative and points to Canada as a place where conditions might support a greater human population.

Gaia is in the process of making us pay for our past and continuing profligacy. The Earth and its life will change environmental conditions to achieve a new balance that gives life the best chance of survival. Lovelock believes that we should try to modify our behaviors and accept the fact that humans are likely to have real survival problems in the near future. We should try to “have a future in communion with our living planet to make her strong again and able to counter the disabling impacts that are due.”

This is an important work. I encourage readers to examine its data and Lovelock’s arguments and conclusions with an open mind. **R.F. Diffendal, Jr.**, *Conservation and Survey Division, School of Natural Resources, University of Nebraska–Lincoln*.

A Dry Oasis: Institutional Adaptation to Climate on the Canadian Plains. Edited by Gregory P. Marchildon. Regina, SK: Canadian Plains Research Center, University of Regina, 2009. xiii + 318 pp. Maps, figures, tables, index. C\$34.95 paper.

A Dry Oasis examines past and potential future climate challenges on the Canadian Plains. The book provides extensive discussion, data, and analysis of challenges related to water supply and management within the South Saskatchewan River Basin (SSRB). Past challenges, experiences, and institutional responses are described and used to frame possible future adaptation pathways under expected future climate change. The book provides an excellent grounding in the historical settlement and development of the SSRB, paying particular attention to the ways that the economy, society, and institutions have adapted in response to climatic variability.

Water management and the different institutional arrangements that exist to manage water resources across the western provinces of British Columbia, Alberta, Saskatchewan, and Manitoba are described and contrasted in chapter 4. Chapter 8 presents a detailed look at potential future climate scenarios for the area and couples these with stream flow models to provide predictions of water

supply and stream flow. Possible areas of vulnerability as a result of water and climate stresses are also identified. Several chapters examine the potential effectiveness of current institutional arrangements for water management under the predicted future climate. A recurring theme is that current water management institutions within the SSRB are diverse, with differing strengths and weaknesses. It is likely that all forms of water governance will need to adapt their ideas about water management in response to predicted future climates and changes in water supply, timing, and variability.

Chapter 5 suggests a framework that could be used to identify what “good water management” is by embracing a wide variety of viewpoints and ideas. The final chapters provide case studies describing how some local communities have tried to adapt their institutions, water management, and economies to climate stresses (such as drought) in more recent times. Their stories and experiences provide lessons with broad-reaching impacts for future adaptation to climate change. **Siân Mooney**, *Department of Economics, Boise State University*.

The River Returns: An Environmental History of the Bow. By Christopher Armstrong, Matthew Evenden, and H.V. Nelles. Montreal: McGill-Queen’s University Press, 2009. xi + 488 pp. Maps, graphs, illustrations, appendix. \$49.95 cloth, \$34.95 paper.

This book should be read more as a collection of essays on a wide variety of topics related to the Bow River than as a monograph. Each of its thirteen chapters examines an aspect of the history of human interactions with the river, ranging from ranching, forestry, hydroelectricity, and irrigation to urban sanitation, recreational fishing, flooding, and park building. The Bow River is amenable to a discussion of such diverse themes. Its headwaters are among the glaciers of the Rocky Mountains in Banff National Park, but it also flows through the ranching country of the foothills, the major urban center of Calgary, Alberta, and fertile but semiarid plains. Thus, the river has been subject to a wide range of anthropogenic modifications that, according to the authors, left it “altered by but not destroyed.” Reflecting developments in environmental history, the authors argue that the Bow River is a “joint project of nature and human culture.”

Most readers of *Great Plains Research* are likely to find the book’s organization convenient. Any chapter can easily be read in isolation. But a book covering many aspects of the history of a river over such a long time

frame is bound to have lacunae. The role of the Canadian Commission of Conservation in early debates over hydroelectricity, for example, is neglected, and the authors do not explain the National Parks Branch's dramatic shift from supporting the construction of hydroelectric dams in Banff National Park in 1912 to opposing such projects during the 1920s. Incomplete citations in the chapter on hydroelectricity make it difficult to locate the archival sources referenced. Nevertheless, the volume offers a valuable addition to the scholarship on the topics of its chapters. Those on forestry and conservation, sanitation projects, and the emergence of "recovery narratives" in the 1970s and 1980s are particularly perceptive.

Environmental historians may be disappointed with the book. Only those interested in the Bow River specifically are likely to read it entirely. The authors, according to their preface, chose their title because they wanted "to stress the circular relationship between the inhabitants of the Bow valley and the river. What is carried downstream comes back. Acted upon, the river invariably returns the consequences of those actions in ways that cannot be avoided." However, they never really elaborate on this vague argument. It is possible to glean an implicit narrative, progressing from relatively passive uses of the river by Native peoples, fur traders, and early ranchers to conflicts between engineers and proponents of aesthetic parks, to the emergence in the mid to late 20th century of "a 'designer' view of nature that privileged . . . recreation," but also sought "a balance between use . . . and respect for natural processes." The authors endorse the benefits of this project for fishing and "green" power. Had the book been organized differently (perhaps chronologically), however, or had its authors written a longer and more interpretively original introduction, its potential impact on environmental history could have been much larger. Thus, the book should be welcomed as a valuable collection of essays on aspects of the history of the Bow River, but not as a model monographic environmental history of rivers. **Ted Binnema** and **David Vogt**, *Department of History, University of Northern British Columbia*.

The Ecology and Management of Prairies in the Central United States. By Chris Helzer. Iowa City: Published for the Nature Conservancy by the University of Iowa Press, 2010. xiii + 216 pp. Map, photographs, illustrations, table, charts, appendices, bibliography, index. \$29.95 paper.

This relatively short book is an informative and easy-to-read account of the author's philosophy and advice

on how to manage prairies in the Central U.S., an area corresponding to the eastern portion of the Great Plains where tall- and mixed-grass prairie occurred. With fragmentation and huge losses of this region's natural prairie habitat, there is a growing appreciation for active management of remnants and prairie restoration. This book provides an excellent introduction to this topic.

Its 11 chapters are arranged into two main sections on prairie ecology and prairie management, respectively. The 56-page section on prairie ecology is an up-to-date primer that describes plant and animal communities, disturbance, the importance of diversity and heterogeneity, and the landscape context of the region's prairies. Although much of the material is fairly basic, the last two chapters in the section on diversity/heterogeneity and landscapes set the stage for the management section that follows. As Chris Helzer notes repeatedly, a goal of prairie management and restoration is to enhance biodiversity. Prairies are not homogeneous areas at any spatial or temporal scale of resolution, and any restored or remnant prairie must be viewed in the context of the landscape in which it sits.

The 100-page section on prairie management—which includes chapters on adaptive management, design strategies, management considerations (i.e., burning and grazing approaches), wildlife considerations, invasive species, and restoration—provides a wealth of well-organized information. The author repeats the mantra that the goal of management and restoration is to enhance and maintain as high a level of biodiversity as possible. I agree. Helzer says numerous times that more details are available elsewhere or that managers should consult with local practitioners for their own particular situation. True, but it is a bit annoying to be told this so often.

The book includes extensive appendices with additional information on grazing, prescribed fire, and introduced species, as well as a list of state contacts, selected extra resources, a list of common and Latin plant names mentioned in the text, and a comprehensive index. The volume is attractively produced with numerous excellent color photographs.

Overall, I enjoyed reading Helzer's work, as will others interested in prairie management and restoration. **David J. Gibson**, *Department of Plant Biology, Center for Ecology, Southern Illinois University Carbondale*.

The Tallgrass Prairie Center Guide to Prairie Restoration in the Upper Midwest. By Daryl Smith, Dave Williams, Greg Houseal, and Kirk Henderson. Iowa City: Published for the Tallgrass Prairie Center by the University

of Iowa Press, 2010. xxi + 301 pp. Photographs, illustrations, maps, tables, charts, glossary, scientific terms list, references, index. \$27.50 paper.

Tallgrass prairie restoration in the Upper Midwest is the focus of this guide. Its geographic area of coverage includes the eastern fifth of South Dakota and Nebraska and northeast Kansas, a region some ascribe to the eastern Great Plains. Two types of prairie restoration are dealt with: prairie reconstruction, which the authors define as creating prairie from scratch on sites where prairie plants no longer exist; and prairie remnant restoration, defined as upgrading degraded existing prairies. The book comprises five sections: "Reconstruction Planning," "Implementing Reconstruction," "Prairie Restoration and Management," "Special Cases," and "Native Seed Production." There are 16 chapters, each written by one of the four authors, an approach that leads to some duplication.

For those wanting to restore prairie, this guide provides thorough coverage of all aspects of restoration ranging from seed collecting and planting to postplanting management. It is also replete with details on restoration methodology. For example, anyone seeking instruction on how to operate a seed drill will find it here. The volume is well illustrated with black-and-white photos demonstrating equipment and methods.

The authors promote a rather rigorous, labor-intensive approach to prairie restoration. They recommend seed cleaning, high seeding rates, drill planting, and postplanting annual weed control. Throughout the Midwest many prairie restorationists now follow a much less meticulous methodology with success. They do little seed cleaning, broadcast plant (which is much faster than drill planting), and do little if any follow-up weed control (in regions with less precipitation weed growth is less robust, perhaps mitigating the need for postplanting weed control). Many restorations are large, some a few hundred acres in size, and restorationists simply don't have the time or funds to follow many of the methods recommended here.

I disagreed with some of the authors' specific recommendations on restoration methodology. For example, they state that one should not broadcast plant seed on snow or ice as this exposes the seed to wind erosion and predation. Some of our best, most diverse plantings have resulted from broadcast planting onto snow. The sun quickly melts the seed into the snow, even hard snow, providing ideal conditions for cold, moist seed stratification. They also recommend drill planting 20 grass and sedge seeds per square foot for typical restorations. This is a fairly high grass seeding rate, especially when drill

planting. Many restorationists now promote low grass seeding rates as the quick-to-establish warm-season grasses compete with, and limit, the establishment and growth of forbs (wildflowers).

Overall, this manual is a useful addition to the literature on prairie restoration. It can provide good guidance, but restorationists should always experiment as local conditions, such as climate and soils, can influence the success of specific restoration methods. **Gerry Steinauer**, *Nebraska Natural Heritage Program, Nebraska Game and Parks Commission*.

The Tallgrass Prairie Center Guide to Seed and Seedling Identification in the Upper Midwest. By Dave Williams. Iowa City: Published for the Tallgrass Prairie Center by the University of Iowa Press, 2010. x + 118 pp. Map, photographs, drawings, glossary, index. \$14.00 paper.

Individuals doing tallgrass prairie plantings and restorations often struggle to identify seedlings because most identification resources require the presence of flowers. Anyone who has spent much time working with plants, however, knows that seedlings can often be identified if you have the experience to spot identifying characteristics. What has been lacking is a resource that organizes and presents these characteristics in an easy-to-use format, allowing identification of seedlings by individuals lacking extensive experience. This is that resource.

This book will please both practitioners of prairie restoration and more general prairie enthusiasts. It includes 72 grass and forb species, and the focus is clearly on species often found in tallgrass prairie plantings in the upper Midwest. The grasses and forbs are presented separately here, and for each group a morphological key is provided to divide the species into "Key Characteristic Groups." Because these groups are based on morphological similarity, species within a group are often—but not always—closely related.

To facilitate broad use, the author has kept jargon to a minimum. When specific terms are necessary, they are defined in the brief glossary and either illustrated or clearly displayed in the photographs associated with each species. The result is a clear, easy-to-follow identification guide.

Information on each species includes three to four photographs showing the seedling as a whole, closeups of the leaf, stem, or both (or sheath, for grasses), and the seed. Seed photographs were taken on a ruler to show size, and sometimes include more than one seed in order to display the seed itself and the seed with the hull or pappus intact.

In addition, each entry includes a bullet-pointed list of identifying characteristics, a written description of seedling emergence and early development, a list of similar species highlighting key differences, and a description of germination and growth patterns. However, one of the book's few shortcomings is its only occasional information on how seedling characteristics change with age, limiting its usefulness in identifying older plants.

Short and highly portable, the book covers the most common species in plantings. The only thing that would have delighted me more would have been having this type of information on even more species. Overall, this is an excellent resource, and one I look forward to using often.

H.L. Hillhouse, *Department of Agronomy and Horticulture, University of Nebraska–Lincoln*.

Gasoline, Diesel, and Ethanol Biofuels from Grasses and Plants. By Ram B. Gupta and Ayhan Demirbas. New York: Cambridge University Press, 2010. xiv + 230 pp. Illustrations, tables, reference list, index. \$75.00 cloth.

Any discussion of biofuels today must match the seriousness of the economic implications of U.S. dependence on foreign oil. The U.S. now imports nearly 60% of its oil consumption at great and growing costs. As global oil production nears its peak, oil is now over \$90 dollars per barrel and projected to continue to increase, up from ~\$20 per barrel in 2000. The cost of foreign oil consumed 2.7% of U.S. gross domestic product in 2008 at \$393 billion and contributed 48% to the U.S. trade deficit. Dependence on foreign oil also contributes to economic instability, adds to U.S. debt, and hampers economic growth needed to emerge from the "Great Recession." In these circumstances, biofuels that can efficiently substitute for petroleum-based fuels are of the highest regional and national importance.

A new book on the production of biofuels by Gupta and Demirbas provides technical insight into the conversion processes that could provide a range of domestic fuels from plant materials to substitute for foreign oil. It focuses primarily on conversion processes for production of cellulosic ethanol, Fischer-Tropsch diesel, pyrolysis bio-oil, and hydrothermal biocrude from biomass resources, as well as "first-generation" grain ethanol and biodiesel from vegetable oil. In addition to a detailed summary of these chemical processes, the book provides a briefer treatment of related matters such as biofuel policy, economics, and environmental issues.

The book does discuss the limitations to many aspects of the conversion processes, but does not strive to

identify the main constraints for developing the biofuel industry, nor does it sufficiently emphasize these problems. These limitations are problematic because the U.S. Energy Independence and Security Act of 2007 requires 16 billion gallons of cellulosic ethanol to be produced annually by 2022 (larger than the current U.S. corn-ethanol industry); industry growth, however, is well below mandated levels, as recently reported in the journal *Science* ("Is There a Road Ahead for Cellulosic Ethanol?," August 13, 2010). Technical and economic issues such as the high costs of capital for biomass pretreatment and biomass burning as well as the high and uncertain costs of enzymes for conversion of biomass to ethanol (also mentioned in the book) have restricted industry growth for this primary "second-generation" biofuel. The other non-first-generation biofuels discussed are at similarly insignificant levels of production, or have not been commercialized on a large scale.

Because of high production costs, abundant and inexpensive biomass feedstocks such as crop and forestry residue will be developed first. Among the possible second-generation biofuels, federal and private funding have recently gone predominantly to the use of corn residue for ethanol production. Great Plains grasses have variable and low yields and will likely be one of the last biomass resources to be developed for advanced biofuels. Furthermore, research has shown that continuous high productivity grassland needed for biofuel production will require much higher levels of nitrogen fertilizer applications than assumed by many observers, and these systems will likely also encounter challenges in harvest, transport, and storage. The Great Plains receives limited attention in this book, and the references cited concerning projected biofuel production in the region are likely overly optimistic.

There are formidable challenges in developing a profitable, competitive, and sustainable large-scale second-generation biofuel industry, and it is unlikely these challenges will be easily and rapidly solved, although many hope otherwise. **Adam J. Liska**, *Departments of Biological Systems Engineering and Agronomy and Horticulture, University of Nebraska–Lincoln*.

620 Wild Plants of North America: Fully Illustrated. By Tom Reaume. Regina, SK: Canadian Plains Research Center, University of Regina, 2009. 784 pp. Maps, illustrations, glossary, references, index. C\$80.00 cloth.

Beautifully and profusely illustrated with the author's black-and-white drawings, the 12-year project that

became this book shows his love for plants. Tom Reaume focuses on a representative selection of primarily native vascular plants of the Great Plains of Canada and the northern United States found in forests, lakes, prairies, rivers, and wetlands. The book appears to be designed as a supplement for an introductory course in plant taxonomy.

The volume is well organized, making it easy for the beginning botanist as well as professionals to find a family, genus, or species of interest. After an introduction, the main text is divided into three major groups: Pteridophytes, Gymnosperms, and Angiosperms; Angiosperms are subdivided into Dicotyledons and Monocotyledons. Within each subgroup families are arranged alphabetically, and within each family alphabetically by genus and species. There are 89 plant families represented by at least one species. The 17 largest plant families have a "Family Characteristics" page highlighting, with illustrations, characters that help identify that family. Each species has a detailed profile. For Angiosperms this includes a sketch (basic description of the plant and its habitat); extensive descriptions of the flowers, fruit, leaves and stem; and labeled illustrations of the plant, plus its various reproductive and vegetative structures. There is a distribution map centered on the Great Plains for each species, and synonyms are given for many species. The book also provides a large reference section, a glossary, and an index of both common and scientific names.

The richly detailed and numerous illustrations are much appreciated since some floras recycle older illustrations or limit or forgo them owing to constraints of funds and space. Reaume has made a commendable effort in gathering information from numerous sources to compose detailed distribution maps for each species. There are some omissions—for instance swamp thistle and hairy wood-rush occur in Iowa. Thirty-four species of *Carex* are covered, which is impressive since many selective regional floras like this book include only a few species in this genus, or none.

This book is a useful reference for those interested in the flora of the northern Great Plains and adjacent regions. I highly recommend it for college and university libraries where botany and biological illustration classes are taught on campus. The accurate, beautiful, and profuse illustrations are worth the price of the book by themselves. **Mark J. Leoschke**, *Wildlife Bureau, Department of Natural Resources, Des Moines, Iowa*.

Pieces of the Plains: Memories and Predictions from the Heart of America. By John Janovy, Jr. Lincoln, NE: J&L Lee Co., 2009. iii + 187 pp. Drawings, notes, sources. \$21.95 paper.

John Janovy, Jr., author, parasitologist, and Varner Professor of Biological Sciences at the University of Nebraska–Lincoln, describes his book as "sort of a memoir, but one in which experience is the main character, instead of the writer." Janovy divides this experience into three sections describing his past, his present, and humanity's future.

He writes about aspects of his (and his wife Karen's) childhood in Oklahoma in the section on the past, providing snapshots of people's lives as a way of representing the Plains. Along with these come insights, such as why watchmakers are found in mountainous Switzerland and not on the level Plains.

In the section describing the present, Janovy discusses a range of topics from lenses (his life spent looking through microscopes and binoculars), to campus politics, to a selection from his recent novel *The Ginkgo: An Intellectual and Visionary Coming-of-Age* (2009) that provides a unique perspective on the life of a college-educated young woman who's part of a Nebraska Sandhills ranch family.

In the future section, Janovy talks less about the Plains and more about his perspective on modern science and the relationship between science and politics. He goes on to examine "What is a Human Being" from a biological and sociological perspective and concludes by speculating about the future of human civilization, predicting that in 2,000 years humans may return to an agrarian-dominated culture, lacking in fossil fuels, perhaps more similar to life in the first century CE than in the 21st.

As "Pieces" in the title suggests, the book is something of a Janovy sampler, containing various specimens of the author's popular writing. His use of the term "Plains" is broad, encompassing martinis and unlimited horizons, marine kelp and barrel racing, intensive care units and cattle branding, as well as the war in Iraq and culture wars. The Plains may look rather simple and idyllic from the author's photograph on the book's cover, yet Janovy's writing portrays many of the region's complexities and tensions.

Janovy the teacher is never far from each chapter's storyline. Describing his central theme as "education in the broadest sense, a constant learning derived from exploration of things and places," he sets out in the book's pages to engage in a discussion of big ideas just

as he does in his classroom. Janovy's love of teaching is evident throughout and ought to inspire other college and university teachers. **Mark Hammer**, *Department of Life Sciences, Wayne State College, Nebraska*.

Raptors of New Mexico. Edited by Jean-Luc E. Cartron. Albuquerque: University of New Mexico Press, 2010. xvi + 710 pp. Photographs, illustrations, maps, appendices, glossary, references, index. \$50.00 cloth.

As a raptor specialist, I eagerly look forward to the publication of state and regional books on birds of prey, typically rich with hard-to-find locally flavored information on distribution and biology. With the publication of *Raptors of New Mexico*, my home state has joined the ranks of the handful of states blessed with such volumes, and in fine form. This is an impressive work both in size and content, but the first thing anyone will notice are the photographs—hundreds, most top-notch, many capturing moods, scenes, and places unique to New Mexican raptors. In many ways the book is a showcase for the 109 or so photographers who contributed images, but there is much more here than gorgeous pictures.

Raptors of New Mexico includes chapters on the 19 species of Accipitriformes, five species of Falconiformes, and 13 species of Strigiformes that regularly occur in New Mexico, as well as a single chapter covering seven additional raptor species considered casual or accidental. Each species chapter includes sections on distribution (with detailed range maps), habitat associations, nesting, diet and foraging, predation and interspecific interactions, status and management, and references. In addition, the book contains introductory chapters on New Mexico's vegetation and floristic zones, the taxonomic classification of the state's raptors, raptor morphology, a concluding statement on the health of New Mexico's raptor species, and a series of appendices presenting data cited in chapters but not available elsewhere. I would have liked an overview chapter on raptor biology and demographics, but it's hard to complain given how much this book, the collective work of 41 authors, does offer.

Of particular interest to those working in the Great Plains are chapters on the Mississippi kite (*Ictinia mississippiensis*), Swainson's hawk (*Buteo swainsoni*), ferruginous hawk (*Buteo regalis*), rough-legged hawk (*Buteo lagopus*), golden eagle (*Aquila chrysaetos*), American kestrel (*Falco sparverius*), merlin (*Falco columbarius*), prairie falcon (*Falco mexicanus*), barn owl (*Tyto alba*), western screech-owl (*Megascops kennicottii*), burrowing owl (*Athene cunicularia*), long-eared owl (*Asio otus*), and

short-eared owl (*Asio flammeus*), all species that come to mind when I think of prairies and their associated forested riparian corridors. Roughly a third of the eastern part of New Mexico is short grass prairie, and chapters covering the above species are packed with detailed observations and information on their biology on the state's prairies. The New Mexico flavor and focus make these accounts less suitable as comprehensive species references, but they more than make up for that in detail and local knowledge that cannot be found elsewhere.

I highly recommend this book to anyone with an interest in New Mexican raptors, but it is a must-have for the serious birder or scientist working with birds of prey in the Great Plains. **Brian A. Millsap**, *U.S. Fish and Wildlife Service, Southwest Region*.

Whooping Crane: Images from the Wild. By Klaus Nigge. College Station: Texas A&M University Press, 2010. vii + 217 pp. Map, photographs. \$45.00 cloth.

When asked to review this book I hadn't yet heard of it or its author, a wildlife photographer well known in his native Germany and the author of four photographic books published there, so I was eager to read it. The book is visually impressive, measuring 11" x 12", making it a true coffee-table production. Inside is a well-written 25-page "primer" on whooping cranes by Krista Schlyer dealing with cranes in myth and legend, crane vocalizations and displays, and breeding biology. She also provides a brief survey of the whooping crane's population history, its near brush with extinction, and the mostly failed efforts since the 1970s to establish additional wild populations. A dozen suggested readings and some relevant websites are also provided.

The heart of the book consists of more than 150 spectacular single- and double-page color photographs obtained at the cranes' wintering grounds in and near Aransas National Wildlife Refuge in Texas and at their breeding grounds in Canada's Wood Buffalo National Park. Nigge is the first professional still photographer ever to be allowed to photograph a pair of Wood Buffalo's whooping cranes during the hatching period. This endeavor meant spending six days and nights alone in a cramped photo blind and enduring all the attendant hardships for a once-in-a-lifetime opportunity to document the experience visually.

The operative word here is visually. Throughout the entire portfolio of amazing photographs, there is not a single caption. In nearly all cases there are white borders around the photos, which would have allowed space for

captions that provided at least the fundamental elements of who, what, where, and when. For example, the wonderful series showing juvenile cranes through their first winter are not dated, making it impossible to track the progression of postjuvenile molt in these birds. Several other species shown interacting or associating with the whooping cranes (sandhill crane, black-bellied whistling duck, American avocet, white-tailed deer, gray squirrel, peccary, blue crab) are not identified. Such omissions mean that this gorgeous volume missed the opportunity of providing substantial educational value, in addition to offering an unwritten testimony to the beauty of a magnificent endangered species and its fragile environment. **Paul A. Johnsgard**, *School of Biological Sciences, University of Nebraska–Lincoln*.

Cougar: Ecology and Conservation. Edited by Maurice Hornocker and Sharon Negri. Chicago: University of Chicago Press, 2010. xiv + 306 pp. Maps, illustrations, figures, tables, appendices, references, index. \$49.00 cloth.

Historically, cougars (mountain lions, pumas, or panthers) had an extensive distribution throughout the Americas, ranging from British Columbia in North America to Patagonia at South America's tip. As a native species and a large obligate carnivore, the cougar has a complex relationship with the human population in the Americas. This current book—the product of multiple authors, all with hands-on experience in cougar work, and written in a clear manner appropriate to most audiences—is an important addition to the scientific literature in the field of carnivore conservation in the New World.

As a product of many authors, *Cougar: Ecology and Conservation* reads more like a textbook than a monograph, each author contributing from his or her expertise, an essential element for a volume covering diverse topics. Most chapters provide an instructive overview of the concepts later discussed in depth, an invaluable feature for the nonbiologist. Many of the authors include excellent scientific literature reviews, providing an extensive resource for readers interested in expanding their knowledge or consulting original works mentioned in the chapters.

Part 1 of this four-part book discusses the history of cougars in the Americas as it relates to cougar evolution, human perception of cougars, and the evolution of cougar management. Cougars at the population level are the focus of part 2, with chapters covering populations in North America and two separate chapters offering insights into the current situation in South America. Insights into the

South American populations are particularly valuable to our knowledge of cougar conservation since many studies conducted in South America are published in Spanish and consequently missed by much of the North American scientific community. Part 3 moves from the population level to species and individuals, providing an excellent overview of studies conducted on behavior, social organization, diet and prey selection, cougar–prey relationships, and competition with other carnivores.

The final part investigates conservation approaches in cougar management and the challenges faced as a consequence of increasing human expansion and its pressures on natural cougar habitat. In addition to examining the importance of cougars as part of the ecosystem and their behavior with and without human presence, this section also reviews the politics involved in making decisions regarding cougar management and the history of changing views within both the general public and government.

Since it deals with ecological concepts and practicalities involved in large carnivore management in relation to the complexities of today's human population, *Cougar: Ecology and Conservation* provides a valuable resource for those interested in large carnivores in general as well as the cougar in particular. **Oranit Gilad**, *Balanced Ecology Inc., Kempner, Texas*.

The Leadership of George Bush: An Insider's View of the Forty-First President. By Roman Popadiuk. College Station: Texas A&M University Press, 2009. xvii + 227 pp. Photographs, notes, index. \$45.00 cloth.

Roman Popadiuk had close and steady access to George H.W. Bush for most of his presidency. He served as the president's deputy assistant and press secretary for foreign affairs and was later appointed U.S. ambassador to Ukraine. He is now the Executive Director of the George Bush Presidential Library Foundation.

Popadiuk presents Bush 41 through varied lenses: his early life, leadership principles, public messaging, diplomacy, working with congress, and the 1992 campaign. Through a collection of anecdotes on each topic, the reader gets a sense of the president's values and his management style. According to Popadiuk, Bush's guiding values are his Episcopalian faith, his devotion to his family, and the importance of friendship. Barbara Bush explains that, for her husband, "it is better to have a friend than an enemy."

In terms of Bush's leadership, Popadiuk explains that Bush 41 is guided by the importance of standing up for your beliefs, telling the truth, being loyal, communicating

well, sharing the credit, and showing your human side. Contrary to prevailing notions of what went wrong for Bush in the 1992 election, Popadiuk blames the campaign staff for the loss, noting that Bush's anxiety during the campaign "pointed to the general lack of coordination and planning that seemed to grip the campaign."

The chapter on Bush's early adult life focuses primarily on the Great Plains. As a teenager attending Phillips Academy in Massachusetts, he was deeply impressed by Tolstoy's *War and Peace*. Instead of going straight to Yale after prep school, he joined the U.S. Navy and became their youngest pilot. Bush was shot down over the Pacific, earning him three Air Medals and the Distinguished Flying Cross. "After the war, Bush was determined, despite the privilege from which he came, to build his own life and shape his own future." So he moved from New England to West Texas. The young Bush couple initially toyed with the idea of becoming farmers after reading Louis Bromfield's novel, *The Farm*, but instead pursued oil exploration. Barbara Bush recalls their move to Texas as "an adventure," and Bush 41 considers himself a Texan to this day.

The Leadership of George Bush is infused with a sentimentality exemplified by the book's opening statement describing the Bushes' emotional response to Bush 43's election to the presidency: "George Bush sat straight up, his back rigid but his chest heaving slightly as he sought to hold back tears. Barbara Bush sat quietly, unmovable, a glint of satisfaction and pride sparkling in her eyes." Despite the author's proximity and long-time affiliation, the book provides scant new information about Bush 41's presidency, mostly because the author fails to connect it with larger literatures on presidential leadership and executive management. Instead, it is a rosy peek at Bush 41 from a loyal subject still enamored with his former boss. **Caroline Heldman**, *Politics Department, Occidental College*.

Kansas Politics and Government: The Clash of Political Cultures. By H. Edward Flentje and Joseph A. Aistrup. Lincoln: University of Nebraska Press, 2010. xxiv + 263 pp. Illustrations, maps, tables, appendices, notes, index. \$70.00 cloth, \$30.00 paper.

Prior to the publication of *Kansas Politics and Government*, there was no essential book on Kansas politics, policy-making, and institutions. Now there is. It's as simple as that. Anyone who wants to understand the Sunflower State's politics should start here.

Most prosaically, this is one more in the Nebraska Press's ambitious series of single-state studies. But Ed

Flentje and Joe Aistrup (disclaimer: I write a column for Kansas papers in rotation with them and two other political scientists) have done more than cover the breadth of the state's politics. In their emphasis on political cultures, they provide an effective way to think about Kansas politics and government over almost 150 years of statehood.

The initial chapter lays out a theoretical approach that emphasizes the competing threads of liberty, order, and equality as central to the Kansas experience. Flentje and Aistrup note the various facets of these elements, which often pop up in unexpected, but complementary, ways. Thus, populists and progressives desire certain kinds of order, including governmental reform and prohibition, while the members of the business community seek predictability for investment and entrepreneurial activities. The authors make a real contribution in their consideration of contemporary conservatives, mostly within the Republican Party, as "bipolar" in their simultaneous embrace of economic liberty and of order on social issues such as abortion.

Books in this series face the difficult task of covering the whole of state government, while placing it within a fifty-state context. The authors do a good job here, all the while providing a real sense of what's singular about the state. For example, Republicans have always dominated Kansas politics; given that dominance, however, parsing the nature of the party's strength over time is crucial. Indeed, Democrats have occupied the governor's office for more years than Republicans since 1957, while never capturing a U.S. Senate seat in that period.

The authors bring to their enterprise more than enough academic literature for the book to be useful for all students of state politics; for history buffs, it offers a start and a host of suggestions for further reading.

There are some curious omissions, which are hard to avoid in such a work. No mention is made of the 2005 creation of a new independent agency, the Kansas Health Policy Administration, which was a partisan political response to Governor Kathleen Sebelius's executive reorganization proposal for Medicare/Medicaid. More surprisingly, Flentje and Aistrup do not address the issues raised by Thomas Frank's *What's the Matter with Kansas?* (2005), the most famous recent book dealing with the state. They clearly diverge from Frank's economic determinism, but Frank does generate some useful data and well-done interviews, which might have informed the arguments here.

In the end, this is an impressive performance, and *Kansas Politics and Government* ranks as one of the best in the Nebraska series. For understanding Kansas and the

politics of the Plains more generally, it should be required reading. **Burdett A. Loomis**, *Department of Political Science, University of Kansas*.

Compact, Contract, Covenant: Aboriginal Treaty-Making in Canada. By J.R. Miller. Toronto: University of Toronto Press, 2009. xiv + 379 pp. Maps, illustrations, notes, bibliography, index. \$85.00 cloth, \$35.00 paper.

Indian treaties are still being negotiated in Canada, giving the treaty-making process there an immediacy far removed from the much more narrowly historical and legal significance these documents have in the United States. Indeed, Congress, in 1874, simply enacted a law ending treaty making, a highly political act, intended both to limit the power of the Senate, but also to deny implicitly that Indian nations were, in fact, nations.

Canada, for the most part, also stopped making treaties after the “numbered treaties” of the prairies in the late 19th century, but because British Columbia, the Yukon, and most of the Northwest Territories had no treaties, various First Nations land claims tied the use of much land there for decades, resulting in a renewed treaty process toward the end of the 20th century that still continues. In addition, because the Canadian north is so vast, many of the Indian peoples there were not represented at treaty meetings and claim to live on unsurrendered Aboriginal land. Even the Plains peoples, represented in the numbered treaties, are demanding a renegotiation of those treaties based on claims of fraud, corruption, or duress.

In Canada, the term First Nations explicitly recognizes a nation-to-nation relationship between the Crown and the original inhabitants of North America that requires treaty making as the primary political and legal process for the taking of Indian lands and the incorporation of Indian nations into the multinational Canadian state. There are great political difficulties embodied in this process, including the continued impoverishment and marginalization of the First Nations, and the repeated failure of successive Canadian governments to carry out their responsibilities under these treaties, but the treaty process remains the required process.

J.R. Miller, perhaps Canada’s leading scholar of Aboriginal history, takes on an ambitious project, a sweeping history of treaty making in Canada with the express goal of making this process understandable to all Canadians in order to promote interracial reconciliation. This is an ambitious book, the first history of treaty making in Canada intended for the general reader as well as for academic historians.

The complexity of the undertaking is obvious. Not only is each treaty-making situation unique to the time, place, and peoples involved, but over almost 400 years of history the social, political, cultural, and legal meaning of the process evolved. Perhaps more importantly, each treaty-making process involved at least two distinct peoples, one of European origin and the other an Indigenous people, with distinct languages, cultures, and understandings of the process. Any scholar who works with Indigenous peoples has heard many different “treaty stories” that describe a particular people’s understanding of one treaty. Miller does the best he can with this, but any history of a Euro-Canadian legal process, essentially English in law and politics, overrelies on these Euro-Canadian sources. All the standard questions are dealt with in the book: “How did Indigenous peoples understand the complex language of these treaties?” “Did the Crown induce the First Nations to sign by outside promises?” “How were the treaties translated?” “Were the Indians present representative of the people whose lands were surrendered?” But in the end, the answers are still incomplete.

Much of this “gap” between the language of the treaties and the reality of Canadian politics and law resulted from 100 years of various government efforts to force assimilation of Indigenous peoples across Canada. In this process, the Canadian government violated all of the treaties in both language and spirit. The result can be seen on any Indian reserve in Canada. The various First Nations stories of the dishonesty, incompetence, and corruption of the treaty process will not end with this book. Still, as Miller reminds his readers in the concluding chapter, “we are all treaty people” and Euro-Canadian property rights derive from the legality of the treaty process. It is the treaty process that incorporated the First Nations into Canada, and neither the Indigenous peoples nor the Euro-Canadian are going anywhere else. **Sidney L. Harring**, *School of Law, City University of New York*.

Canada’s Indigenous Constitution. By John Borrows. Toronto: University of Toronto Press, 2010. x + 427 pp. Notes, index. \$80.00 cloth, \$35.00 paper.

Thanks to the driving force of *Canada’s Indigenous Constitution*, John Borrows’s studies of Indigenous peoples’ laws will now be more publicly known. While we might have thought his earlier books reached the limits of creativity regarding Indigenous issues in North America (and Canada in particular), his new work demonstrates that such an assumption would have been wrong.

This text's major thesis, that "Canada cannot presently, historically, legally, or morally claim to be built upon European-derived law alone," has been mentioned before. Yet in those earlier musings by Borrows and others, such a statement has never been documented so well as it is here. Borrows contemplates that others, besides those sympathetic with Indigenous perspectives, might just admit such a thesis is the case. Moreover, they might also support the creation of social and economic policies that demonstrate such a belief. But observing it in Canada's current legal system—really? Keenly aware of skeptics, Borrows has thought as much about his method as his content. As a result, he trumps other authors by using the proverbial "master's tools" to take down the "master's house," revealing to us that the Canadian legal system is, first and foremost, imbued with Indigenous law. The problem, he simultaneously details, is that too many people do not interpret it as such.

His method is the following: introduce the places one can find Indigenous law, then detail these places in an advanced way, followed by observations about Indigenous law in (non-Indigenous) common and civil law systems; then acknowledge the problems that arise due to these systems' interplay; identify the actual multijuridical nature of Canada's interpretation of the "rule of law"; explain how courts and legislatures can encourage the multijuridical nature to protect democratic values; notice how religion also influences what everyone considers the fair treatment of individuals and groups; and, finally, predict how Indigenous norms can help address future (and inevitable) problems in our society. Clearly, Borrows wants to allay any fears about Indigenous perspectives being foreign, unhelpful, or illegal. The strongest quality of *Canada's Indigenous Constitution* is the number of ways Borrows finds to show how Indigenous practices are alive and well and have already proven useful to non-Aboriginals who have worked to make North America more domestically governable and more internationally enviable.

Borrows wants us to realize Indigenous ways are not that different—religions, private property, and positivism are apparently part of many Indigenous cultures. At the same time, he argues the Earth is a legal personality in law, he envisages "Recognition Acts," he believes non-Indigenous judges are not incapable of empathizing with Indigenous concerns, and he contends that some of the academic sources touted as the most accurate (and Borrows does not use subtlety here) actually *hinder* proper legal analysis today. Jurisprudence interpreters beware: if you believed only cases that clearly mention "Aboriginal rights" are about Indigenous constitutionalism, Borrows

demands you think again. This Anishnaabe legal scholar uses history, courtroom events, and legislative prerogatives assertively (yet respectfully) to inform you that a more advanced understanding of the past and of law is required. By the time you finish the book, meeting characters like "Mandamin" along the way, it is likely you won't disagree.

Borrows concludes that the law is "a peaceful, vicious being" and will eventually expose your contradictory values if you choose not to eliminate your inconsistent authoritative methods (like most interpretations of Canadian law). The book tells us we are approaching an intellectual and jurisprudential abyss, and it is about time we make a quick turnaround—the rule of law demands it. **Signa A. Daum Shanks**, *College of Law, University of Saskatchewan*.

Aboriginal Title and Indigenous Peoples: Canada, Australia, and New Zealand. Edited by Louis A. Knafla and Haijo Westra. Vancouver: UBC Press, 2010. vi + 267 pp. Notes, bibliography indices. C\$85.00 cloth, C\$32.95 paper.

This volume contains a number of intelligent, insightful essays that, as a collection, are meant to offer comparative perspectives on Aboriginal title issues in Canada, Australia, and New Zealand. A relatively limited number of the essays actually engage in direct comparison, although David Yarrow's examination of the place of Indigenous jurisdiction in Australia and Canada, Kent McNeil's scrutiny of the source and content of Indigenous land rights in Australia and Canada, and Louis Knafla's superb introduction are welcome exceptions. Most of the other chapters frame a set of comparisons by engaging with issues in a single jurisdiction, although some are also devoted to specific topics farther removed from the book's main thrust. Many of these are nonetheless interesting, and there are chapters by seasoned academics as well as new writers in the field. Significantly, the book crosses disciplinary boundaries: law, history, anthropology, and other disciplinary approaches are represented, with some chapters addressing the intersections of these disciplines.

Because of its emphasis on Aboriginal title and associated issues, the collection bears on the Great Plains more implicitly than directly, with the exception of a piece by Japanese academic Kenichi Matsui on negotiations around Aboriginal water rights on the Canadian prairies in the early 20th century. Nonetheless, the book's indirect bearing on the Great Plains remains largely relevant, with perspectives on general issues concerning the foundations

of Aboriginal title and discussions of the very nature of judges' engagement with Indigenous rights relating indirectly to Indigenous rights in the Great Plains region.

Although *Aboriginal Title* does not state the point directly, its papers had their origins in a conference held at the University of Calgary in 2003. A seven-year delay from the authors' first engagement with the themes to the time of publication is unfortunate, despite the fact that there has obviously been some serious effort at updating and including subsequent literature. The papers are nonetheless framed somewhat in the mindset of a few years ago or end up focusing on adjudicated cases from the early 1990s. Sophisticated though their comments are, delayed dissemination of academic work is unfortunate.

Overall, this collection offers a welcome contribution to the growing literature on comparative Indigenous rights frameworks. Its essays will be of interest within academic and nonacademic contexts, and it should help stimulate further thinking that crosses national and disciplinary borders while addressing issues of interest to the Great Plains. **Dwight Newman**, *College of Law, University of Saskatchewan*.

"I Thought Pocahontas Was a Movie": Perspectives on Race/Culture Binaries in Education and Service Professions. Edited by Carol Schick and James McNinch. Regina, SK: Canadian Plains Research Center, University of Regina, 2009. xxi + 191 pp. Notes, references, index. C\$29.95 paper.

This edited volume argues that a race/culture binary lies at the heart of Canada's ongoing relationship with the descendants of the country's First Peoples. In looking at the service professions, editors Carol Schick and James McNinch trouble taken-for-granted assumptions based upon racial, cultural, and ethnic difference, arguing that representations of Indigenous peoples as culturally inferior, a trope that has replaced the idea of biological inferiority, is highly instrumental in the social positioning and unequal power relations that exists today in Canadian society. In turn, the editors tie this discussion back to Canada's colonial history and the social, material, and ideological conditions produced in previous eras.

In comparing "race as biology" to "culture as destiny," the editors refer to the early 20th-century shift in thinking (in large part, the legacy of early ethnographers) whereby culture rather than race comes to be seen as the determining factor in a people's fate. Following Australian scholar Aileen Moreton-Robinson (*Talkin' Up to the White Woman: Indigenous Women and White Feminism*,

2000), who describes the concepts of race and culture as constituting "a priori essential meanings and biological essentialism," the editors make the case that Canada's Indigenous peoples continue to be burdened by these ideas in the 21st century.

There is a definite Canadian perspective offered by authors in areas such as education, health care, and law enforcement. Contributors deal with the problems associated with the "management of difference"; for example, Joyce Green's chapter, "From Stonechild to Social Cohesion," highlights the fact that ongoing colonialism, racism's feeding ground, has yet to be sufficiently named in the Canadian prairie context; hence, the job of dismantling it has yet to begin. Contributors also raise serious questions regarding the push to commodify knowledge in the academy. Andrea Smith speaks to this issue in her chapter "Native Studies Beyond the Academic-industrial Complex," perhaps the most important in the collection given its proffered strategies for countering the domination of the academic-industrial complex and tying the work of decolonization and Indigenous resistance to movement building and collective action for social change at the community level. Smith argues for the need to move past antiracism, or what she describes as "taking power," and into the realm of movement building for sovereignty and social justice—in other words, "making power." She points to instances, for example in Latin America, where this work is already under way.

The scope of this book asks the reader to consider the problems associated with current approaches to addressing social injustice and inequality that rely on race (e.g., antiracism) and culture (e.g., cultural competence). This reminds the reader that the service professions remain too often focused on social justice at the level of the service professional, and too often caught up in the mechanics of overcoming ethnic, cultural, and racial difference, while in the process losing sight of to whom and to what we should be accountable, and also of what decolonization truly means. The book is an important opportunity to begin to reflect upon these much larger ideas. **Tracy L. Friedel**, *Department of Curriculum and Pedagogy, University of British Columbia*.

The Seminole Nation of Oklahoma: A Legal History. By L. Susan Work. Foreword by Lindsay G. Robertson. Norman: University of Oklahoma Press, 2010. xx + 334 pp. Illustrations, notes, bibliography, index. \$45.00 cloth.

In this fascinating and well-documented account, L. Susan Work illustrates how a myriad of federal laws and

legal rulings limited tribal self-government and otherwise sought to dissolve the modern Seminole Nation. Along the way, the former attorney general of the Seminole Nation and a member of the Choctaw Nation explores the legal peculiarities of Seminole history and the ways that the federal government frequently chose to homogenize the Five Tribes into a single legal standard. Dissolution, of course, did not occur, and Work carefully reconstructs the process by which the Seminole Nation capitalized on changes in federal policies and various legal rulings to secure its sovereignty in modern America.

Most of *The Seminole Nation of Oklahoma* examines the meaning and implementation of dozens of treaties, laws, regulations, court rulings, and ordinances. It also details the explanations of various legislators and litigators, as they crafted policies intended to destroy a tribal government and otherwise dispossess the Seminoles of their land and ignore their legal claims. The volume also contains a rich governmental history, exploring 20th-century Seminole Nation–United States relations in depth as well as the dissolving and then ultimate creation of a strong tribal government. As a result, Work provides a standard text for anyone interested in understanding these modern events.

Unfolding chronologically, chapters investigate the history of the Seminoles in Indian Territory (1831–1898), the subsequent period prior to Oklahoma statehood (1897–1907), the struggle to maintain a tribal government (1906–1968), the writing of the Seminole Constitution (1964–1968), and groupings of tribal administrations (1969–1977, 1977–1985, and 1985–1993). Work covers the long-standing struggle with the federal government over mining and land rights (1904–2002) in chapter 3, and the Seminole Claims Cases (about mineral rights, railroads, leases, removal, and other issues) in chapter 4.

As a scholar and vested participant, Work acutely and persuasively offers her personal and intellectual assessments of policies and legal rulings. Hers is a powerful critique. Nevertheless, she struggles to distinguish between the various degrees of merit behind the myriad of Seminole claims against the federal government for not engaging in “fair and honorable dealings.” Instead, all legal defeats occurred despite the evidence and through faulty anti-tribal reasoning. This is a small criticism, though, of an important and compelling book.

By rendering the most informed legal history of the Seminole Nation, Work has provided what will certainly become the standard text for anyone interested in the Seminoles’ struggle for legal sovereignty and the various legal roadblocks erected by the federal government. It is

sure to become necessary reading in Native American legal history and among scholars of the Five Tribes. **Andrew K. Frank**, *Department of History, Florida State University*.

Kiowa Military Societies: Ethnohistory and Ritual.

By William C. Meadows. Norman: University of Oklahoma Press, 2010. xx + 455 pp. Photographs, figures, tables, appendix, bibliography, index. \$75.00 cloth.

No other region of Native North America has been the focus of more scholarly attention to the roles that warfare and conflict have played in Indigenous societies than among those living in the Great Plains. Historians and anthropologists have produced a voluminous literature about the warrior culture as an integral facet of Plains Indian life. While previous studies have examined either general aspects of Plains Indian warfare or provided ethnographic descriptions of Great Plains military societies, no diachronic, comprehensive account of military societies has been undertaken focusing on a single society.

Drawing on over a decade of research, in combination with archival and published anthropological and historical literature, William C. Meadows provides a detailed ethnographic account of Kiowa military societies and their historical development. Employing a perspective spanning from the prereservation era to the present, Meadows describes each military society’s origins, structures, rituals, ceremonies, functions, and associated music, dances, songs, and material culture within the context of the Kiowa military society system. Beginning with Rabbits Society in the first chapter, he graphically portrays the Mountain Sheep Society, Horse Headdress Society, the Black Legs Society, Unafraid of Death or Skunkberry Society, Scout Dogs Society, the Bone Strikers, as well as the Omaha Society and Kiowa Women’s Societies, devoting a chapter to each.

Throughout his study, Meadows not only successfully integrates the wide array of data into a comprehensive examination of each major Kiowa military society, but also elucidates through his extensive fieldwork with Kiowa elders and consultants how the Kiowas feel about their societies and their continuing importance in honoring military service and Kiowa cultural traditions. The final chapter provides a summary of the current role military and dance societies play in Kiowa culture. Over the course of time, as Meadows meticulously details, Kiowa military societies have undergone numerous changes in form, function, and meaning. These changes have paralleled the larger developments and changes that have

periodically altered Kiowa society. Despite changes owing to the forces of history, Kiowa military societies at their core have evolved today into a social mechanism for the perpetuation of Kiowa identity and culture.

Lavishly illustrated with photographs and accompanied by an appendix of society membership since the late 1800s, *Kiowa Military Societies* stands as the most in-depth piece of scholarship concerning the evolution of military societies in a particular Great Plains tribe. The book is a valuable addition, not because it contributes any new, revealing insights or provides a theoretical analysis of the topic, but because it draws together a mass of literature that is meticulously and skillfully integrated. It is its comprehensive, synthetic nature that makes it a significant work. **Gregory R. Campbell**, *Department of Anthropology, University of Montana*.

Immigration and Settlement, 1870–1939. Edited by Gregory P. Marchildon. Regina, SK: Canadian Plains Research Center, University of Regina, 2009. vii + 608 pp. Maps, photographs, figures, tables, notes, index. \$39.95 cloth.

This is the second volume in the History of the Prairie West Series, which focuses on the settlement of the Canadian Prairies by Ukrainian, German, Welsh, Jewish, Dutch, and other immigrants. The collection brings together twenty articles previously published in *Prairie Forum* grouped according to the themes of the early “opening” of the West, First Nations during the settlement era, patterns of settlement, and ethnic relations. An index greatly aids in finding common themes among the diverse topics.

The collection includes articles that made important contributions to settlement history when they first appeared in *Prairie Forum*, such as the 1997 analysis of American immigration by Randy Widdis, R. Bruce Shepard’s 1985 article on the immigration of Blacks from Oklahoma, and D.J. Hall’s 1977 discussion of politician Clifford Sifton’s role in Indian Affairs while a cabinet minister in the Laurier Liberal government. Other more recent articles are stimulating interjections into the conversation about the history of the Canadian Prairies. The opening article by J.C. Lehr, John Everett, and Simon Evans suggests the Canadian Prairies were a diverse cultural and physical landscape often at odds with “the prevailing images of those outside the region.” Jason Kovacs’s article weaves together the colorful personality of Count Paul O. d’Esterhazy and the Hungarian settlement of Esterhazy, later Esterhazy, Saskatchewan, concluding that although

he may not have been the figure he made out to be, Esterhazy was “an important catalyst for early Hungarian and Slavic immigration to Canada.”

The range of time represented when the collection’s articles were written does mean that research and interpretations have, in many cases, moved on. Unfortunately, editor Gregory Marchildon’s introduction provides little in the way of historiographical context for the essays, summarizing and suggesting instead how the articles fit into the collection’s thematic structure. The time frame of the selected articles may also aggravate the preponderance of analyses of patterns, policies, and personalities and the lack of clearer attention to the stories of women, of literary and artistic worlds, and the everyday experience of immigrant settlers. With the exception of a few passing references, the collection also paints the Canadian West as a rural landscape without cities. By 1939, the end date for the volume chosen by the editor, cities were ascendant and an important feature of the economy and culture of the region.

Certainly the collection fulfills its stated aim of bringing together in one place the articles from *Prairie Forum* that explored the history of the Northern Great Plains. The addition of new photographs, illustrations, and an attractive flyleaf will make it a pleasing and useful reference for students and teachers. **Hans Werner**, *Department of History, University of Winnipeg*.

Immigrants in Prairie Cities: Ethnic Diversity in Twentieth-Century Canada. By Royden Loewen and Gerald Friesen. Toronto: University of Toronto Press, 2009. viii + 257 pp. Notes, bibliography, index. \$60.00 cloth, \$27.95 paper.

It is remarkable how the adage “the more things change, the more they stay the same” still applies. This was one of my initial thoughts while reading chapter 1 of *Immigrants in Prairie Cities*. Loewen and Friesen trace the origins of public concern about the adverse influence of immigrants in terms of increased competition for jobs, threats to social cohesion, questioning the loyalties of newcomers at the beginning of the 20th century—issues remarkably similar to the mythology describing immigrants in western societies today. Readers may be tempted to ask, “If the situation in the 1900s is so similar to today’s, why read this book?” Not only will readers get a sense of the longevity of these and other myths surrounding migration, they will learn about the creation of ethnic culture in the prairies and leave with a better understanding of immigration in Canada that is germane

to comprehending current migrant issues. It is a book that all scholars of Canadian migration history should read.

Loewen and Friesen chronicle the growth of ethnic diversity in several prairie communities, but focus most of their analyses on an in-depth examination of Calgary, Edmonton, and Winnipeg, the region's three largest urban centers. Using the concepts of ethnic webs, hybrid cultures, imagined boundary zones, and third spaces, popularized by Clifford Geertz, Edward Said, Homi Bhabha, Frederick Barth, and others, the authors show how new ethnic groups grew and changed the region's urban landscapes. Theirs is not a chronological journey but a thematic one, examining family experience, racism, globalization, gender issues, ethnic associations, religious institutions, and ethnic identities.

The chapters are written in an engaging manner, and even experts on migration history will gain some valuable knowledge. Given *Immigrants in Prairie Cities's* attention to statistical detail, particularly in the early chapters, it would have been useful had the authors included thorough tables outlining the growth of ethnic populations in each center, thereby helping readers understand ethnic contexts and visualize the region's great ethnic diversity with greater clarity. Although refugees are discussed, there is little attempt to examine this group's unique space. Refugees to the prairie region make up a significant portion of the population, and a more sustained attention to their experiences would have strengthened the book's utility.

Finally, the authors may overemphasize the Winnipeg experience, particularly to the detriment of more sustained examinations of Saskatoon, Regina, and even Edmonton. I realize that both Loewen and Friesen reside in Winnipeg, both have considerable expertise in this region, and the city was the region's historical hub, but the attention to this city tends to dominate the text. This, however, is a minor quibble that ought not to detract from the significant contribution their volume makes.

Lori Wilkinson, *Department of Sociology, University of Manitoba*.

Environmental City: People, Place, Politics, and the Meaning of Modern Austin. By William Scott Swearingen, Jr. Austin: University of Texas Press, 2010. x + 273 pp. Photographs, appendix, notes, index. \$50.00 cloth.

Two years ago, I was with friends and their dog on Red Bud Isle, a small dogpark/island in downtown Austin. As Cleo sprinted ahead, unleashed, the bipeds enjoyed the cool evening and lush surroundings. Looking around, I gained the distinct impression that this community had a

deep appreciation for a lifestyle that connected it with the natural environment.

I am not alone in loving Austin's quirky, exciting, and beautiful cultural landscape. But how did it get that way? Who were the players involved, and what were the major forces that made it the thriving metropolis it is? William Scott Swearingen, Jr.'s *Environmental City* is a social history of how a place like Red Bud Isle and the larger city surrounding it could come to exist.

Swearingen opens with the founding of Austin, and takes the reader through the ideals shaping its modern era: the battle between the twin paradigms of "growth" and "green." At its heart, the book tells the story of the success of Austin's green campaign: how "place" was created, fought for, and won. Not all battles were victories, but Swearingen points to key moments, and unpacks the slow process of institutionalizing broad environmental concepts into concrete municipal policies. He identifies the particular moments (e.g., protests, votes, and elections) and ideas (e.g., "The Five Minute Walk") that set this history in motion.

If there are concerns about the book, they are in its intellectual heft and contribution. Molotch's concept of the growth machine, Goffman's *Frame Analysis*, and Zukin's groundbreaking work on place-making are mentioned, but not critically applied or examined, and dropped at the conclusion of chapter 1. Lefebvre's name is given, but his "trialectics" for analyzing place (that there are mental, physical, and social components) is ignored. Because of this lack of conceptual and substantive engagement with the literature, the book isolates the case of Austin, denying important comparative touchstones for the reader: Does Austin's development differ from other, more studied cities? How does Austin's "green machine" compare with social movements elsewhere? (A few references to other urban developments are relegated to footnotes, separated from the book's main discussion.) *Environmental City* lacks a firm conclusion—a natural place for such comparisons and perhaps policy implications—leaving the reader to do the work of contextualizing the findings within a broader literature. It makes the book, unfortunately, feel parochial.

Reservations aside, students of Austin, academic or otherwise, would benefit from the book's contents, for Swearingen does the yeoman's work of identifying just how one of the key aspects of Austin's culture came to be. Although lacking in comparison, *Environmental City* is a good book for reading about how tensions play out in a city other than Los Angeles, Chicago, or New York. There is a great expanse between the coasts, and a good deal can

be learned about Austin's case and applied to cities in the South, the Midwest, and the Plains by activists and urban planners. And, paired with Barry Shank's more riveting tale of the development of the city's music scene, *Dissonant Identities* (1994), a broad picture of Austin can take shape. **Jonathan R. Wynn**, *Department of Sociology, University of Massachusetts–Amherst*.

Weird City: Sense of Place and Creative Resistance in Austin, Texas. By Joshua Long. Austin: University of Texas Press, 2010. viii + 207 pp. Illustrations, notes, bibliography, index. \$50.00 cloth, \$25.00 paper.

Joshua Long makes a fine contribution to the literature on urban places with *Weird City*. It is written in a way that makes it a natural for students of urban geography and an equally solid choice for classes devoted to urban sociology, community organization, urban planning, or public history.

The book provides an in-depth look at the cultural landscape in a specific urban location. In laying out his analysis, Long introduces us to characters that run the gamut from elected officials to neighborhood personalities, as well as some famous and not-so-famous musicians. For me, the material accompanying some of the biographical sketches could have been a bit more detailed. Nonetheless, no sooner is a character introduced than you begin to see how this individual fits into the picture in a very place-specific sense.

The result is a detailed look at one of the Great Plains' more interesting urban places. Long takes the reader on a journey through a myriad of interest groups, all sharing the common characteristic of being locked in a battle over a sense of place. He gives meaning to the notion of "Keep Austin Weird," a phrase so well known in Austin that it eventually became a popular bumper sticker. For me, the standout chapter is "Aliens, Affluence, and Abnormality," which drew me in simply because it focuses on the old-timer-versus-newcomer divide that seems to have voice in so many smaller communities. What Long alerts us to is the same sort of division playing itself out in a much larger context.

The book is well documented and includes a relevant and well-written annotated glossary of terms that is, regrettably, too short.

In sum, Long has given us the sort of writing that appeals beyond the classroom. He has also given us an intimate look at a very subtle yet important aspect of urban life—a sense of urban place. **Sally Caldwell**, *Department of Sociology, Texas State University San Marcos*.

Hollowing Out the Middle: The Rural Brain Drain and What It Means for America. By Patrick J. Carr and Maria J. Kefalas. Boston, MA: Beacon Press, 2009. xiv + 239 pp. Map, notes, references, index. \$26.95 cloth, \$16.00 paper.

"Hollowing out the middle" refers to the loss of the well-educated young adults in rural communities of America's Heartland—the Corn Belt and Great Plains. Declining rural communities invest their meager resources to educate their brightest youth, thereby providing them opportunities for rewarding careers in distant cities. This further contributes to the communities' woes because it guarantees not only population loss, but also loss of expertise and leadership that could help them solve their problems.

Carr and Kefalas's contribution to understanding the dilemma of rural communities promoting and supporting the loss of the best and brightest is through an in-depth analysis of young adults' decisions regarding their futures and the role of local institutions and organizations, especially schools, in developing and reinforcing those decisions. They conducted a case study of Ellis, Iowa (a pseudonym), population 2,014, examining the decisions and actions of young adults who graduated from high school in the late 1980s and early 1990s. Their research identified four paths or types: achievers, stayers, seekers, and returners.

Achievers are identified early in school and receive special treatment in terms of opportunities, encouragement, and support to reach their potential and go on to college with no expectations of returning to the community. Stayers receive little encouragement or support, do not go to college, marry early, and end up in blue collar, low-paying jobs. Seekers also do not receive encouragement or support, but they see little future for themselves in their community. Lacking good grades and financial support to attend a major college, they often see military service as their pathway out.

Returners can be subdivided into high fliers and boomerangs. High fliers are achievers who become disillusioned with big city ambiance and long for simpler small-town life with close friend and family ties. Local and state policy makers actively seek to attract high fliers. Boomerangs, who have much in common with the stayers, are more likely to return, often after a military hitch or community college experience, ready to get on with life. Many ultimately end up on welfare roles. Ellis's educators and leaders were fully aware that their support of achievers was detrimental to the town's long-term

viability, but believed it was their responsibility. Carr and Kefalas suggest it is unconscionable not to provide opportunities and support for stayers. Realistically, stayers are the hope for the future of many rural communities.

This volume is ideal for undergraduate and graduate courses on community, community development, rural development, and rural life to help students understand the problems rural communities face. More importantly, it should be read by all Great Plains school board members

and principals, community leaders, and state policy makers. Great Plains states and communities need to implement creative development strategies that explicitly include enhancing stayers' human capital. Without a major paradigm shift in relation to those most likely to stay in the community, the fictional "buffalo commons" may become "surreal" for much of the rural Great Plains. **Peter F. Korsching**, *Department of Sociology, Iowa State University*.

NEWS AND NOTES

CONFERENCES

July 28–31, 2011

The 74th Annual Meeting of the Rural Sociological Society in conjunction with the Community Development Society will take place at the Boise Center, The Grove Hotel, and Hampton Inn in Boise, ID. The theme for this meeting is “Shifting Boundaries: Rural Diversity and Change in an Urbanizing Society.” For more information, see the website: www.ruralsociology.org.

August 7–12, 2011

The 96th Annual Meeting of the Ecological Society of America will be at the Austin Convention Center, Austin, TX. The theme is “Earth Stewardship: Preserving and Enhancing the Earth’s Life-Support Systems.” Website: www.esa.org/austin.

October 6–8, 2011

The annual meeting of the **Great Plains/Rocky Mountains Division of the Association of American Geographers** will take place in the Department of Geography and Environmental Sciences at the University of Colorado–Denver. Chair: Deborah Thomas, <deborah.thomas@ucdenver.edu>. Website: www.aag.org/cs/events/event_detail?eventId=233.

October 9–12, 2011

The Annual Meeting of the Geological Society of America will be in Minneapolis, MN. The theme is “Archean to Anthropocene: The Past is the Key to the Future.” Website: www.geosociety.org/meetings.

November 13–16, 2011

The 59th Annual Meeting of the Entomological Society of America will be held at the Reno Sparks Convention Center in Reno, NV. The theme is “Identify . . . Clarify . . . Speak Out!” Website: www.entsoc.org.

November 16–20, 2011

The 110th Annual Meeting of the American Anthropological Association will be held in Montreal,

QC, Canada. The theme is “Traces, Tidemarks and Legacies,” words that evoke the shifting and changeable character of differences. Website: www.aaanet.org/meetings/.

CALL FOR PAPERS

March 28–30, 2012

The 38th Interdisciplinary Symposium sponsored by the Center for Great Plains Studies, University of Nebraska–Lincoln, in collaboration with Homestead National Monument of America, National Park Service, will be held on the university campus in Lincoln, NE, and at Homestead National Monument in Beatrice, NE. The theme is “1862–2012: The Making of the Great Plains.”

The federal government acted in 1862 to implement its vision for the development of the Great Plains. Congress passed the **Homestead Act**, the **Morrill Act**, the **Pacific Railroad Act**, and the act establishing the **U.S. Department of Agriculture**. The **Dakota Conflict**, which ended with the defeat and forcible removal of the Dakota, also inadvertently provoked more general hostilities with the Lakotas and Yanktonais. How did these acts and events drive regional development over the ensuing decades in some directions and foreclose it in others? How did they shape the culture, economy, environment, social customs, land use, demography, history, technology, literature, and politics of the Great Plains as well as the nation? How do they continue to have relevance today and in the future?

We invite presentations on any topics exploring the influence of these acts and events on the Great Plains and beyond. Eligible topics include but are not limited to: settlement patterns; gender relations; regional and national literature; university research; urban development; Indian–white relations; land tenure and land use; economic development; impact of railroads; Native American culture; agriculture and conservation; art and culture; natural resources; attitudes, work habits, values; and politics.

The Symposium Committee also invites submissions of proposals for papers, panels, and posters fo-

cusing on the impact of these events on the subsequent historical development of the Great Plains and on its present and future.

Please submit your proposal/abstract of 150–200 words with a brief resume by **NOVEMBER 1, 2011**. SUBMIT ELECTRONICALLY at the website: www.unl.edu/plains using the [Abstract Submission Form](#).

Program co-chairs are Richard Edwards and Mark Engler. Edwards is professor of economics and Center for Great Plains Studies, University of Nebraska–Lincoln. Engler is superintendent of Homestead National Monument of America. Contact the Center through the website at www.unl.edu/plains or e-mail <cgps@unl.edu>.

CHARLES E. BESSEY AWARD

Great Plains Research is pleased to announce that the winners of the Charles E. Bessey Award for the best paper in natural sciences published during the volume year 2010 are Michael J. Keables and Shitij Mehta for their paper, “A Soil Water Climatology for Kansas,”

Great Plains Research 20, no. 2 (Fall 2010):229–48. The annual award includes a cash prize of \$250.

Keables is associate professor of geography at the University of Denver, and Mehta is with ESRI in Redlands, CA.

LESLIE HEWES AWARD

The winners of the Leslie Hewes Award for the best paper in social sciences published in *Great Plains Research* during the volume year 2010 are Richard Edwards and Eric Thompson for their paper, “The Role of Conservation Research and Education Centers in Growing Nature-Based Tourism,” *Great Plains Research* 20, no. 1 (Spring 2010):51–70. This annual award also includes a cash prize of \$250.

Edwards is professor of economics, interim chair of management, and fellow of the Center for Great Plains Studies, and Thompson is director of the Bureau of Business Research at the University of Nebraska–Lincoln.

GREAT PLAINS RESEARCH

A JOURNAL OF NATURAL AND SOCIAL SCIENCES



Western prairie fringed orchid. Photo by F. Adnan Akyüz.

www.unl.edu/plains

EDITOR: Robert F. Diffendal, Jr.

Established in 1991, GREAT PLAINS RESEARCH is a biannual multidisciplinary international journal that publishes peer-reviewed articles on the natural and social sciences of the Great Plains. The journal also publishes book reviews on topics related to the Great Plains. Cash awards are given annually for the best natural science article and the best social science article in a volume year. ISSN 1052-5165.

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- For a book:
Blouet, B.W., and F.C. Luebke, eds. 1979. *The Great Plains: Environment and Culture*. University of Nebraska Press, Lincoln, NE.
- For an article in a book or conference volume:
Wedel, W.R. 1994. Coronado and Quivira. In *Spain and the Plains*, ed. R.H. Vigil, F.W. Kaye, and J.R. Wunder, 45–66. University Press of Colorado, Niwot, CO.



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