Spring 2012

Great Plains Research, Volume 22, Number 1, Spring 2012 (complete issue)

GREAT PLAINS RESEARCH

A JOURNAL OF NATURAL AND SOCIAL SCIENCES

VOLUME 22, NUMBER 1 SPRING 2012

CENTER FOR GREAT PLAINS STUDIES
UNIVERSITY OF NEBRASKA-LINCOLN

Center for Great Plains Studies

THE CENTER FOR GREAT PLAINS STUDIES was established in 1976 by the University of Nebraska Board of Regents to promote a greater understanding of the people, culture, history, and environment of the Great Plains through a variety of teaching, research, and outreach programs. Under the administration of the College of Arts and Sciences at the University of Nebraska-Lincoln, the Center encompasses nine divisions: the Great Plains Art Museum, three academic journals (*Great Plains Quarterly, Great Plains Research*, and *Plains Song Review*), Plains Humanities Alliance, undergraduate and graduate programs, editing projects, research support, outreach programs, interdisciplinary symposia, and Fellows and Associate Fellows.

Great Plains Research

Cover image: Late spring prescribed burn on Nine-Mile Prairie near Lincoln, Nebraska. Photograph by James Stubbendieck, retired Director of the Center for Great Plains Studies and Emeritus Professor of Grassland Ecology, University of Nebraska-Lincoln. See the article by Rhett L. Mohler and Douglas G. Goodin on page 15 in this issue for research on the mapping of burned areas in the Flint Hills of Kansas and Oklahoma.

GREAT PLAINS RESEARCH (ISSN 1052-5165) is published biannually in Spring and Fall by the Center for Great Plains Studies, University of Nebraska-Lincoln.

Articles from Volume 1 through Volume 19 may be found on the UNL Digital Commons website: http://digitalcommons.unl.edu/greatplainsresearch/

Subscriptions per year:
U.S. Individual $25.00; Institutional $50.00
Canada Individual $30.00; Institutional $55.00
other foreign Individual $35.00; Institutional $60.00
Make checks payable to **GREAT PLAINS RESEARCH**
Tel.: (402) 472-3082; FAX: (402) 472-0463
E-mail: cgps@unl.edu
Web page: **www.unl.edu/plains**

Nonprofit standard postage paid at Hanover, PA. **Postmaster: send address changes to** Center for Great Plains Studies, University of Nebraska-Lincoln, P.O. Box 880214, Lincoln, NE 68588-0214. Return postage is guaranteed.

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;
- **overviews** of critical environmental, economic, and social issues for the plains;
- **reviews** of knowledge on important questions and their regional application; and
- **syntheses and cross-disciplinary analyses** relevant to the Great Plains.

Great Plains Research is indexed or abstracted in *America: History and Life, BIOSIS Previews, Biological Abstracts, Environment Abstracts, Historical Abstracts, Geographical Abstracts* and *GEOBASE, Meteorological and Geoastrophysical Abstracts*, and CSA *Sociological Abstracts, Inc.*

The editor encourages those submissions in particular that report general findings in the sciences relevant to this vast region. Articles should include thoughtful reviews of critical scientific findings and issues relevant to the Great Plains, whether the research was done in the Great Plains or not. The key to acceptance will be how well the findings are related to the region, and how well the science is communicated to other scientists outside the specific discipline, in the style of *Scientific American*, for example. The Board of Governors' Publication Committee will select annually the best paper in natural sciences and the best paper in social sciences. The author/s of the winning papers will be presented cash prizes for the **Charles E. Bessey Award** (natural sciences) or the **Leslie Hewes Award** (social sciences).

Scientists doing interesting work with important implications for this region are invited to synthesize their significant research results and present them to our readers. The overall goals are to develop *Great Plains Research* as a centralized outlet for science of regional importance, to communicate important scientific findings to as wide an educated audience as possible, and to help keep scientists, interested citizens, and leaders of this region up-to-date on scientific progress relevant to the Great Plains.

This publication is printed on acid-free 10% SFI certified recycled paper by The Sheridan Press, Hanover, PA.

TABLE OF CONTENTS

BOOK REVIEWS

Great Plains Research 22 (Spring 2012):3–14

IDENTITY, INTEGRATION, AND ASSIMILATION RECORDED IN MANITOBA'S POLISH AND UKRAINIAN CEMETERIES

Lukasz Albanski

Institute of Education Sciences
Pedagogical University of Cracow
Ingardena 4
30-060 Cracow, Poland
lukash.albanski@gmail.com

and

John C. Lehr

Department of Geography
University of Winnipeg
515 Portage Avenue
Winnipeg, MB Canada R3B 2E9
j.lehr@uwinnipeg.ca

ABSTRACT—Polish and Ukrainian rural cemeteries in southeastern Manitoba reflect the process of negotiating complex religious, geographic, and ethnic identities within Canadian society. Before 1914 the identities of Slavic immigrants from eastern Europe to western Canada were influenced more by religious affiliation than by geographic origins. This Slavic population, now assimilated into mainstream Anglophone society, retains elements of Polish and Ukrainian on grave markers as expressions of difference and acts of resistance against total homogeneity. In rural Manitoba grave markers record the process of exogamy and cultural blending, while cemetery landscapes replicate the social relationship between cultural groups from the same region in Europe. Headstone designs reflect economic progress, while language use reveals how ethnic identities were, and are, imagined and expressed.

Key Words: cemeteries, ethnicity, Manitoba, Poles, Ukrainians

INTRODUCTION

Cemeteries and churches are the most visible symbols of ethnic identify in the modern prairie landscape. But as congregations dwindle, prairie churches face an uncertain future of declining use, deconsecration, and abandonment. Cemeteries, however, as places of memory, remain etched in the landscape, the most enduring of sacred places "surrounded by the trappings of remembrance, emotion, and commemoration" (Sayer 2010, 59). Across the Canadian prairies, other elements of pioneer landscapes are fast disappearing. Traces of the multitude of ethnicities that were the hallmarks of prairie rural settlement are becoming ever more rare as rural depopulation and farm consolidation take their toll on the landscape. Even 40 years ago, domestic architecture with roots in a half dozen European countries created a mosaic of distinct landscapes, but today there is scant evidence of cultural diversity, a result of onrushing modernity and the triumph of architectural homogeneity. Nowhere is this landscape transformation more evident than in those parts of southeastern Manitoba settled by people from central and eastern Europe at the dawn of the twentieth century.

CEMETERIES

Scholars from a variety of disciplines have studied the form and meaning of cemeteries (Kong 1999). In the 1960s most studies focused on the cemetery as an artifact of vernacular culture and tended toward description rather than analysis, as folklorists and some geographers catalogued styles of grave markers and noted regional

Manuscript received for review, March 2011; accepted for publication, September 2011.

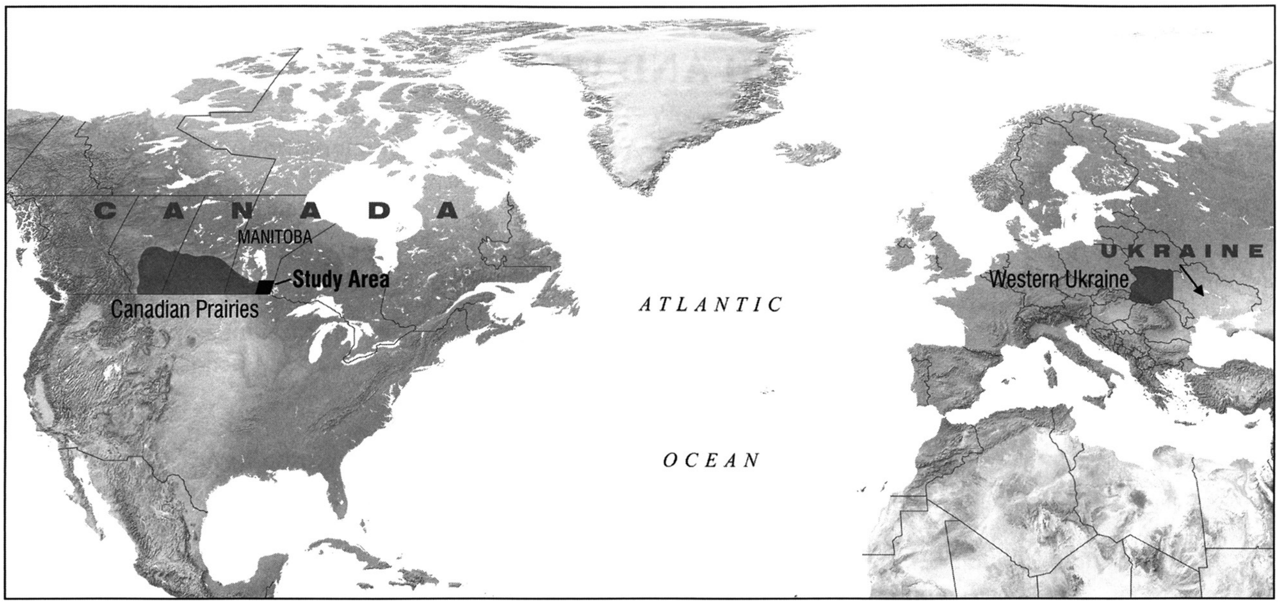

Figure 1. Map of the study area in Canada and the emigrant source area, western Ukraine.

variations in their design and their change over time. Kniffen (1967) argued that cemeteries could be valuable "indices of diffusion, evolution and invention," but Jeane (1972, 146) made a plea for the end of descriptive "tombstone geography." More recently, studies have explored the political and social meanings of the cemetery. Scholars acknowledge that cemeteries are repositories of social values. Deliberately created and highly organized cultural landscapes that express collective identity and collective memory, cemeteries are more than places to bury the dead (Francaviglia 1971, 501; Graves 1993, 42–55). Christopher (1995) and Kruger-Kahloula (1994), for example, have demonstrated that social attitudes and policies of racial segregation were manifest in South African and some United States cemeteries through the establishment of separate cemeteries for each racial group. Kruger-Kahloula (1994, 130) argued that patterns of burial reveal not only religious affiliation and social distinctions but also intra- and intergroup and personal relationships, and "project them into eternity."

Within the cemetery, headstone inscriptions can be a historical record (Hargreaves and Holland 1997) and the language used in epitaphs, when carefully examined, can reveal much about the political attitudes and linguistic abilities of those burying their dead (Baird 1992, 1996; Eckhert 2001, 2002). Use of minority languages may be a symbol of resistance against cultural dominance and an assertion of identity (Mythum 1994), as well as a record of the progress of language change (Eckhert 2002). Even the absence of grave markers can carry cultural meaning, as Lever (2009) has demonstrated. Geographers Lehr (1989) and Darlington (1991) have argued that the process of acculturation is embedded in the headstone decoration and the linguistic changes in epitaphs on headstones in Ukrainian-Canadian rural cemeteries on the prairies. Even pet cemeteries tell much about our attitudes toward death, burial, and the afterlife as they replicate the features and symbols of human cemeteries (Selwood and Lehr 1989).

SLAVS IN MANITOBA

From 1896, until the outbreak of war in Europe terminated immigration from Europe, thousands of Polish and Ukrainian immigrants settled on Manitoba's agricultural frontier lands (Fig. 1). Ukrainian settlers vastly outnumbered Poles in most areas of western Canada, but in the late 1890s and the early years of the 20th century, a series of relatively small settlements were established in eastern Manitoba where the numbers of both Poles and Ukrainians were approximately equal: the Prawda-Hadashville, Cooks Creek, and Libau-Ladywood areas (Fig. 2).

Almost all these Slavic immigrants came from Galicia, an area that was a province of the Austrian Empire until 1918. In the eyes of the receiving society, these immigrants were simply Galicians, but the settlers themselves were keenly aware of ethnic and national differences. The "Galician" immigrants would describe themselves

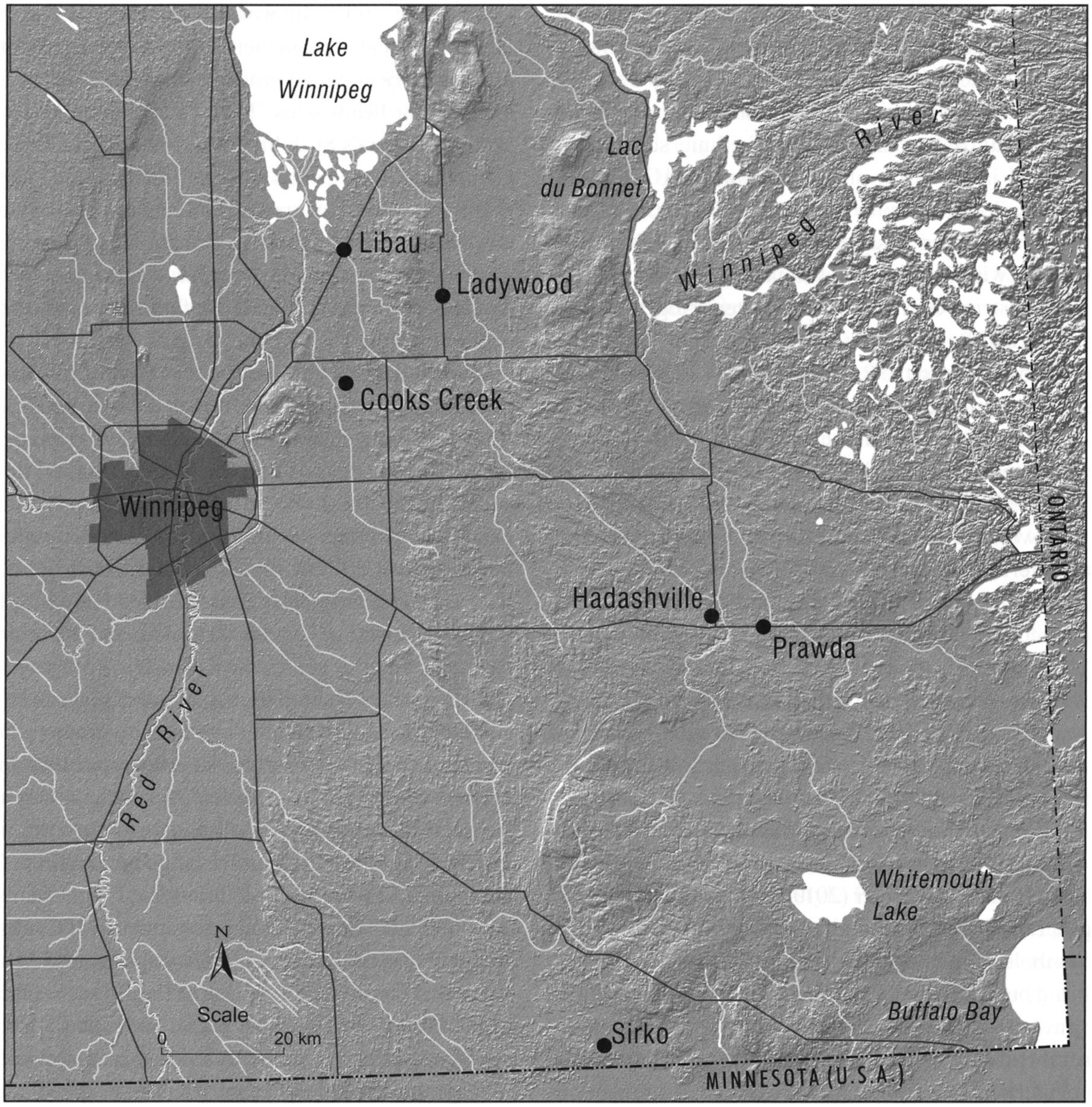

Figure 2. Towns in the study area, Manitoba, Canada.

as Polish or Ukrainian based on an identity constructed on religion, language, and culture, rather than by their geographical point of origin. Turczynski (1976) termed this a "confessional nationality," since religious affiliation was conflated with national identity. In Canada, Slavs negotiated their identities both within this context and within that of a nativist society, one that saw little merit in distinguishing between Poles and Ukrainians and which simply cast them in the role of a homogeneous "other."

Newly arrived Slavic settlers entered a world largely devoid of a cultural infrastructure that met their needs. Although their most pressing concern was survival in a harsh environment, the lack of spiritual outlets remained a nagging concern. All societies need the rituals that govern the yearly round; they need to solemnize marriages, name children, and bury their dead. It is possible to delay marriages and christenings, but death does not wait, so settlers established graveyards and cemeteries as soon as they organized parishes, sometimes before.

Cemeteries carry cultural signatures, revealing religious and cultural identities. Eckhert (2001, 148), in a study of Czech-Moravian cemeteries in Texas, contends that "walking through the cemetery is like surveying the community history." In cemeteries' geographical locations, and the positioning of graves within them, family and even interethnic relationships are permanently entrenched in the

landscape. In Cooks Creek, for example, there are cemeteries serving the Roman Catholic community, which is mostly Polish with a few French and Métis. Ukrainian-Catholic cemeteries exclusively serve the Ukrainian community. Their locations reflect the pattern of ethnic settlement: Poles settled in the north of the community, Ukrainians in the south. Some 30 km to the north of Cooks Creek, the Libau area was religiously homogeneous though ethnically mixed, with Germans, Ukrainians, and Poles settling within the district. German settlers clustered together, and Ukrainians and Poles intermixed. Settlers of all three ethnic backgrounds lie in the Roman Catholic cemetery there. The socio-geographic relationships of the community in its early days are entrenched in the distribution of their burial plots. Ukrainian and Polish graves are intermixed on the cemetery's west side, and German graves occupied the east side, with the two groups separated by a undeveloped swath of territory some 5 m wide. United only by their Catholic faith and residential proximity, the Slavic and Teutonic communities retained a geographical expression of their separate identities even in death.

Grave markers and memorials similarly allow societies to express their culture, values, and norms. Choosing a grave marker and the inscription thereon is a deeply emotional process and one that is fraught with social meaning involving input from family and friends of the deceased, and often, from monument salespeople and engravers (Baird 1996, 138). As Sayer (2010) points out, the surviving generation governs the memorial process, the forms and symbols of memory and the rituals that accompany death and burial. In the selection of cemetery, the location of a gravesite within the cemetery, the form of the grave marker, headstone, or memorial, and the inscription and ornamentation placed upon it, there is a deep connection with identity, place, and territory (Mythum 1994, 253).

The physical appearance of religious symbols changes slowly, if at all. Congregations are reluctant to see change in liturgies or in the rituals of worship because they represent the familiar and give stability in a changing world. However, perhaps because of the complexity and severalty of meanings embodied in Slavic pioneer cemeteries, their physical appearance has changed over time. Most obviously, the material employed to mark graves has varied according to accessibility, affordability, and desirability. Early markers in pioneer cemeteries were hand-hewn wooden crosses with hand-carved inscriptions. Few survive. By the 1930s concrete or wrought-iron markers had largely replaced them. In the 1950s more opulent and sophisticated polished granite headstones, which suggest greater permanence and respect, in turn displaced them (Darlington 1991). Improved economic circumstances, desire for greater permanence, and resistance to cultural homogeneity impelled progressive changes in the materials used for headstones. This was common to all ethnic groups. In Zora's St. John the Baptist Ukrainian Catholic Cemetery, near Cooks Creek, for example, imposing granite markers have replaced many of the original concrete headstones of the 1920s and 1930s. Many original markers lie discarded in a corner of the cemetery. Those driving the memorials' renewal faithfully reproduced the original wording in Cyrillic script.

Language is a vital component of culture. According to some, our language determines the way we think, and it reflects the genealogy of our culture. For immigrants, language was a unifying theme, distinguishing their social group from the "other." Ukrainian settlers, for example, held that *bez movy, nema narodu* (without our language, we are not a people), and Polish immigrants held similar sentiments. Both peoples had endured linguistic restrictions under Prussian and Russian rule. Even within the multiethnic Austria-Hungary of the Habsburgs, Polish and Ukrainian were regarded as inferior languages spoken only by minority groups who were assigned second-class status. German was the language of the Austrian ruling class and the de facto language of imperial administration. In Canada, although immigrants were free to speak their native language within their own community, the need to communicate with mainstream Anglo-Canadian society necessitated use of English on a frequent basis. Government policy also promoted assimilation and favored the adoption of English as the language of the West. The Canadian press, both Liberal and Conservative, displayed a rare unanimity in agreeing that all immigrants should adopt the Protestant creed, abandon their ancestral languages and culture, and conform to Anglo-Canadian social mores (Lehr and Moodie 1980).

Within a decade or so of the first settlement of Poles and Ukrainians in Canada, their Canadian-based ethnic newspapers carried editorials inveighing against the erosion of language, equating it with loss of identity. The *Gazeta Katolicka* argued, "Every Polish parent is obligated to teach his or her children to speak and write Polish. Let us get together!" The editorial pointed out that many Poles appeared to turn away from their mother tongue:

> Due to the fact that there has been total restriction of language use in their homeland under foreign rule, it is incomprehensible. Thus, their compatriots retain the Polish language in face of severe punishment. However, some

> Polish settlers in Manitoba do not care for speaking Polish, and it must be understood that they are not threatened by any sanctions, as they might experience some penalty in the homeland. Moreover, Slavic people seem to be full of pride that they manage to change their names, or even surnames to make them sound more English. We can understand easily that they want to become more English, or even to gain an acceptance of the British people, but we cannot tolerate that they are sending letters to our newspaper, signed as John, Joseph, or Mike. We must add to that list Stanley and Lizzie as well. We cannot wait to see a letter from Maggie, Aggie, Rosy, and Emmy. After that, we would be able to create a list of new Polish names. However, we must ask ourselves do those names sound familiar? We doubt it. Therefore, our dear readers please respect and preserve your mother language. Use it as long as you can. Do not be ashamed of beautiful Polish speech. (*Gazeta Katolicka*, March 25, 1908, 4)

The editor later quoted Ruskin's poetry as an example of English patriotic pride, arguing that Poles should adopt a similar attitude toward their homeland (*Gazeta Katolicka*, May 11, 1908, 4).

The struggle for language retention played out in the fight for bilingual schools. Until 1916 Manitoba permitted bilingual education; thereafter only English was permitted as the language of instruction (Lehr and McGregor 2009). Thus until 1916 most Polish and Ukrainian children of school age who lived in rural areas had the opportunity to formally learn to read and write their parents' language. Although there was no legal restriction on the use of Polish or Ukrainian outside the school, a sea of English swamped both languages, so it increasingly became the lingua franca of the "foreign" settlements. The Slavic lexicon commonly incorporated English expressions; in fact, many Slavs were proud to demonstrate their proficiency in English as a mark of their social status. After 1916, Ukrainian and Polish were learned only at home, usually informally, and the formal instruction in grammar, reading, and writing was delivered, if at all, by the church clergy and secular enlightenment institutions. In the Ukrainian-Canadian press, correspondents from the Ukrainian settlements lauded those teachers who taught Ukrainian within the bilingual school system until its abolition in 1916 and thereafter as an extracurricular offering. There was a consensus among the Ukrainian intelligentsia that to maintain Ukrainian identity in Canada, language retention was vital. Ukrainians should follow the example of the Jews, wrote a correspondent from southeastern Manitoba, and teach their children both language and religion, the twin pillars of identity (*Canadian Farmer*, December 6, 1918).

Aware of the connection between language and culture as a distinguishing element of their identity, successive generations found it doubly important to embed the ancestral language into the commemoration of their dead. Cemetery markers bear testimony to this. The continued use of Polish and Ukrainian in headstone inscriptions resisted the overwhelming dominance of English in the secular life of Slavic communities. Congregations are notoriously reluctant to modify liturgies or the rituals associated with the practice of their faith. The rituals of burial are no exception. While it can be argued that maintaining the ancestral language on headstones was simply a manifestation of religious tradition, it is suggested here that it was a visible and conscious declaration of a collective memory of difference.

Variation in the language used in epitaphs recorded generational changes in spelling and grammar that paralleled changes in the spoken language of the immigrant communities. In the 1925 headstone inscription of Juzefa Benczarska, in Hadashville's St. John the Baptist Church Cemetery, for example, the inscription is in everyday peasant-style Polish, reflecting a lack of familiarity with the conventions of literary language (Fig. 3). On the other hand, the 1924 gravestone of Katazyna Hula in Cooks Creek Roman Catholic Cemetery simply shows poor writing skills in Polish (Fig. 4). *Katazyna* should be *Katarzyna*, and the word *przżezyła* (she lived) is incorrectly rendered as *pszczyla*. Occasionally, lack of familiarity with correct usage led to serious errors of meaning. That these were not identified and corrected at the time that the marker was placed suggests that the community as a whole was either not concerned or, more likely, was not sufficiently acquainted with literary Polish to be aware of the errors in the inscription. The invocation *Śpij w spokoju* (Rest in peace) was occasionally rendered as *Spi w pokoju*, which translates as "He is resting in the room," suggesting Polish was not spoken fluently by any family members, so the more subtle nuances of the language were lost on them (Fig. 5). Similarly, inscriptions on tombstones in Ukrainian cemeteries showed a lack of familiarity with literary Ukrainian. A generation whose knowledge of the language was strictly aural etched their pronunciation into unfamiliar Cyrillic characters, using єму instead of йому (to him), for example, misspelling

Figure 3. Josefa Benczarska's headstone, in the St. John the Baptist Church Cemetery in Hadashville, uses everyday peasant Polish language.

Figure 4. Gravestone showing poorly written Polish. Cooks Creek Roman Catholic Cemetery, Manitoba.

Figure 5. Spi wpokoju (He is resting in the room") is a poor rendition of the intended Śpij w spokoju (Rest in Peace) in Polish.

words and recording the rendition of the spoken language at a particular time. This trend continued when the transition was made into English. In Hadashville's Ukrainian-Catholic cemetery the English inscription on a 2001 memorial to the district's pioneers includes a rendering of the possessive *whose* as *who's,* a mistake the community was either unconcerned about or unaware of.

Cemeteries are not usually places of informality. The exception is the common use of diminutive forms of father (*Tato*), mother (*Maty*), grandfather (*Dido*), and grandmother (*Baba* or *Babucia*). All serve to express affection. Elsewhere, formality is the rule, and the evidence suggests that families strove to achieve this through adherence to standard expressions. It is unlikely that dialectical forms were deliberately inscribed on grave markers. On the other hand, humor is not always absent. In Sirko's St. Elias Ukrainian Orthodox Cemetery, one gravestone carries the injunction, in English, "Don't tell me what to do."

CULTURAL CHANGE

The content of headstone inscriptions records the assimilation process. On Ukrainian gravestones, the abandonment of Cyrillic script and its replacement by the Latin alphabet show the slow creep of acculturation.

Figure 6. Although most details are written here in Ukrainian using Cyrillic script, the names and relationships are rendered in English. The inscription says that Mother Katherine (Kateryna) was born in Novocil'tsi, in western Ukraine, and died at age 70 in 1939. Her husband, Joseph (Josef) Franko(w)ski, was born in L'viv and died in 1946 at age 76. They came to Canada in 1912. Prawda Cemetery.

Figure 7. The process of acculturation. Retention of Polish name but adoption of "R.I.P." in Prawda Cemetery.

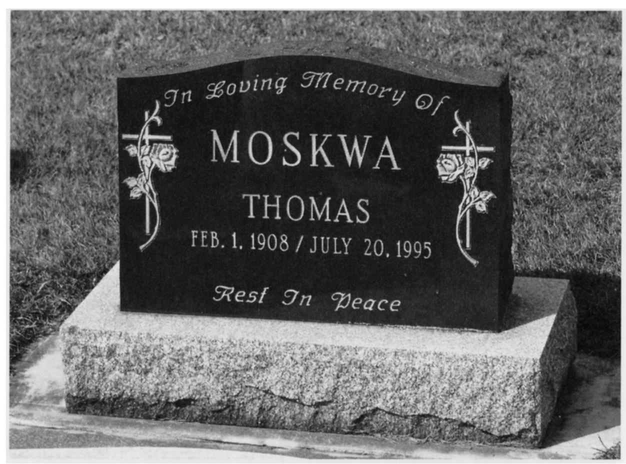

Figure 8. Total anglicization of a Moskwa family grave marker, Prawda Cemetery.

Even when the switch was made to the Latin alphabet and English used for recording the deceased's name and personal details, the Ukrainian invocation *Vichna Pam'yat* (Eternal Memory) was usually retained in Cyrillic script (Fig. 6).

Among Poles and Ukrainians, names were soon anglicized. Wasyl became Bill, Iwan turned into John, and so on. From the 1920s, *Maty* became "Mom," the formal *Bat'ko* (Father) morphed into the familiar *Tato*, then into the English "Dad." *Dido* (Grandfather) became *Gido* but *Baba* (Grandmother) seemed immune from change. In Prawda's cemetery, the Moskwa family's grave markers reveal a steady process of acculturation. Some members kept their Polish names (Fig. 7); others changed them into English variants: Tomasz became Thomas on a completely anglicized gravestone (Fig. 8). Surnames were no exception. In virtually every Polish or Ukrainian cemetery in southeastern Manitoba, members of the same family spelled their surname in different ways. At times, this resulted from cavalier recording of names by immigration agents who tried to reflect the phonetics of an unfamiliar language, as best they could, without regard to the conventions of transliteration. In other instances,

father and son would have slightly different spellings of the family name as anglicization proceeded. Even very Polish names such as Wojtek (Wojciech) became Vojtech to mimic the English phonetic pronunciation, an indication that the ability to write in Polish was diminishing (Fig. 9). Figure 10 illustrates how both last and first names were altered to facilitate interaction with non-Polish society, demonstrating that the level of interaction with mainstream anglophone Canadian society had developed to the point that Poles now considered themselves *a part* of the mainstream rather than *apart* from it. Here Cza has become Chay, and the female name Aniela anglicized to Nellie.

For others, correct language use was a fundamental part of their identity. Figure 11 shows a memorial in Cooks Creek Roman Catholic Cemetery to Stanisław and Karolina Kolbuch, both born in Poland, with an inscription in perfect Polish. In the same cemetery is a solitary gravestone with a Cyrillic inscription, the grave of a Roman Catholic (Latinized) Ukrainian. Retention of the Ukrainian vocabulary and Cyrillic alphabet was a symbolic affirmation of a Ukrainian rather than Polish identity despite membership in a largely Polish Roman Catholic congregation and burial in a Roman Catholic cemetery. For settlers such as these, identity was not a clear-cut matter; it was complicated by religious and cultural adherences often seen to be opposed.

This confusion of identities is best illustrated by reference to one individual whose national identity was negotiated within a milieu where religion and nationality were frequently conflated. Wasyl Nazarewich was born in Stare Oleszyce, Galicia, located in an area now in Poland, close to the present Ukrainian border. At the time of his emigration, this was a mixed Ukrainian and Polish area, and most immigrants from the area would have defined their nationality as Austrian but their ethnicity according to their religious affiliation: Catholics were Polish and Eastern-Rite Catholics (Ukrainian Catholics) were Ukrainian. They had what Turczynski (1976, 189–93) termed a "confessional nationality." After immigration to Canada in 1897, Nazarewich settled in Cooks Creek, Manitoba. He became an active member of Holy Ghost Roman Catholic Parish in Winnipeg; in fact, he was married in that church, and documents show he was an active parishioner. On this basis, he would appear to be Polish. However, he donated a few acres of his Cooks Creek property to St. Nicholas Ukrainian-Catholic parish for use as a cemetery, and he, his wife, and their children are buried there, suggesting that the Nazarewich family were ethnically Ukrainian, and self-identified as such.

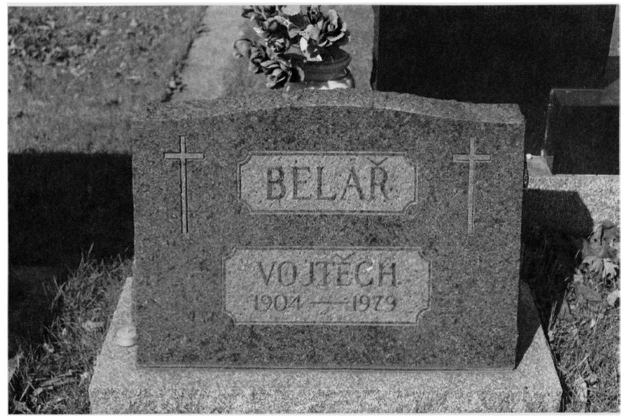

Figure 9. Wojtek (Wojciech) became Vojtech, which represents a linguistic change in Polish to mimic English pronunciation.

Figure 10. Alteration of first and last names, from Polish to English, indicates acceptance of mainstream values.

Figure 11. Stanisław and Karolina Kolbuch were both born in Poland. Their inscription is in perfect Polish. Cooks Creek Roman Catholic Cemetery.

INTERETHNIC RELATIONS

Slavic settlers were frequently of mixed ethnic origins. In eastern Galicia Ukrainians and Poles sometimes intermarried. Such unions were more common between the Latynyky (Roman Catholic Ukrainians) and Poles. Wenzel Baker's gravestone in Ladywood Roman Catholic Cemetery testifies that intermarriage also occurred between Poles and Germans. Born in Bekersdorf, Galicia, in 1848, Baker died in Ladywood, Manitoba, in 1916; by that time, he was a member of the district's Polish community (Fig. 12). Although in this instance we do not know if intermarriage took place, in other cases there is unequivocal evidence. A gravestone in Cooks Creek Roman Catholic Cemetery documents intermarriage between the Dombrowski, Lamb, and Ouellette families, when Polish, English, and French (quite probably Métis) ethnicities were merged (Fig. 13). It is difficult to determine with certainty the ethnic background of the surname "Hart," (Fig. 14), which could be of English or German origin, but when accompanied with a Christian name of Rozalia, it seems that a Pole married outside her ethnic group and did so in the early years of settlement.

Attachment to one's homeland is a powerful and enduring emotion, a core element of identity, sufficient for some to desire its commemoration from beyond the grave. Most usually this is seen in straightforward statements as to where the deceased was born. In Ukrainian rural cemeteries, headstones of the first settlers frequently carry a simple statement in Ukrainian confirming they were born in Ukraine or, more commonly, giving the name of a village or district as the place of birth. Some examples from Sts. Peter and Paul Roman Catholic Cemetery at Ladywood illustrate this well. Figure 15, a memorial to Ben and Ludwika Kupczynski, not only provides images of both but also tells that Ben was born in Ladywood, Manitoba, and his mother, Ludwika, was born in Buczacz, Poland (now in Ukraine). The inscription also reveals that Ben died in Chicago, Illinois, in 1944. Similarly, an adjacent memorial tells that Jan Greszczuk was born in Zobowie, Małopolsce (Little Poland or Galicia) (Fig. 16). Stanisław Polkowski's headstone reads in Polish that he was born in Pennsylvania in 1892 and had a hard life, until his death in 1918: "He suffered a lot and experienced a miserable life. Before he died, he made his peace with God. Rest in peace here." Occasionally a more dramatic statement really clarifies the strength of feeling attached to national identity. The memorial to a Polish veteran in Cooks Creek Roman Catholic Cemetery carries the now faded inscription of the white eagle, the Polish national

Figure 12. Although he was born in the German colony of Bekersdorf in Galicia in 1843, Wenzel Baker was fully integrated into the Polish community near Ladywood. His inscription is in Polish.

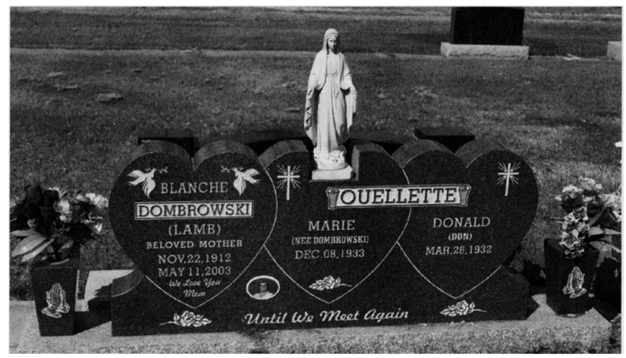

Figure 13. Intermarriage between Polish, English, and French. Cooks Creek Roman Catholic Cemetery.

Figure 14. Although information is scanty, this marker suggests Polish-English intermarriage. Cooks Creek Roman Catholic Cemetery.

Figure 15. This tombstone gives dates and places of birth and death. Sts. Peter and Paul Roman Catholic Cemetery, Ladywood.

emblem, circumscribed by the words *Czolem Ojczyznie, pazurem wrogowi* (Respect your country, lacerate your enemies).

In eastern European peasant society, death was perceived to be an integral part of life. Child mortality was countered by high fertility rates, so the death of a child, while tragic, was common. Women sometimes died in childbirth. Real tragedy was when the breadwinner passed away, which could spell economic disaster for the widow and children. To die alone or away from one's home territory was also considered tragic. To die in a foreign land far from home increased the emotional trauma of death for those close to the deceased. It disrupted the circle of nature in that the deceased could not return to the soil of the homeland, to which European peasants had a strong and almost mystical bond. The complex concept of a bond between a people in their land is difficult to express in English. "Home territory" is too narrow a term and "sense of place" fails to capture the emotional tie to the land. The German term *heimat* comes close, but in Polish, the word *swojskość* describes precisely the concept of a personal bond with the land and the soil. In peasant society, the preservation of traditions was important, thus the ritual of burial, and burial in one's ancestral land had deeply symbolic meaning. To symbolize respect and the deceased's place in the world and to maintain the continuity of life even in death, appropriate commemoration and burial within the sacred ground of the village cemetery or church graveyard was needed. In Canada, when the Canadian-born generation laid their immigrant parents to rest they faced not only the loss of a parent but also the erosion of *swojskość*—the symbolic tie to their ethnic homeland. By adorning their parents' graves with

Figure 16. In Sts. Peter and Paul Roman Catholic Cemetery at Ladywood, Jan Greszczuk's headstone tells, in Polish, that he was born in Zobowie, Little Poland (Galicia) and died in Cromwell, Manitoba.

both secular/national and religious symbols, and by using the sacred language of the homeland in the epitaph, the bereaved appropriated territory and reaffirmed commitment to their heritage. It was a gentle act of remembrance and resistance.

By the 1940s new loyalties were replacing the old attachments to European homelands among second- and third-generation Canadians. To the Canadian-born, Canada was their home and where their first loyalties lay. While they may have retained a sentimental fondness for their parents' ancestral land, Canada was *their* country, and they demonstrated their commitment to it by serving in the Canadian armed forces during World War II. When this generation passed, around the end of the 20th century, their headstones displayed family pride in their service, with details of their combat experiences sometimes recorded. In the Immaculate Conception Ukrainian Catholic Cemetery in Cooks Creek, for example, the epitaph of Nicholas Syrotiuk proudly states, in English,

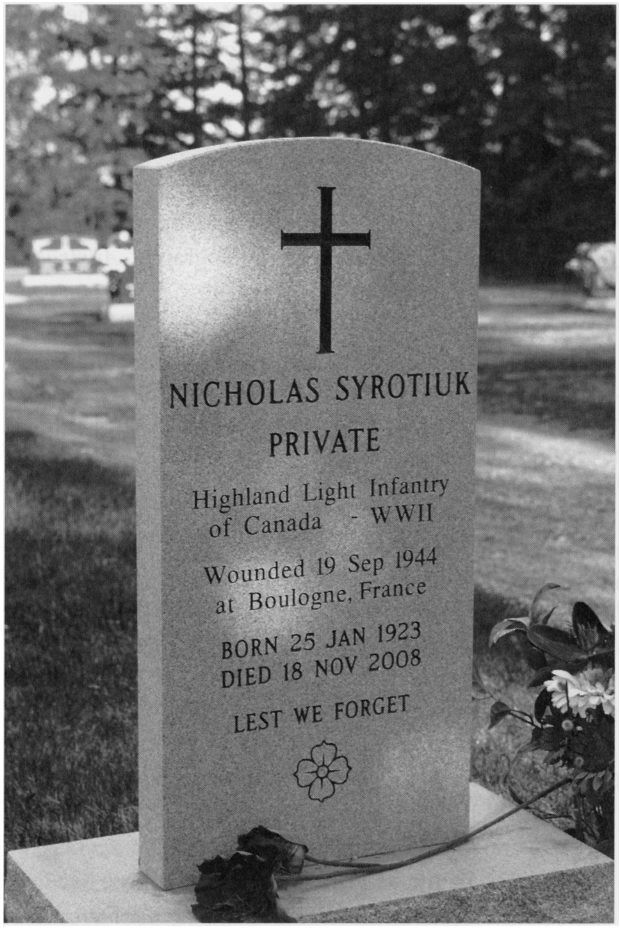

Figure 17. New marker identifies those who served in the Canadian forces. Cooks Creek Ukrainian-Catholic Cemetery.

Fig 18. This headstone in St. Elias Ukrainian Orthodox Cemetery, Sirko, Manitoba, gives details of occupation and place of death.

that he was a private in the Highland Light Infantry and wounded in action at Boulogne, France, in September 1944, leaving no doubt that his primary identity was Canadian (Fig. 17). Similarly, in Sirko's St. Elias Ukrainian Orthodox Cemetery, the English-only inscription on the grave marker of Eli Skrumeda states that he was a "Veteran W.W. II 1942–1946," who was killed on April 23, 1946, while mining in Ontario (Fig. 18).

CONCLUSION

Cemeteries express the collective memory of a society in a concrete, visible, and enduring way. In the ethnic borderlands of southeastern Manitoba, the ways through which those of Slavic ancestry expressed identity in the wider cultural landscape declined as they adopted Britannic social norms. Domestic architecture, once a strong marker of identity, faded from the landscape in the 1960s and 70s; wearing "ethnic" clothing was uncommon long before then, and fluency in Polish or Ukrainian, common in the 1920s and 1930s, became far less so by the end of the century. The rituals of death and commemoration showed symbolic resistance to the process of globalization and cultural homogenization. The increasing opulence and expense of grave memorials mirrored and symbolized economic progress within North American society.

Many of the features identified in Slavic cemeteries can be seen in the rural cemeteries of other ethnic groups that settled across the Canadian prairies. All groups apart from the English and French were subject to the same assimilative pressures and erosion of ancestral languages. In the larger urban centers the picture is less clear, primarily because large cemeteries would serve a multitude of ethnicities. Large urban Roman Catholic cemeteries served French, southern Germans, and Poles; Protestant cemeteries accommodated British and a host of peoples from northwestern Europe: Icelanders, Swedes, Finns, Norwegians, and northern Germans.

In a spatial sense, cemeteries trace the geography of rural ethnic group settlements. Epitaphs and inscriptions record the identities, histories, and affiliations of those within them. As such, they are a record of social attitudes

at particular times and reveal much about the way that individuals, families, and communities constructed and negotiated their identity at particular times in the past, and how they continue to self-define. The examples given here selected from cemeteries in the Polish- and Ukrainian-settled areas of southeastern Manitoba, show how modernity encroached into traditional life and eroded long-held cultural practices. The changing forms of grave memorials and the nature of the inscriptions on them also give voice to the past and speak to the present.

REFERENCES

Baird, S. 1992. Language codes in Texas German graveyards. *Markers: The Annual Journal of the Association for Graveyard Studies* 9:217–55.

Baird, S. 1996. Taylor, Texas, city cemetery: A language community. *Markers: The Annual Journal of the Association for Graveyard Studies* 13:112–41.

Christopher, A.J. 1995. Segregation and cemeteries in Port Elizabeth. *Geographical Journal* 161 (1):38–46.

Darlington, J. 1991. The Ukrainian impress on the Canadian West. In *Canada's Ukrainians: Negotiating an Identity*, ed. Lubomyr Luciuk and Stella Hryniuk, 53–80. University of Toronto Press, Toronto, 1991.

Eckhert, E. 2001. Gravestones and the linguistic ethnography of Czech-Moravians in Texas. *Markers: The Annual Journal of the Association for Graveyard Studies* 18:146–87.

Eckhert, E. 2002. From Moravia to Texas: Immigrant acculturation at the cemetery. *Markers: The Annual Journal of the Association for Graveyard Studies* 19:174–211.

Francaviglia, R. 1971. The cemetery as an evolving cultural landscape. *Annals of the Association of American Geographers* 61 (3):501–9.

Graves, T.E. 1993. Keeping Ukraine alive through death: Ukrainian-American gravestones as cultural markers. In *Ethnicity and the American Cemetery*, ed. Richard E. Meyer, 36–76. Bowling Green State University Popular Press, Bowling Green, Ohio.

Hargreaves, R., and P. Holland. 1997. Graven on stone: Epitaphs as windows on the past. *New Zealand Journal of Geography,* April, 1–4.

Jeane, D. 1972. A plea for the end of tombstone-style geography. *Annals of the Association of American Geographers* 62 (1):146–49.

Kniffen, F. 1967. Necrogeography in the United States. *Geographical Review* 57:426–27.

Kong, L. 1999. Cemeteries and columbaria, memorials and mausoleums: Narrative and interpretation in the study of deathscapes in geography. *Australian Geographical Studies* 37 (1):1–10

Kruger-Kahloula, A. 1994. On the wrong side of the fence: Racial segregation in American cemeteries. In *History and Memory in African-American Culture*, ed. Robert O'Meally, 130–49. Oxford University Press), New York.

Lehr, J. 1989. The Ukrainian sacred landscape: A metaphor of survival and acculturation. *Material History Bulletin* 29 (Spring):3–11.

Lehr J., and B. McGregor. 2009. The geography of bilingual schools in Manitoba. *Manitoba History* 61 (Fall):33–36.

Lehr, J., and D.W. Moodie. 1980. The polemics of pioneer settlement: Attitudes to Ukrainian immigrants in the Winnipeg press. *Canadian Ethnic Studies* 12 (2):88–101.

Lever, M. 2009. When absence is the artifact: Unmarked graves in the Jewish section, Melbourne General Cemetery. *International Journal of Historical Archeology* 13 (4):464–87.

Mythum, H. 1994. Language as a symbol in churchyard monuments: The use of Welsh in nineteenth- and twentieth-century Pembrokeshire. *World Archaeology* 26 (2):252–67.

Sayer, D. 2010. Death and the family: Developing generational chronologies. *Journal of Social Archaeology* 10 (1):59–91.

Selwood, J.H., and J. Lehr. 1989. God's creatures all: The pet cemetery as an element in the landscape of death. *Bulletin Association of North Dakota Geographers* 39:104–12.

Turczynski, Emanuel. 1976. *Konfession und Nation: Zur Frühgeschichte der serbischen und rumänischen Nationsbildung*. Pädagogischer Verlag Schwann, Düsseldorf.

Great Plains Research 22 (Spring 2012):15–25

MAPPING BURNED AREAS IN THE FLINT HILLS OF KANSAS AND OKLAHOMA, 2000–2010

Rhett L. Mohler and **Douglas G. Goodin**

Department of Geography
Kansas State University
Manhattan, KS 66506
rmohler@hotmail.com
dgoodin@ksu.edu

ABSTRACT—Prescribed burning is commonly used to prevent succession of tallgrass prairie to woody vegetation, which preserves the prairie's value to ranching and native wildlife. However, burning has negative effects as well, including potentially harming wildlife and releasing pollutants into the atmosphere. Research concerning the effects of fire on vegetation dynamics, wildlife, and air quality would benefit greatly from maps of burned areas in the Flint Hills, as no reliable quantification of burned areas currently exists. We used Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery to map burned areas in the Flint Hills for each year from 2000 to 2010. Our maps revealed the total amount and spatial pattern of burning for each year. They also revealed the frequency with which different parts of the study area were burned during the 11-year study period. Finally, our maps showed that nearly all burning took place during the month of April.

Key Words: burned-area mapping, MODIS, prescribed fire, remote sensing, tallgrass prairie

INTRODUCTION

Effects of Prescribed Burning in Tallgrass Prairie

Prescribed burning greatly influences the sustainability, species composition, and productivity of plant communities in tallgrass prairie (Knapp and Seastedt 1998), and is partly responsible, along with drought and grazing, for the evolution of grasslands in central North America (Anderson 1990, 2006). Burning suppresses the growth of woody plants, allowing prairies to maintain their current extent (Collins 1992; Glenn et al. 1992; Collins and Steinauer 1998; Hartnett and Fay 1998), and to expand their range into forests (Keeley and Rundel 2005). Burning also prevents nonnative cool-season grass species from decreasing the abundance of native warm-season grasses and forbs (Abrams and Hulbert 1987; Smith and Knapp 1999; Towne and Kemp 2003; Simmons et al. 2007). Because many nonnative grasses and woody species are less palatable to livestock, properly timed prescribed burning represents a cost-effective way to increase cattle weight gain, particularly when burning occurs in mid- to late spring (Anderson et al. 1970). This increases the economic viability of ranching in tallgrass prairie (Bernardo et al. 1988).

Manuscript received for review, July 2011; accepted for publication, October 2011.

In addition to plant communities, prescribed fire affects wildlife. Wilgers and Horne (2006) found that different reptile species show a preference for specific burn frequencies, while Kaufman et al. (1998a) noted that fire can cause direct mortality of reptiles, particularly when they are less mobile due to cool temperatures. Small mammal communities also vary depending on the frequency and timing of burning, with some species increasing and some decreasing due to the same conditions (Kaufman et al. 1990; Kaufman et al. 1998b). They also suffer direct mortality from fires (Kaufman et al. 1990). Changes in vegetation communities due to burning can also affect insect populations. Evans (1984) notes that grasshopper diversity is greatest on areas with intermediate burn frequencies, as these areas are used by both forb- and grass-feeding species. Like with small mammals, the effects of fire on grassland birds can be positive or negative depending on species, drought status, and the spatial scale at which burning takes place (Zimmerman 1992; Fuhlendorf et al. 2006; With et al. 2008).

A negative consequence of prescribed burning is the release of chemical and particulate pollutants, which can have serious health implications for humans living within the airsheds of burned areas (Radke et al. 2001). Moreover, these airsheds can extend for hundreds of miles (Niemie et al. 2005). Chemicals commonly produced

by biomass burning, both directly and indirectly, are oxocarbons (CO_X), sulfur oxides (SO_X), ozone (O_3), ammonia (NH_3), nitrogen oxides (NO_X), methane (CH_4), and other nonmethane hydrocarbons (NMHC) (Dennis et al. 2002; Pope et al. 2002). Although brief exposure to these chemicals causes little risk, longer-term exposure can be harmful, particularly in the case of sulfur oxides (Pope et al. 2002) and ozone (Meng et al. 1997). More likely to affect health in the short term are particulates released during burning—particularly those less than 2.5 µm in size—which are strongly associated with elevated mortality due to lung cancer and other cardiopulmonary-related causes (Pope et al. 2002).

Burned-Area Mapping in Tallgrass Prairie

Remotely sensed imagery is ideal for burned-area mapping because of its high temporal resolution, wide spatial coverage, cost effectiveness, and ability to access otherwise inaccessible areas (Pereira et al. 1997; Al-Rawi et al. 2001; Roy et al. 2002). Currently, most remote sensing–based burn-mapping research done in temperate rangelands has been done in semiarid areas rather than in mesic tallgrass prairies (e.g., Rahman and Gamon 2004; Cao et al. 2009). Because burning in tallgrass prairie typically occurs in the spring, burn scars disappear quickly as both burned and unburned areas rapidly regrow vegetation (Mohler and Goodin 2010). This is not necessarily the case in savannahs and semiarid grasslands—particularly when fires do not coincide with the growing season. For this reason, we used a burned-area mapping method that was developed specifically for tallgrass prairie (Mohler and Goodin 2011).

Prescribed burning affects a wide range of human and natural systems in the Flint Hills, and studying the effects of fire on these systems is important. These studies would benefit from maps showing how much of the Flint Hills is burned in a given year, the exact location of the burned areas (including spatial pattern), how frequently different parts the region are burned, and the temporal pattern of the fires throughout the burn season. Currently, the only existing sources of burned-area information are products derived from satellite imagery and a voluntary burning report. The global nature and relatively coarse spatial resolution of the former poses problems for burned-area mapping in grasslands (Eva and Lambin 1998; Boschetti et al. 2004), while the latter is not designed to be a complete catalog of burned areas in the Flint Hills. Our objective, therefore, was to quantify and map burned areas in the Flint Hills of Kansas and Oklahoma on an annual basis between 2000 and 2010.

METHODS

Study Area

We mapped burned areas across 18 counties in Kansas and Oklahoma (Fig. 1). These counties were chosen because they contain the major grassland portions of the Flint Hills physiographic region, which is the largest extant tract of tallgrass prairie in the world (Kollmorgen and Simonett 1965; Knapp and Seastedt 1998). Nongrassland vegetation types include crops in the area's floodplains as well as trees and shrubs in riparian areas and in areas where burning has been suppressed. Additionally, many species of forbs are common throughout the region (Freeman 1998).

Data Acquisition and Processing

We used Moderate Resolution Imaging Spectroradiometer (MODIS) data (MOD09GQ, MYD09GQ) due to its balance of temporal (twice daily) and spatial (250 m) resolution. We downloaded all images acquired between March 1 and May 10 (an image from February 28, 2002, was also used) in each of 11 study years (2000–2010) from the Warehouse Inventory Search Tool (WIST) of the National Aeronautics and Space Administration (NASA). This provided two images per day except in 2000, 2001, and 2002, when only one MODIS sensor was in orbit. Each image consisted of MODIS band 1 (red, 0.62–0.67 µm) and band 2 (NIR, 0.841-0.876 µm). We converted all images from their native hierarchical data format (HDF) to tagged image file format (TIFF), georectified them to the Universal Transverse Mercator (UTM) coordinate system (zone 14), and subset them to the 18-county study area.

We visually checked each image and did not use images in which clouds or their shadows were present across the entire study area. Images with partial cloud cover were used, as burns could still be detected in cloud-free areas. However, burns mapped in cloudy areas were not included in the final results, as cloud shadows are spectrally similar to burned areas and cause burn overestimation. These burns did not go unmapped, since they were visible in images from the dates surrounding the cloudy image. In order to reduce data redundancy, we used only the best image for each date. We kept the image that had the best combination of

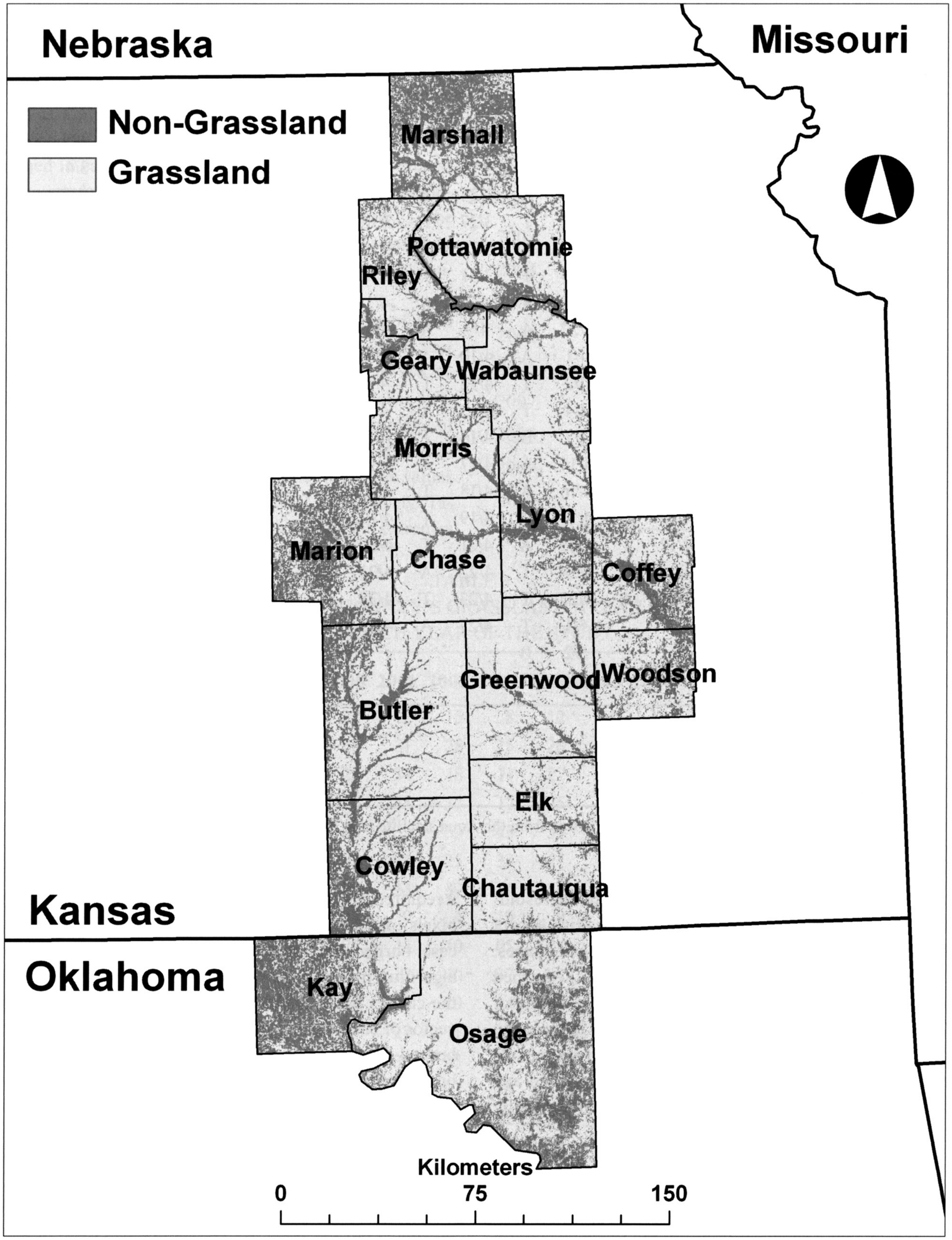

Figure 1. The 18-county study area showing grassland and nongrassland areas. Land cover was adapted from Gap Analysis Program data (KARS 2001).

TABLE 1
DATES OF MODERATE RESOLUTION IMAGING SPECTRORADIOMETER SCENES USED IN THIS STUDY

2000	2001	2002	2003		2004		2005		2006		2007		2008		2009		2010	
3/5	3/8	2/28	3/2	A	3/7	T	3/1	T	3/2	T	3/3	A	3/1	A	3/1	T	3/2	A
3/25	3/13	3/9	3/6	A	3/9	T	3/4	A	3/3	A	3/4	T	3/4	T	3/8	A	3/3	T
3/28	3/20	3/29	3/9	T	3/11	A	3/5	T	3/16	A	3/8	A	3/8	A	3/16	T	3/4	A
3/30	3/22	4/1	3/13	A	3/12	A	3/11	A	3/24	T	3/9	T	3/10	A	3/17	A	3/18	A
4/2	3/31	4/3	3/15	A	3/14	T	3/12	T	3/27	T	3/16	T	3/11	T	3/19	A	3/25	A
4/4	4/7	4/5	3/23	T	3/18	T	3/13	A	3/28	A	3/17	A	3/15	A	3/21	T	3/26	T
4/7	4/9	4/9	3/24	A	3/21	T	3/19	T	3/31	T	3/18	T	3/19	A	3/24	A	3/29	T
4/8	4/11	4/10	3/26	A	3/23	T	3/20	T	4/2	A	4/1	T	3/20	T	3/30	T	3/31	T
4/10	4/12	4/17	3/29	A	3/28	A	3/27	A	4/9	A	4/2	A	3/21	A	3/31	A	4/1	A
4/11	4/13	4/22	3/30	T	3/31	A	4/1	A	4/10	A	4/3	T	3/23	T	4/3	A	4/2	T
4/14	4/18	4/23	3/31	A	4/1	T	4/2	T	4/12	T	4/4	A	3/25	A	4/4	T	4/3	A
4/17	4/21	4/24	4/1	T	4/2	A	4/4	T	4/13	A	4/7	A	3/27	T	4/7	A	4/4	T
4/18	4/25	4/25	4/2	A	4/4	A	4/7	B	4/16	T	4/8	T	4/1	A	4/8	T	4/5	A
4/19	4/27	4/28	4/7	A	4/8	T	4/14	A	4/17	A	4/15	T	4/2	A	4/10	A	4/6	A
4/22	5/9	5/5	4/9	T	4/11	A	4/16	A	4/18	T	4/16	A	4/4	A	4/11	T	4/9	T
5/10		5/9	4/10	A	4/16	A	4/17	B	4/19	T	4/19	T	4/5	T	4/14	A	4/10	A
			4/11	T	4/17	T	4/23	A	4/21	T	4/20	A	4/6	A	4/20	T	4/14	A
			4/12	A	4/19	T	4/24	T	4/22	A	4/21	A	4/13	A	4/21	A	4/17	A
			4/14	A	4/27	A	4/27	T	4/23	T	4/28	T	4/14	T	4/22	T	4/19	A
			4/18	A			5/1	T	4/27	A	4/29	A	4/15	A	4/23	A	4/23	A
			4/21	A			5/2	B					4/19	T	4/24	T	4/27	T
			4/22	T			5/4	T					4/22	A	4/28	A	4/29	T
			4/26	T									4/25	A	5/8	T		
			5/5	A									4/28	T				
													4/29	A				
													5/3	T				

Notes: Letters beside each scene denote whether it was from the Aqua satellite (A), Terra satellite (T), or both (B). All scenes from 2000 to 2002 are from Terra.

cloud cover (as little as possible) and high spatial resolution (where the study area was closest to nadir), except for three dates in 2005, for which we used both images. Table 1 shows the dates of all scenes used in the burned area reconstruction, and the specific satellite (Aqua or Terra) from which each scene originated. In order to prevent all nongrassland cover types and areas outside the study region from being analyzed, we created and used a mask based on the procedure outlined in Mohler and Goodin (2011).

Classification

We applied a supervised, minimum distance classification technique to each masked image in each of the 11 years. Because this classification technique is supervised, it required training data, which are user-selected example pixels of each land cover type being classified (in this case, burned and unburned areas). A minimum distance algorithm then assigns each pixel in the image to one of the classes based on its Euclidean distance to the mean vector of each training class (Jensen 2005). We selected burned-area training pixels only from the most recently burned areas in each image, which minimized false positives that would otherwise occur due to the spectral similarity of unburned areas and older burns. This allowed accuracy levels of approximately 90% or greater when burned areas were mapped less than two weeks after they were burned (Mohler and Goodin 2011). When clouds prevented burned areas from being mapped in all or part of the study area for more than two weeks, we assumed accuracy values below 90%.

RESULTS

The amount of grassland burned annually within the study area ranged from as low as 414,456 ha in 2007 to as high as 1,320,556 ha in 2005. This translates to between 15% and 48% of the grasslands in the study area being burned in each of the 11 years. Although these percentages varied greatly from year to year, no trend was apparent over the 11 years covered by the study (Table 2). The estimate of total grassland area (2,778,643 ha) is based on Kansas Gap Analysis Program (GAP) data (Kansas Applied Sensing Program [KARS] 2001).

At the county level, the mean percentage of total grassland area burned across all 11 years of the study varied from as high as 56% for Chase County (which is 87% grassland) to as low as 11% for Kay County (which is 40% grassland; Table 3). In Chase County, the percentage of grassland burned each year varied from a high of 80% in 2005 to a low of 13% in 2007. In Kay County, these values ranged from 24% in 2003 to 3% in 2002, respectively (Table 3). Chase and Kay counties demonstrate the extremes

TABLE 2
TOTAL AND PERCENT OF GRASSLAND BURNED WITHIN THE STUDY AREA FOR EACH OF THE 11 YEARS OF THE STUDY

Year	Burned grassland (ha)	Percentage burned
2000	1,064,994	38
2001	760,769	27
2002	543,119	20
2003	1,077,588	39
2004	696,594	25
2005	1,320,556	48
2006	755,813	27
2007	414,456	15
2008	1,074,944	39
2009	1,212,281	44
2010	905,738	33

TABLE 3
PERCENTAGE OF EACH COUNTY'S GRASSLAND AREA THAT WAS BURNED IN EACH YEAR OF THE STUDY

County	Grass (ha)	Grass (%)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean
Marshall	77,514	33	22	42	15	8	12	24	15	12	17	25	12	**18**
Riley	101,515	64	36	31	28	25	28	51	39	28	37	46	35	**35**
Pottawatomie	154,836	70	28	34	18	11	27	44	24	15	32	33	31	**27**
Geary	71,259	67	26	23	17	17	25	59	34	13	39	43	35	**30**
Wabaunsee	165,161	80	48	32	33	43	39	69	67	22	59	64	45	**47**
Morris	132,198	73	41	24	25	33	21	53	42	6	38	34	39	**32**
Lyon	149,519	67	45	23	39	51	28	58	60	17	43	55	33	**41**
Marion	116,515	48	23	9	4	19	9	28	6	4	18	22	21	**15**
Chase	172,128	87	75	43	40	65	44	80	46	13	67	73	66	**56**
Coffey	96,821	57	29	12	40	37	17	47	42	26	32	51	18	**32**
Greenwood	252,354	85	49	24	29	54	24	57	29	22	49	57	44	**40**
Butler	269,743	72	45	27	11	39	19	47	14	18	40	44	36	**31**
Woodson	85,772	65	35	35	23	40	29	47	25	26	41	46	28	**34**
Elk	138,170	83	38	34	17	46	31	47	20	18	43	52	37	**35**
Cowley	193,548	67	36	23	5	42	24	41	13	14	40	31	27	**27**
Chautauqua	132,105	81	28	15	8	38	23	35	20	7	26	38	12	**23**
Osage (OK)	369,597	63	33	35	10	45	26	38	11	9	30	37	26	**27**
Kay (OK)	96,340	40	12	11	3	24	9	14	7	5	17	12	12	**11**

Note: The first column is the total amount of grassland in each county, while the second column is the percentage of each county's area that is grassland.

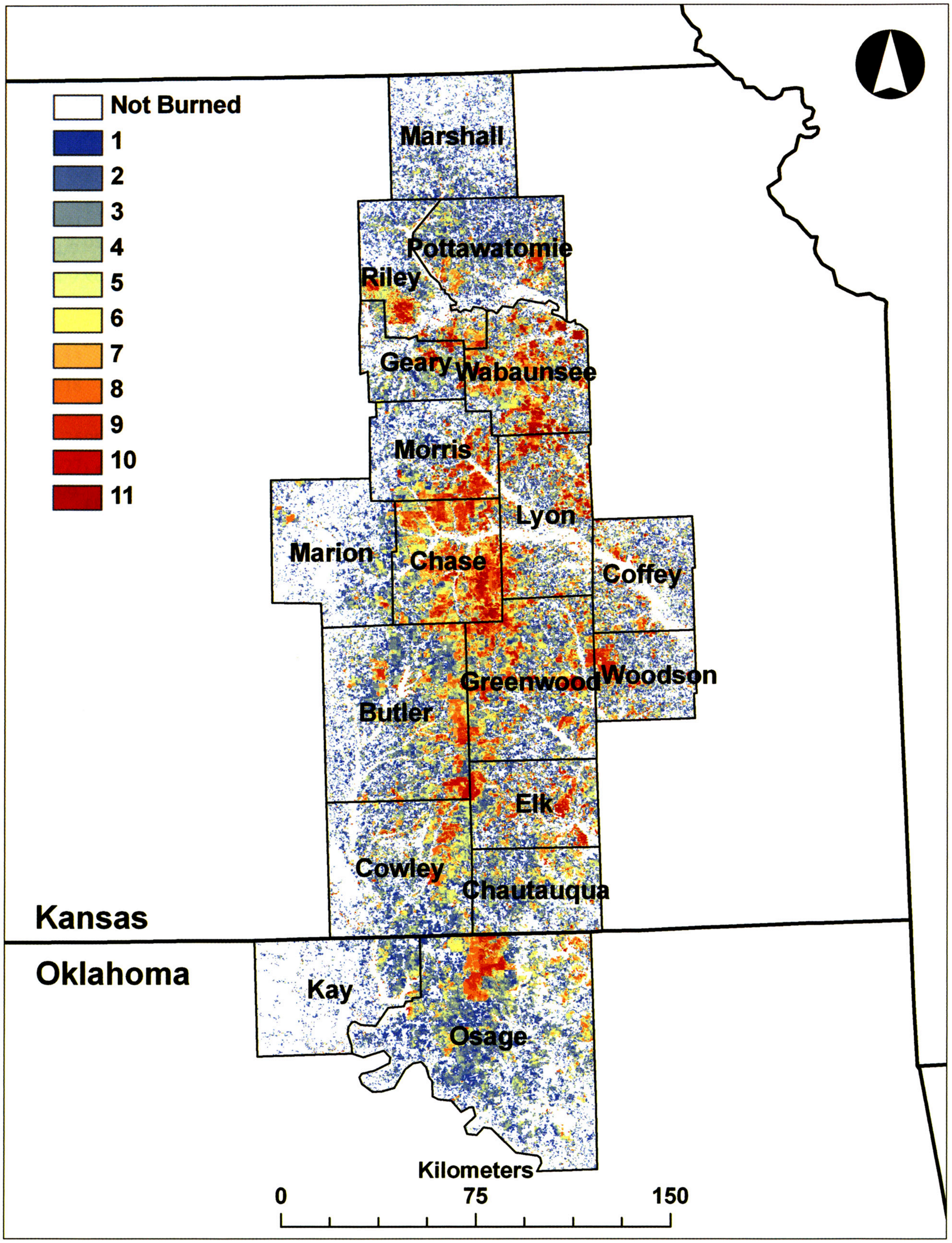

Figure 2. Burn frequency for the study area from 2000 to 2010. The value in the legend indicates the number of years out of 11 that an area was burned.

of a general trend apparent in the data—that parts of the study area with higher percentages of grassland will have more of that grassland burned in a given year than areas with low percentages of grassland.

The frequency with which grassland areas were burned varied throughout the study area (Fig. 2). Of all grassland burned at least once, only 1% was burned in all 11 years of the study, while 15% was burned in only one year (Table 4). This represents the extremes of a general trend in which the amount of grassland burned at a given frequency decreased as burn frequency increased. This trend was only apparent at the scale of the whole study area.

At the county level, grasslands in counties with low percentages of grassland, such as Marshall (33% grassland), Marion (48%), and Kay (40%), were generally burned less frequently than grasslands in counties with higher percentages of grassland, such as Chase (87%). For example, most areas in the former three counties were burned between one and three years out of 11 (if at all), and less than 1% of grasslands in these counties were burned more frequently than eight years out of 11. In Chase County, however, most grassland was burned at frequencies between five and nine years out of 11, with 2% of grasslands burned in all 11 years of the study (Table 5; Fig. 3). As with total burned area, these counties are

TABLE 4
CUMULATIVE GRASSLAND BURNING STATISTICS FOR ALL 11 YEARS OF THE STUDY

Burn frequency (years)	Total burned (ha)	Percentage burned
1	419,738	15
2	347,031	12
3	305,219	11
4	260,356	9
5	228,906	8
6	202,813	7
7	172,006	6
8	153,838	6
9	119,913	4
10	61,200	2
11	24,419	1

Note: Total percentage of grassland burned does not equal 100% because not all grassland was burned during the study period.

TABLE 5
PERCENTAGE OF GRASSLAND BURNED BY BURN FREQUENCY (YEARS OUT OF 11 TOTAL) FOR EACH COUNTY IN THE STUDY AREA

County	Grass (ha)	Grass (%)	1	2	3	4	5	6	7	8	9	10	11
Marshall	77,514	33	38	22	14	8	4	2	1	0	0	0	0
Riley	101,515	64	14	11	11	10	8	8	7	6	4	4	1
Pottawatomie	154,836	70	22	17	13	10	8	5	4	4	2	1	0
Geary	71,259	67	15	15	15	13	9	6	4	3	3	2	1
Wabaunsee	165,161	80	9	8	8	9	11	11	11	9	7	5	4
Morris	132,198	73	15	11	9	7	7	6	5	6	7	3	1
Lyon	149,519	67	11	12	12	11	10	9	8	7	6	4	2
Marion	116,515	48	18	11	9	6	4	3	2	1	0	0	0
Chase	172,128	87	4	5	6	8	11	13	14	15	13	6	2
Coffey	96,821	57	17	14	13	11	10	7	6	4	3	1	1
Greenwood	252,354	85	11	11	11	11	10	10	9	8	6	3	1
Butler	269,743	72	15	14	12	10	9	6	6	5	3	2	0
Woodson	85,772	65	16	15	13	10	8	6	6	6	8	1	0
Elk	138,170	83	12	12	10	9	8	8	6	6	5	4	1
Cowley	193,548	67	16	13	10	9	9	7	5	4	3	0	0
Chautauqua	132,105	81	14	13	12	10	8	6	4	2	1	0	0
Osage (OK)	369,597	63	19	15	13	10	7	6	4	5	3	1	0
Kay (OK)	96,340	40	17	10	7	5	3	2	1	1	0	0	0

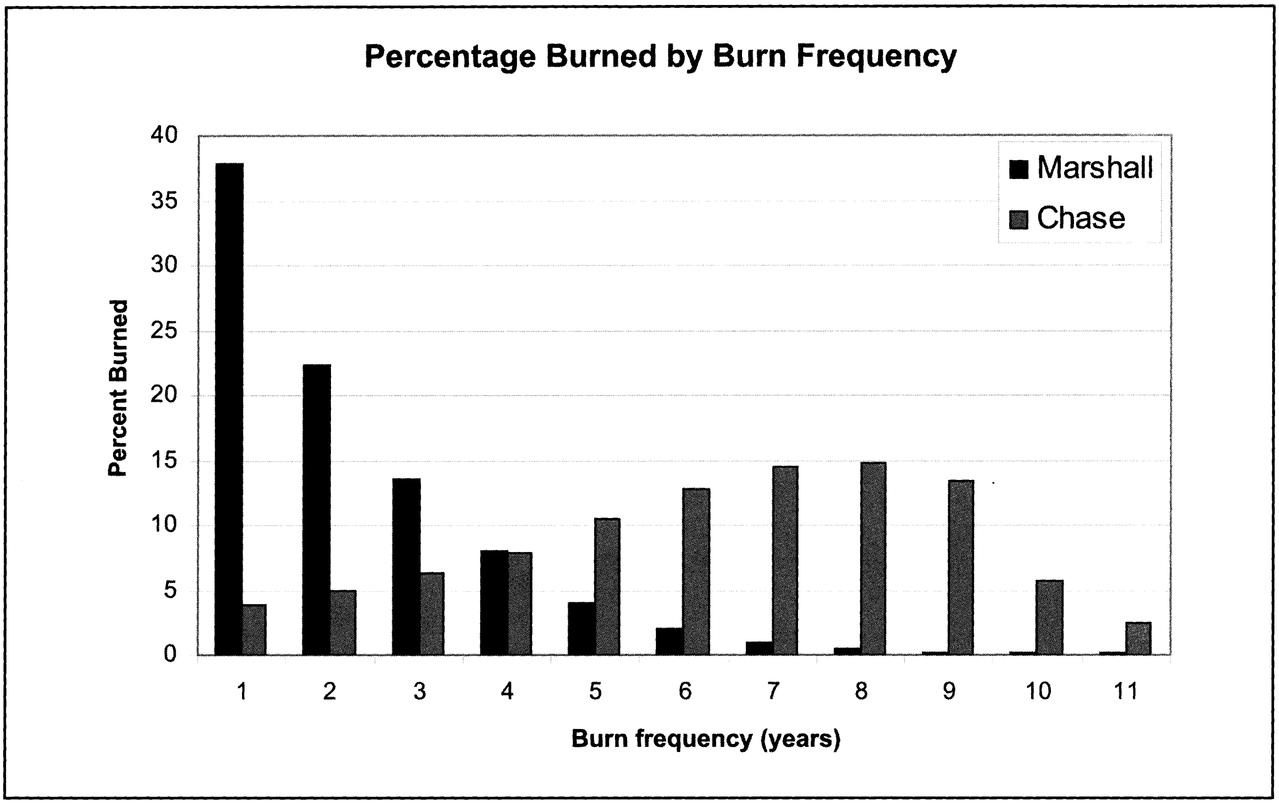

Figure 3. Burn frequency comparison for Marshall and Chase Counties.

used for descriptive purposes only, and the trend was not affected by the arbitrary county boundaries.

Finally, in all 11 years of the study, the vast majority of burning occurred in April (Fig. 4).

CONCLUSIONS

Our maps have quantified the annual amount of burning in the Flint Hills from 2000 to 2010, the location and spatial pattern of that burning, the timing of that burning, and the frequency with which different parts of the area were burned. This data can serve as the basis for many studies that investigate the effects of burning on human and natural systems. For example, With et al. (2008) noted declines in three common grassland bird species in the Flint Hills, where the continuous, intact nature of the prairie was thought to serve as a demographic source for these species, rather than a sink. They suggest that land management practices, including burning, may be responsible. Additionally, Robbins et al. (2002) suspect that the current burning regime, in conjunction with intensive early-season stocking of cattle, is responsible for declines in greater-prairie chicken populations throughout the Flint Hills. Our data allow for direct investigations into the effects of burning amount, frequency, and timing on these and other grassland bird species, as well as on small mammal and insect species.

Another use of our maps and burn data will be to investigate the effects of prescribed prairie burning on air quality. Currently, the link between burning and air quality problems in Kansas City and other urban areas is largely speculative and based on anecdotal evidence. Our maps and data will allow for an investigation into (and quantification of) the precise influence of prescribed burning on air quality, and the role of climate in this relationship.

Finally, the production of these burned-area maps exposes one trend that should be the focus of a future study: that grasslands are burned more frequently (and therefore more likely to be burned in a given year) when they reside in regions of the study area with larger percentages of grassland (typically in the center of the Flint Hills, rather than on the periphery; Figs. 1 and 2). In fact, grasslands on the periphery are often burned only one to three years out of 11. This frequency is well below that predicted by the dominant philosophy of burning annually or biennially to maximize productivity (Towne and Owensby 1984). Possible reasons for this tendency include safety,

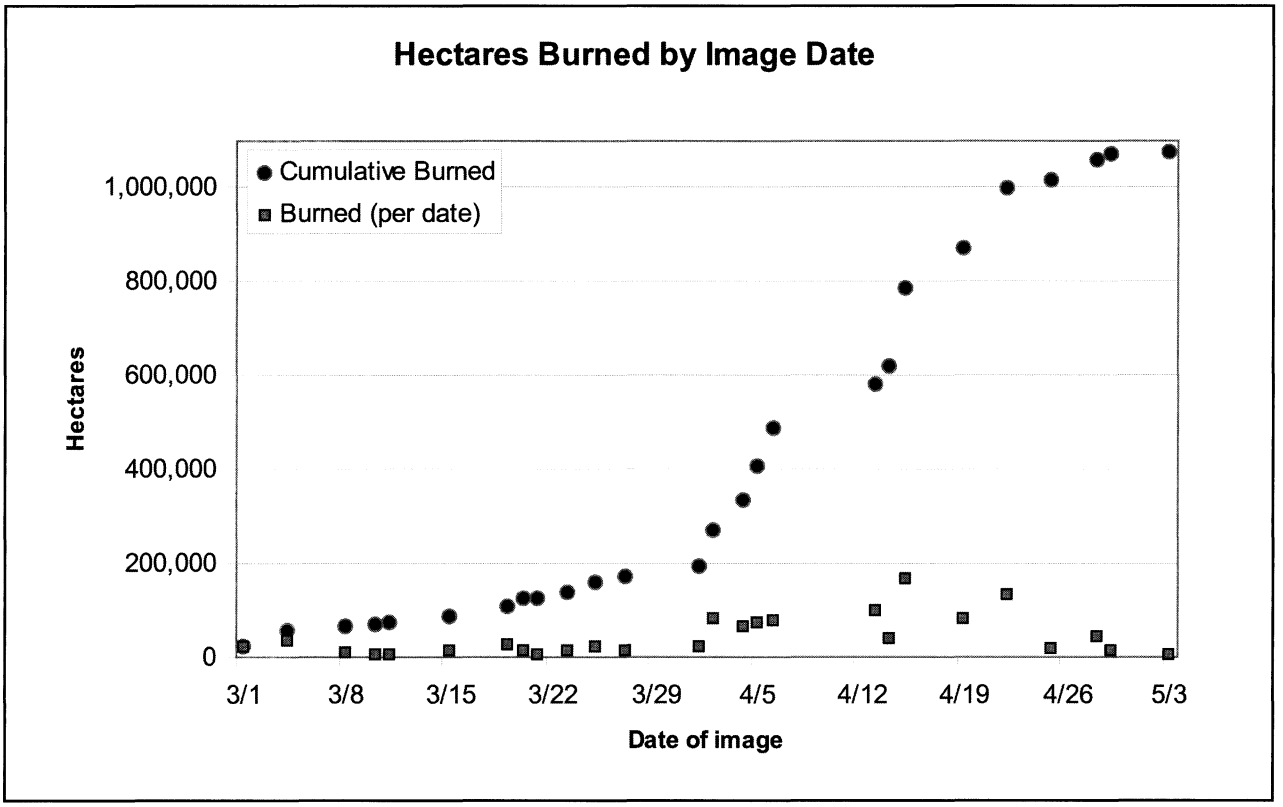

Figure 4. Temporal distribution of burned areas detected in 2008.

liability, and efficiency considerations associated with smaller patches and patches interspersed with croplands, a lack of a burning mindset or tradition, the possibility that infrequently burned Conservation Reserve Program (CRP) grasses make up a large share of these grasslands, that cropland burning is creating noise in the data, and that areas where farming is more prevalent place less emphasis on rangeland management.

ACKNOWLEDGMENTS

This research was supported by a grant from the USDA-NIR Air Quality Program (award #2008-55112-18801), and by a grant from the NSF DDRI Program (award #1003116). We would like to thank numerous colleagues who improved this research through their comments and suggestions. Finally, we would like to thank two anonymous reviewers, whose suggestions were critical in revising the manuscript.

REFERENCES

Abrams, M.D., and L.C. Hulbert. 1987. Effect of topographic position and fire on species composition in tallgrass prairie in northeast Kansas. *American Midland Naturalist* 117:442–45.

Al-Rawi, K.R., J.L. Casanova, and A. Calle. 2001. Burned area mapping system and fire detection system, based on neural networks and NOAA-AVHRR imagery. *International Journal of Remote Sensing* 22:2015–32.

Anderson, R.C. 1990. The historic role of fire in the North American grassland. In *Fire in North American Tallgrass Prairies*, ed. S.L. Collins and L.L. Wallace, 8–18. University of Oklahoma Press, Norman.

Anderson, R.C. 2006. Evolution and origin of the Central Grassland of North America: Climate, fire, and mammalian grazers. *Journal of the Torrey Botanical Society* 133:626–47.

Anderson, K.L., E.F. Smith, and C.E. Owensby. 1970. Burning bluestem range. *Journal of Range Management* 23:81–92.

Bernardo, D.J., D.M. Engle, and E.T. McCollum. 1988. An economic assessment of risk and returns from prescribed burning on tallgrass prairie. *Journal of Range Management* 41:178–83.

Boschetti, L., H.D. Eva, P.A. Brivio, and J.M. Gregoire. 2004. Lessons to be learned from the comparison

of three satellite-derived biomass burning products. *Geophysical Research Letters* 31: Article L21501.

Cao, X., J. Chen, B. Matsushita, H. Imura, and L. Wang. 2009. An automatic method for burn scar mapping using support vector machines. *International Journal of Remote Sensing* 30:577–94.

Collins, S.L. 1992. Fire frequency and community heterogeneity in tallgrass prairie vegetation. *Ecology* 73:2001–6.

Collins, S.L., and E.M. Steinauer. 1998. Disturbance, diversity, and species interactions in tallgrass prairie. In *Grassland Dynamics: Long-Term Ecological Research in Tallgrass Prairie*, ed. A.K. Knapp, J.M. Briggs, D.C. Hartnett, and S.L. Collins, 140–56. Oxford University Press, New York.

Dennis, A., M. Fraser, S. Anderson, and D. Allen. 2002. Air pollution emissions associated with forest, grassland, and agricultural burning in Texas. *Atmospheric Environment* 36:3779–96.

Eva, H., and E.F. Lambin. 1998. Remote sensing of biomass burning in tropical regions: sampling issues and multisensor approach. *Remote Sensing of Environment* 64:292–315.

Evans, E.W. 1984. Fire as a natural disturbance to grasshopper assemblages of tallgrass prairie. *Oikos* 43:9–16.

Freeman, C.C. 1998. The flora of Konza Prairie: A historical review and contemporary patterns. In *Grassland Dynamics: Long-Term Ecological Research in Tallgrass Prairie*, ed. A.K. Knapp, J.M. Briggs, D.C. Hartnett, and S.L. Collins, 69–80. Oxford University Press, New York.

Fuhlendorf, S.D., W.C. Harrell, D.M. Engle, R.G. Hamilton, C.A. Davis, and D.M. Leslie Jr. 2006. Should heterogeneity be the basis for conservation grassland bird response to fire and grazing. *Ecological Applications* 16:1706–16.

Glenn, S.M., S.L. Collins, and D.J. Gibson. 1992. Disturbances in tallgrass prairie: Local and regional effects on community heterogeneity. *Landscape Ecology* 7:243–51.

Hartnett, D.C., and P.A. Fay. 1998. Plant populations: patterns and processes. In *Grassland Dynamics: Long-Term Ecological Research in Tallgrass Prairie*, ed. A.K. Knapp, J.M. Briggs, D.C. Hartnett, and S.L. Collins, 81–100. Oxford University Press, New York.

Jensen, J.R. 2005. *Introductory Digital Image Processing: A Remote Sensing Perspective*. Pearson Prentice Hall, Upper Saddle River, NJ.

Kansas Applied Remote Sensing Program (KARS). 2001. Gap analysis program raster. http://www.Kansas-GIS.org (accessed February 9, 2011).

Kaufman, D.W., E.J. Finck, and G.A. Kaufman. 1990. Small mammals and grassland fires. In *Fire in North American Tallgrass Prairies*, ed. S.L. Collins and L.L. Wallace, 46–80. University of Oklahoma Press, Norman.

Kaufman, D.W., P.A. Fay, G.A. Kaufman, and J.L. Zimmerman. 1998a. Diversity of terrestrial macrofauna. In *Grassland Dynamics: Long-Term Ecological Research in Tallgrass Prairie*, ed. A.K. Knapp, J.M. Briggs, D.C. Hartnett, and S.L. Collins, 101–12. Oxford University Press, New York.

Kaufman, D.W., G.A. Kaufman, P.A. Fay, J.L. Zimmerman, and E.W. Evans. 1998b. Animal populations and communities. In *Grassland Dynamics: Long-Term Ecological Research in Tallgrass Prairie*, ed. A.K. Knapp, J.M. Briggs, D.C. Hartnett, and S.L. Collins, 113–39. Oxford University Press, New York.

Keeley, J.E., and P.W. Rundel. 2005. Fire and Miocene expansion of C_4 grasslands. *Ecology Letters* 8:683–90.

Knapp, A.K., and T.R. Seastedt. 1998. Introduction: Grasslands, Konza Prairie, and long-term ecological research. In *Grassland Dynamics: Long-Term Ecological Research in Tallgrass Prairie*, ed. A.K. Knapp, J.M. Briggs, D.C. Hartnett, and S.L. Collins, 3–18. Oxford University Press, New York.

Kollmorgen, W.M., and D.S. Simonett. 1965. Grazing operations in the Flint Hills-Bluestem Pastures of Chase County, Kansas. *Annals of the Association of American Geographers* 55:260–90.

Meng, Z., D. Dabdub, and J.H. Seinfeld. 1997. Chemical coupling between atmospheric ozone and particulate matter. *Science* 277:116–19.

Mohler, R.L., and D.G. Goodin. 2010. A comparison of red, NIR, and NDVI for monitoring temporal burn signature change in tallgrass prairie. *Remote Sensing Letters* 1:3–9.

Mohler, R.L., and D.G. Goodin. 2011. Identifying a suitable combination of classification technique and bandwidth(s) for burned area mapping in tallgrass prairie with MODIS imagery. *International Journal of Applied Earth Observation and Geoinformation* 14:103–11.

Nieme, J.V., H. Tervahattu, H. Vehkamaki, J. Martikainen, L. Laakso, M. Kulmala, P. Asrnio, T. Koskentalo, S. Sillanpaa, and U. Makkonen. 2005. Characterization of aerosol particle episodes in

Finland caused by wildfires in Eastern Europe. *Atmospheric Chemistry and Physics* 5:2299–2310.

Pereira, J.M.C., E. Chuvieco, A. Beaudoin, and N. Desbois. 1997. Remote sensing of burned areas: A review. In *A Review of Remote Sensing Methods for the Study of Large Wildland Fires*, ed. E. Chuvieco, 127–84. Departamento de Geografía Universidad de Alcalá, Alcalá de Henares, Spain.

Pope, C.A. III, R.T. Burnett, M.J. Thun, E.E. Calle, D. Krewski, K. Ito, and G.D. Thurston. 2002. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *Journal of the American Medical Association* 287:1132–41.

Radke, L.F., D.E. Ward, and P.J. Riggan. 2001. A prescription for controlling the air pollution resulting from the use of prescribed biomass fire: clouds. *International Journal of Wildland Fire* 10:103–11.

Rahman, A.F., and J.A. Gamon. 2004. Detecting biophysical properties of a semi-arid grassland and distinguishing burned from unburned areas with hyperspectral reflectance. *Journal of Arid Environments* 58:597–610.

Robbins, M.B., A.T. Peterson, and M.A. Ortega-Huerta. 2002. Major negative impacts of early intensive cattle stocking on tallgrass prairies: the case of the greater prairie-chicken (*Tympanuchus cupido*). *North American Birds* 56:239–44.

Roy, D.P., P.E. Lewis, and C.O. Justice. 2002. Burned area mapping using multi-temporal moderate spatial resolution data—a bi-directional reflectance model-based expectation approach. *Remote Sensing of Environment* 83:263–86.

Simmons, M.T., S. Windhager, P. Power, J. Lott, R.K. Lyons, and C. Schwope. 2007. Selective and non-selective control of invasive plants: The short-term effects of growing-season prescribed fire, herbicide, and mowing in two Texas prairies. *Restoration Ecology* 15:662–69.

Smith, M.D., and A.K. Knapp. 1999. Exotic plant species in a C_4-dominated grassland: Invisibility, disturbance, and community structure. *Oecologia* 120:605–12.

Towne, E.G., and K.E. Kemp. 2003. Vegetation dynamics from annually burning tallgrass prairie in different seasons. *Journal of Range Management* 56:185–92.

Towne, E.G., and C. Owensby. 1984. Long-term effects of annual burning at different dates in ungrazed Kansas tallgrass prairie. *Journal of Range Management* 37:392–97.

Wilgers, D.J., and E.A. Horne. 2006. Effects of different burn regimes on tallgrass prairie herpetofaunal species diversity and community composition in the Flint Hills, Kansas. *Journal of Herpetology* 40:73–84.

With, K.A., A.W. King, and W.E. Jensen. 2008. Remaining large grasslands may not be sufficient to prevent grassland bird declines. *Biological Conservation* 141:3152–67.

Zimmerman, J.L. 1992. Density-independent factors affecting the avian diversity of the tallgrass prairie community. *Wilson Bulletin* 104:85–94.

Great Plains Research 22 (Spring 2012):27–33

PAROCHLUS KIEFFERI (GARRETT, 1925) IN NEBRASKA (DIPTERA: CHIRONOMIDAE)

Barbara Hayford

Wayne State College
1111 Main Street
Wayne, NE 68787
bahayfo1@wsc.edu

ABSTRACT—A rare species of nonbiting aquatic midge, *Parochlus kiefferi* (Garrett, 1925), was discovered in Squaw Creek in the Pine Ridge of northwest Nebraska. *Parochlus* is a genus of midge found throughout the Southern Hemisphere and is only represented by this one species in the Northern Hemisphere. The typical North American species distribution of *P. kiefferi* includes high alpine and northern latitude streams, so the collection of *P. kiefferi* from a low elevation and low-latitude stream in Nebraska represents a range extension for the species. A survey for *P. kiefferi* from 83 samples from 53 stream sites in northern Nebraska yielded only four specimens of *P. kiefferi*, indicating that this species has a limited distribution. The stream survey was combined with a review of historical data dating back to the 1980s for stream macroinvertebrates from Nebraska, and the results confirmed that *P. kiefferi* is a rare species in the state.

Key Words: Chironomidae, freshwater conservation, rare species, stream ecology

INTRODUCTION

Parochlus kiefferi (Garrett, 1925) was collected from a small stream in the Pine Ridge of Nebraska during the early spring of 2008. The species belongs to a genus of podonomine nonbiting midges (Diptera: Chironomidae) known for its interesting distribution. The genus is found primarily in the Southern Hemisphere, with one species found in islands of Antarctica and another, *P. kiefferi*, found as far north as the 65th parallel, giving the genus a nearly bipolar distribution (Brundin 1966; Cranston et al. 2010; Medelytė 2010). *Parochlus kiefferi* is the only one of 51 *Parochlus* species to be found in the Northern Hemisphere, where it has a patchy distribution (Brundin 1966; Ashe and O'Connor 2009). Typically, it is rare to minimally abundant at ecological study sites where it is collected as a larva or pupa (Ruse et al. 2000; Brabets and Whitman 2002; Aagaard et al. 2004; Lencioni et al. 2007; Medelytė 2010). *Parochlus kiefferi* is found at high elevations in mountainous regions or at high latitudes in the western United States (Wirth and Sublette 1970; Brundin 1989). It has been designated a cold obligate, favoring habitats such as mountain streams, cold springs, and fern bogs (Wirth and Sublette 1970; Brundin 1989; Lindegaard 1995).

Manuscript received for review, April 2011; accepted for publication, September 2011.

Pupal exuviae, the cast-off exoskeletons, of *P. kiefferi* were collected from Squaw Creek in the Nebraska Pine Ridge, which is located at the relatively low latitude of 42° and at an elevation of 1,237 m above sea level, placing the Nebraska population outside the species' known range of high latitudes and elevations (Brundin 1966; Brundin 1989; Cranston et al. 2010). Its unique geographical location relative to other populations within the species and the typical rarity of the species led to a survey for *P. kiefferi* in Nebraska. The goals of this survey were to (1) establish the range of *P. kiefferi* in Nebraska, (2) determine whether it is a rare species in Nebraska, and (3) describe habitat for populations of the species within the state. The ecology and biogeography of *P. kiefferi* are discussed in relation to conservation of the species.

METHODS AND MATERIALS

Historical Data

No records of *P. kiefferi* from the Great Plains had been published as of 2004 (Hayford and Bouchard 2004). At least one population has been reported from Saskatchewan (Ashe and O'Connor 2009), but it is unclear whether the record is from the northern Great Plains. The author and personnel from the Nebraska Department of

Environmental Quality (NDEQ) and the Nebraska Game and Parks Commission (NGPC) searched the historical data on incidence of larval Chironomidae, ranging from 1984 to the present, for records of the species in Nebraska. These records can be found in unpublished documents gathered by the Central Plains Center for Bioassessment (CPCB) and by NDEQ and NGPC.

Study Sites

Nebraska has an estimated 81,573 stream miles, of which 17,783 are perennial (American Rivers 2011). In order to focus the search effectively, survey sites mainly included habitats similar to those in which *P. kiefferi* has been commonly found, such as small perennial streams and cold spring seeps. Furthermore, survey sites were restricted to the northern third of the state because the species is more common in northern latitudes, and this would maximize the chance of finding more populations in Nebraska. The survey included 27 sites from the Pine Ridge, 12 sites from the Verdigris and Bazile Creek watersheds, six streams in the northern Sandhills, five streams in the central Sandhills, and three streams in eastern Nebraska (Fig. 1). Most sites were sampled during late winter or early spring or mid- to late autumn. Sites in the central Sandhills and eastern Nebraska were sampled during late summer and autumn. Streams were sampled from 2001 to 2010, with most sites sampled during 2006–2010.

Collection and Identification Methods

The surface-floating pupal exuviae (SFPE) method, used to collect cast-off exoskeletons of Chironomidae, was effective at finding *P. kiefferi* in Nebraska. The SFPE method (modified from Ferrington 1987), was used to designate a 25–50 m reach along each stream site. Surface-floating pupal exuviae (SFPE) were collected by dipping a small white pan into the flow of the water along regions of the stream where exuviae accumulate, such as eddies and overhanging blades of grass. The SFPE samples were collected from downstream to upstream along the reach. The contents of the pan were poured through a sieve with a 250 µm mesh pore diameter. Exuviae and all other macroinvertebrates were collected from the sieve into jars and preserved in the field, preserved in 80% ethanol, and labeled. Specimens were sorted from debris in the laboratory and specimens were examined at 4′ magnification using a Leica MS5 stereo dissecting microscope. Permanent slide mounts of *P. kiefferi* were prepared using Euparal slide-mounting medium; slides were labeled and specimens were identified using dichotomous keys by Brundin (1986) followed by confirmation using Brundin (1966). Voucher specimens were sent to the Academy of Natural Sciences of Philadelphia.

Water-quality data were collected for the following parameters: conductivity (µS/cm), air and water temperature (°C), pH (IU), and salinity (ppm). A Horriba multiparameter field meter and probe were used to collect in situ water-quality data.

RESULTS AND DISCUSSION

A total of 10,073 specimens of Chironomidae SFPE were examined from 81 stream samples in the search for *P. kiefferi* in Nebraska (Fig. 1). Only four specimens of SFPE *P. kiefferi* were collected from Squaw Creek from four different dates, two in autumn and two in early spring (Table 1). Squaw Creek is singular among the 53 stream sites surveyed by being the only site to support a small population of *P. kiefferi,* but Squaw Creek's physical properties, habitat, and water quality are similar to those of the other sites, particularly in the Pine Ridge. For example, average conductivity (366 µS/cm) in Squaw Creek was within the range of conductivity (277–656 µS/cm) for streams in the Pine Ridge. Many other streams in the Pine Ridge were characterized by cobble substrate, like Squaw Creek (Table 1). The only observable difference was that cobble at the Squaw Creek site was not embedded in sediment.

Review of over 20,000 historical records of Chironomidae yielded no records of *P. kiefferi* from Nebraska prior to the specimens collected from Squaw Creek. These specimens represent the first record of *P. kiefferi* from Nebraska and from the southern Great Plains ecoregion as defined by Omernik (1988). The species is rare and has an extremely limited distribution in Nebraska (Fig. 2). The single known habitat for the species in Nebraska, Squaw Creek, is a narrow, first-order stream flowing through ponderosa pine (*Pinus ponderosa*) and deciduous woodland (Schneider et al. 2005). The stream is characterized by cobble and gravel substrate; is fed by spring seeps; and exhibits moderate levels of conductivity, low salinity, and has neutral to slightly acidic water (Table 1). Collection of SFPE of *P. kiefferi* in mid-autumn and early spring indicates that the species emerges during the colder months of the year, and it may emerge as an adult over the entire winter season. Adults of *P. kiefferi* have been collected throughout the spring, summer, and fall months in the United States (Wirth and Sublette 1970; Anderson and Anderson 1995; Ferrington 1998)

Figure 1. Sites surveyed in the search for *Parochlus kiefferi* in Nebraska. Circles indicate sampling sites. The cluster of sites in the western part of the state is in the Pine Ridge region. It represents 47 different sampling events from 27 different sampling sites. The cluster of sites in the northeastern part of the state is in the Bazile Creek and Verdigris Creek watersheds. It represents 20 different sampling events from 12 different sampling sites.

TABLE 1
WATER QUALITY, PHYSICAL, AND HABITAT DATA FOR SQUAW CREEK

Site information					
Sampling date	3/20/2007	3/23/2008	10/25/2008	4/5/2010	10/9/2010
Air temperature (°C)	3.0	0.0	15.0	9.0	13.0
Water temperature (°C)	8.9	10.6	10.4	15	13.1
Conductivity (μS/cm)	422	366	390	399	390
pH	ND	ND	7.65	6.86	7.71
Salinity (ppm)	0.00	0.01	0.00	0.01	0.01
Substrate type (%)					
Cobble (64–256 mm diameter)	62	65	54	61	50
Gravel (2–64 mm diameter)	12	10	10	9	8
Sand (0.06–2 mm diameter)	5	2	3	5	2
Silt (0.004–.06 mm diameter)	10	10	16	20	20
Clay (<0.004 mm diameter)	0	0	0	0	0
Course particulate organic matter	2	5	6	2	12
Fine particulate organic matter	9	8	11	3	8
Green algae (coverage in study reach)	25	ND	40	ND	35
Parochlus kiefferi	Absent	Present	Present	Present	Present

Note: ND = no data.

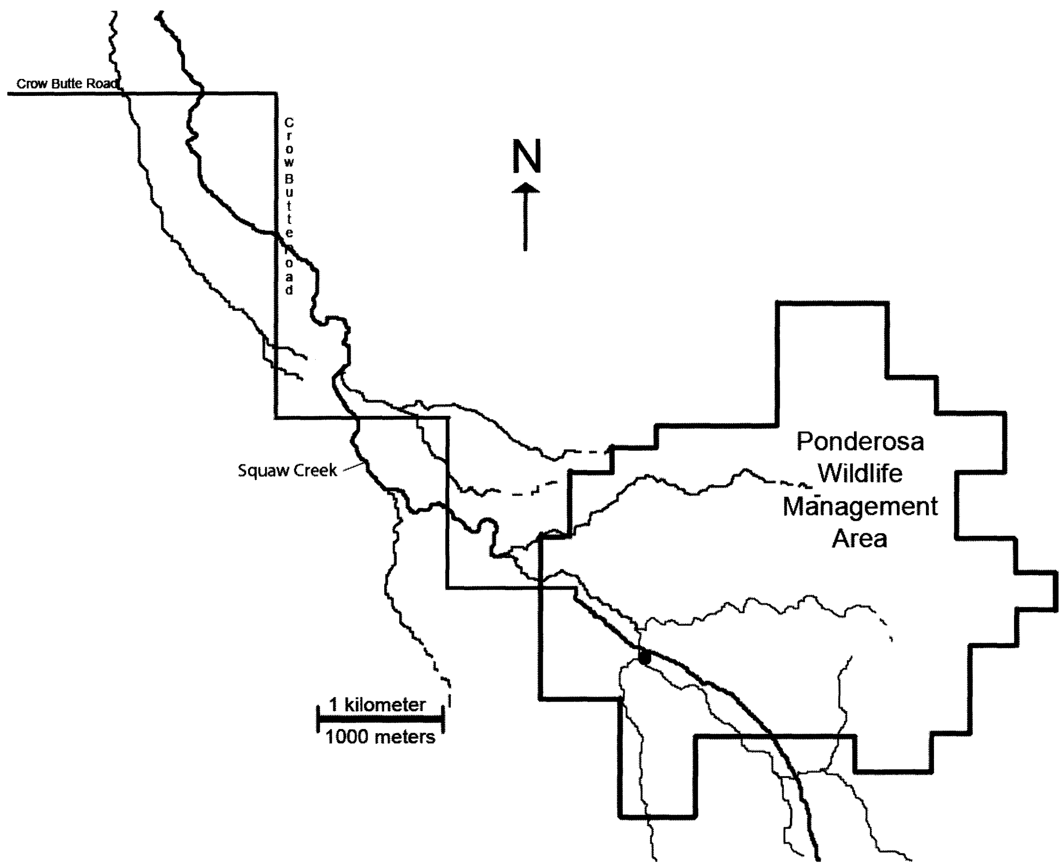

Figure 2. Squaw Creek watershed, Dawes County, Nebraska. The Squaw Creek site where *Parochlus kiefferi* specimens were collected is marked by a solid circle. The stream site is located in the Ponderosa Wildlife Management Area.

and throughout the ice-free season in Europe and Canada (Brundin 1966). Some specimens have been observed emerging only during a period of time just past snowmelt in Germany (Brundin 1966), perhaps showing a similar emergence window to the population in Nebraska. Further research on the phenology of *P. kiefferi* from Squaw Creek is needed to establish if it emerges over the winter months. Restriction to a fall through early spring emergence may be an adaptation of the species to the warmer temperatures of the lower-latitude and lower-elevation habitat of Squaw Creek.

Parochlus belongs to the subfamily Podonominae, an ancestral subfamily of Chironomidae that has a Southern Hemisphere distribution (Brundin 1966). The most species-rich genus of Podonominae is *Parochlus,* of which only *P. kiefferi* is found in the Northern Hemisphere (Ashe and O'Connor 2009). Phylogenetic analysis of the subfamily supports the hypothesis that *P. kiefferi* diverged from other species in the *Parochlus auraucanus* group, which is found in the northern Andes of South America (Cranston et al. 2010). *Parochlus* currently has a gap in distribution with other species in the *P. auraucanus* group found in the northern Andes and points south (Ashe and O'Connor 2009) and *P. kiefferi* found only as far south as the mountainous areas of southern Arizona and California (Wirth and Sublette 1970). The species may have dispersed along high-elevation habitats from the Andes into the southern mountains of western North America (Brundin 1966). The most geographically proximate locations of the species to the population of *P. kiefferi* found in Nebraska are in the Bighorn Mountains of Wyoming, where adults were collected above 2,400 m above sea level, and the Rocky Mountains west of Boulder in Colorado, where adults were collected also above 2,400 m above sea level (Wirth and Sublette 1970). These high alpine sites are dominated by coniferous forests, whereas the site in the Pine Ridge of Nebraska is characterized by a mixture of ponderosa pine and deciduous forest and is 1,163 m closer to sea level. The Pine Ridge site exhibits far warmer temperatures, as air temperatures can reach above 43°C in the Pine Ridge during summer months. Despite the differences between the Pine Ridge and the Rocky and Bighorn mountains, the three regions share a common past. Rocky Mountain pine and boreal forests

spread across Nebraska to mix with eastern hardwood deciduous forests by the end of the Pleistocene glaciations. This period, characterized by extension of the pine and boreal forests across Nebraska, was followed by a warmer, dryer climate at the end of the last glacial maximum (~12,000 years ago) (Ratcliffe and Hammond 2002). The drier climate favored loss of the boreal forest and extension of grassland prairie, which was accelerated by cultural practices of Native American tribes that included burning the landscape to attract prey (grazers) and to deter enemy tribes (Schmidt and Wardle 1998; Ratcliffe and Hammond 2002). Prairie, and subsequently agricultural lands, eventually came to surround relic islands of pine and hardwood forests that still exist today along the Pine Ridge. The pattern of glaciations followed by retraction of the pine and hardwood forests has produced an interesting modern biogeography of insects in Nebraska (Ratcliffe and Hammond 2002). North American populations of *Parochlus kiefferi* probably originated between 1 and 10 million years ago (Cranston et al. 2010). Therefore, it is plausible that they could have extended into the Great Plains by the time of the Pleistocene glaciations. The Wisconsin Glacier only covered the eastern third of the state (Ratcliffe and Hammond 2002). Hence, *P. kiefferi* could have extended across Nebraska in small streams and spring seeps in the cold regions below and to the west of the glacier, which suggests its current presence in the Nebraska Pine Ridge may represent a relic population.

Parochlus kiefferi is rare in most collections of both adult and immature stages in North America (Colbo 1991; Anderson and Anderson 1995; Ferrington 1998; Ruse et al. 2000). However, an interesting pattern appears when examining ecological studies of the species across the Holarctic region. *Parochlus kiefferi* is rare in ecological studies in the western Nearctic (Ruse et al. 2000; Brabets and Whitman 2002), is listed as less abundant but certainly not rare in some studies on habitats in the Northwest Palaearctic (Aagaard et al. 1997; Aagaard et al. 2004; Medelytė 2010), and appears to be quite rare in the first record from the Italian Alps (Lencioni et al. 2007). Establishing biogeographic patterns related to ecological abundances would be useful in studying such a rare and interesting species. The creation of an ecological data repository (e.g., Reichman et al. 2011), particularly one that listed species by latitude, longitude, and date of collection, would facilitate research and understanding of *P. kiefferi*'s rarity as well as the rarity of other species. Such data can be found on websites such as the Global Diversity Information Facility, but the freshwater invertebrate data are miniscule relative to data for many species of vertebrates, and ecological data are not included in the databases.

Paucity of information makes it difficult to determine the rarity of a species of freshwater invertebrates at a time when biodiversity of aquatic ecosystems is in precipitous decline (Dudgeon et al. 2006; Strayer 2006). Freshwater ecosystems represent only 0.01% of all water and 0.8% of land surface on Earth, making them insular habitats surrounded by land. In fact, freshwater may be the most endangered type of ecosystems on Earth, with a rate of loss greater than in terrestrial ecosystems. Freshwater animals are being lost at a rate of 4% per decade in North America (Dudgeon et al. 2006). The isolated nature of freshwater habitat may be nowhere more apparent than in grassland biomes of the Great Plains and Nebraska, which can be characterized as a sea of grass dissected by ~18,000 perennial stream miles (American Rivers 2011) and covered by scattered wetlands and lakes in the Sandhills (Bleed and Ginsberg 1990).

Aquatic ecosystems in Nebraska face threats from nitrates in groundwater (Gurdak and Qi 2006) as well as surface runoff and atmospheric deposition of pesticides (Frankforter 1995; Goldsborough and Crumpton 1998), but perhaps the greatest threat to freshwater in Nebraska is reduced water availability. Groundwater levels have dropped as much as 46 m in the area south of the Pine Ridge since presettlement times and have dropped as much as 12 m between 1980 and 1999 (McGuire 2001, 2009). Streams in the Pine Ridge, particularly streams in the headwaters of the White River such as Squaw Creek, are hydrologically connected to their source of groundwater, the Arikaree Aquifer. Groundwater input from the aquifer stabilizes the streams in the Pine Ridge, creating perennial flow (UNWNRD 2004), which is necessary to support populations of *P. kiefferi*. Stressors such as increased use of groundwater by irrigation can deplete water in the Arikaree Aquifer and affect base flow of streams in the Pine Ridge (UNWNRD 2004). Thus, Squaw Creek is at risk of becoming an intermittent stream, and if it does it will no longer support populations of *P. kiefferi* and other species that depend on perennial streamflow.

Strayer (2006) suggested that protecting and conserving freshwater invertebrates should be linked to conservation of broad, regional actions to protect and conserve water for human use. Conservation strategies for regions of Nebraska have already been suggested or employed by the Nebraska Natural Legacy Plan (Schneider et al. 2005). The plan lists the Pine Ridge as one of its "biologically unique landscapes" of Nebraska, and a survey on the

flora of the region has already been conducted to produce data for use by future legacy plan practitioners (Steinauer 2008). Another sign of hope is that the Upper Niobrara–White Natural Resources District is tasked with monitoring groundwater use in the area and as of 2009 had designated the groundwater in the region in and around the Pine Ridge as fully appropriated. This designation resulted in a continuation and spatial extension of the moratorium on construction of new water wells in the region (UNWNRD 2009), which should help conserve the groundwater that not only feeds Squaw Creek and other streams in the region but also supplies drinking water to the residents of northwest Nebraska.

This unique and rare species deserves conservation status in Nebraska. Its presence represents perennial, spring-fed streamflow and a healthy stream habitat. Perhaps the best way to protect *P. kiefferi* is to support existing strategies to conserve its habitat, support drinking water in the Pine Ridge, and to create or maintain good-quality recreation in the region.

ACKNOWLEDGMENTS

This research was funded in part by the National Science Foundation (DEB #0816910) and the Chadron State College Research Institute. The work was done under the auspices of the Chadron State College Department of Physical and Life Sciences and Wayne State College Department of Life Sciences. Terri Headly provided invaluable assistance in obtaining articles. Thanks to Jessica Wimmer, Lisa Rech, Cassidy Gerdes, and Brent Herdlicka for assistance with field sampling. Thanks to Sergio Orozca for assistance in sorting samples in the laboratory. Ken Bazata of the Nebraska Department of Environmental Quality, Steve Schainost of the Nebraska Game and Parks Commission, and Debra Baker of the Central Plains Center for Bioassessment assisted in the search through historical data. This manuscript was greatly improved by the input of reviewers.

REFERENCES

Aagaard, K., J. Solem, T. Nøst, and O. Hanssen. 1997. The macrobenthos of the pristine stream, Skiftesåa, Høylandet, Norway. *Hydrobiologia* 348:81–94.

Aagaard, K., J. Solem, T. Bongard, and O. Hanssen. 2004. Studies of aquatic insects in the Atna River 1987–2002. *Hydrobiologia* 521:87–105.

American Rivers. 2011. Stream miles by state. http://act.americanrivers.org/site/DocServer/Stream_Miles_Table_FINAL__2_.pdf?docID=4081 (accessed February 19, 2011).

Anderson, T., and N. Anderson. 1995. The insect fauna of spring habitats in semiarid rangelands in central Oregon. *Journal of the Kansas Entomological Society* 68:65–76.

Ashe, P., and J.P. O'Connor. 2009. *A World Catalogue of Chironomidae (Diptera), Part 1: Buchonomyiinae, Chilenomyiinae, Podonominae, Aphroteniinae, Tanypodinae, Usambaromyiinae, Diamesinae, Prodiamesinae and Telmatogetoninae.* Irish Biogeographical Society in association with the National Museum of Ireland, Dublin.

Bleed, A., and M. Ginsberg. 1990. Lakes and wetlands. In *An Atlas of the Sand Hills*, ed. A. Bleed and C. Flowerday, 115–22. Resource Atlas no. 5a, Conservation and Survey Division, Institute of Agriculture and Natural Resources, University of Nebraska–Lincoln.

Brabets, T.P., and M.S. Whitman. 2002. *Water Quality of Camp Creek, Costello Creek, and Other Selected Streams on the South Side of Denali National Park and Preserve, Alaska.* U.S. Geological Survey in conjunction with National Park Service, Water-Resources Investigations Report 02-4260. http://pubs.usgs.gov/wri/wri02-4260/pdf/wri024260.pdf (accessed January 5, 2012).

Brundin, L.Z. 1966. Transantarctic relationships and their significance, evidenced by chironomid midges. With a monograph of the subfamilies Podonominae and Aphroteniinae and the austral Heptagyiae. *Kungliga Svenska VetenskapsAkademiens Handlingar* 11:1–472.

Brundin, L.Z. 1986. The pupae of Podonominae (Diptera: Chironomidae) of the Holarctic region. In *Chironomidae of the Holarctic Region—Keys and Diagnoses*, *Part Two: Pupae*, ed. T. Wiederholm. *Entomologica Scandinavica* Supplement 28:19–30.

Brundin, L.Z. 1989. The adult males of Podonominae (Diptera: Chironomidae) of the Holarctic region—keys and diagnoses. In *The Adult Males of Chironomidae (Diptera) of the Holarctic Region—Keys and Diagnosis*, ed. T. Wiederholm. *Entomologica Scandinavica* Supplement 34:23–36.

Colbo, M.H. 1991. A comparison of the spring-inhabiting genera of Chironomidae from the Holarctic with those from natural and manmade springs in Labrador, Canada. *Memoirs of the Entomological Society of Canada* 155:169–79.

Cranston, P., N. Hardy, G. Morse, L. Puslednik, and S. McCluen. 2010. When molecules and morphology

concur: The "Gondwanan" midges (Diptera: Chironomidae). *Systematic Entomology* 35:636–48.

Dudgeon, D., A.H. Arthington, M.O. Gessner, Z.I. Kawabata, D.J. Knowler, C. Lévêque, R.J. Naiman, A.H. Prieur-Richard, D. Soto, M.L.J. Stiassny, and C.A. Sullivan. 2006. Freshwater biodiversity: Importance, threats, status and conservation challenges. *Biological Reviews* 81:163–82.

Ferrington, L. 1987. Collection and identification of surface floating pupal exuviae of Chironomidae for use in studies of surface water quality. U.S. EPA Standard Operating Procedure No. FW 130A. Washington, DC.

Ferrington, L. 1998. Generic composition of the chironomid fauna in springs of North America. In *Studies in Crenobiology: The Biology of Springs and Springbrooks*, ed. L. Botosaneanu, 141–55. Backhuys, Leiden.

Frankforter, J.D. 1995. Association between local land use and herbicide concentrations in wetlands of the Platte River Basin, Nebraska. In *Versatility of Wetlands in the Agricultural Landscape*, ed. K. L. Campbell, 539–48. American Society of Agricultural Engineers, Tampa, FL.

Garrett, C.B.D. 1925. *Seventy new Diptera*. Cranbrook, British Columbia: Cranbrook Courier Print.

Goldsborough, G., and W. Crumpton. 1998. Distribution and environmental fate of pesticides in prairie wetlands. *Great Plains Research* 8:73–95.

Gurdak, J., and S. Qi. 2006. *Vulnerability of Recently Recharged Groundwater in the High Plains Aquifer to Nitrate Contamination*. U.S. Geological Survey Scientific Investigations Report 2006–5050.

Hayford, B.L., and R.W. Bouchard. 2004. Distribution of Chironomidae in the Great Plains. Paper presented at the annual meeting of the Kansas Entomological Society, Lincoln, NE.

Lencioni, V., L. Marziali, and B. Rossaro. 2007. The first record of *Parochlus kiefferi* (Garrett, 1925) (Diptera, Chironomidae, Podonominae) from Italy. *Entomological News* 118 (2):127–33.

Lindegaard, C. 1995. Chironomidae (Diptera) of European cold springs and factors influencing their distribution. *Journal of the Kansas Entomological Society* 68:108–31.

McGuire, V.L. 2001. Water-level changes in the High Plains aquifer, 1980 to 1999. U.S. Geological Survey Fact Sheet, USGS FS-029-01.http://pubs.usgs.gov/fs02901/ (accessed December 5, 2011).

McGuire, V.L., 2009. Water-level changes in the High Plains aquifer, predevelopment to 2007, 2005–06, and 2006–07. U.S. Geological Survey Scientific Investigations Report 2009–5019. http://pubs.usgs.gov/sir/2009/5019/ (accessed February 19, 2011).

Medelytė, G. 2010. *Influences of Forests on Invertebrate Communities in Icelandic streams*. Master's thesis, University of Iceland.

Omernik, J. 1987. Ecoregions of the conterminous United States. *Annals of the Association of American Geographers* 77:118–25.

Ratcliffe, B.C., and P.C. Hammond. 2002. Insects and the native vegetation of Nebraska. *Transactions of the Nebraska Academy of Sciences* 28:29–47.

Reichman, O.J., M.B. Jones, and M.P. Schildhauer. 2011. Challenges and opportunities of open data in ecology. *Science* 331:703-5.

Ruse, L.P., S.J. Herrmann, and J.E. Sublette. 2000. Chironomidae (Diptera) species distribution related to environmental characteristics of the metal-polluted Arkansas River, Colorado. *Western North American Naturalist* 60:34–56.

Schmidt, T.L., and T.D. Wardle. 1998. The forest resources of Nebraska. Research Paper NC-332. U.S. Department of Agriculture, Forest Service, North Central Research Station, St. Paul, MN.

Schneider, R., M. Humpert, K. Stoner, and G. Steinauer. 2005. *The Nebraska Natural Legacy Project: A Comprehensive Wildlife Conservation Strategy*. Final draft submitted to the U.S. Fish and Wildlife Service.

Steinauer, R.F. 2008. Pine Ridge Ecological Community Survey, Sheridan, Dawes and Sioux Counties, Nebraska. White Paper. Lincoln, NE: Nebraska Game and Parks Commission, 2008.

Strayer, D.L. 2006. Challenges for freshwater invertebrate conservation. *Journal of the North American Benthological Society* 25:271–87.

UNWNRD (Upper Niobrara–White Natural Resources District). 2004. *Report on Hydrologically Connected Ground Water and Surface Water in the Upper Niobrara–White Natural Resources District*.

UNWNRD (Upper Niobrara–White Natural Resources District). 2009. Integrated management plan jointly developed by the Upper Niobrara White Natural Resources District and Department of Natural Resources. http://www.unwnrd.org/downloads/UNWNRD_Final_IMP_5-14-09.pdf (accessed March 8, 2011).

Wirth, W., and J. Sublette. 1970. A review of Podonominae of North America with descriptions of three new species of *Trichotanypus*. *Journal of the Kansas Entomological Society* 43:335–54.

Great Plains Research 22 (Spring 2012):35–43

ADAPTATION OF ANNUAL FORAGE LEGUMES IN THE SOUTHERN GREAT PLAINS

John A. Guretzky

Department of Agronomy and Horticulture
University of Nebraska–Lincoln
Lincoln, NE 68583-0915
jguretzky2@unl.edu

Twain J. Butler

Forage Improvement Division
Samuel Roberts Noble Foundation
Ardmore, OK 73401
tjbutler@noble.org

and

Jim P. Muir

Texas AgriLife Research and Extension Service
Stephenville, TX 76401
j-muir@tamu.edu

ABSTRACT—Our objective was to evaluate adaptation and compatibility of cool-season annual legumes overseeded into perennial grasses in the southern Great Plains. Freeze damage, vigor, and standing crop of 14 annual legume species were evaluated during spring at three locations in Oklahoma and Texas from 2006 to 2008. Across locations and years, standing crop of hairy vetch (*Vicia villosa* Roth) and Austrian winter pea [*Pisum sativum* L. ssp. *arvense* (L.) Poir.] averaged 3,513 and 3,210 kg dry matter (DM) ha^{-1}, respectively. Standing crop of crimson clover (*Trifolium incarnatum* L.) and arrowleaf clover (*T. vesiculosum* Savi) averaged 1,138 and 1,071 kg DM ha^{-1}, respectively. Although subject to freeze damage, annual medics produced more spring forage than annual clovers on soil with pH > 8.0. Most of the annual legumes survived winter, demonstrating their adaptability to pastures in the southern Great Plains, but hairy vetch and Austrian winter pea consistently provided the most spring forage.

Key Words: annual clovers, annual medics, hairy vetch, overseeding, pasture management, Austrian winter pea

INTRODUCTION

Introduced forage legumes are an important component of pasture-based livestock production systems. When integrated into existing grass pastures, legumes improve seasonal distribution, quality of forage, and availability of nitrogen in soil (Heichel 1985). Temperate forage legumes, primarily of Mediterranean origin, are most productive at 20°C (Sheaffer and Evers 2007). Where precipitation is abundant and summer temperatures are moderate, perennials such as alfalfa (*M. sativa* L.), red clover (*T. pratense* L.), and white clover (*T. repens* L.) may be used successfully. In the southern Great Plains, where winters are mild but summers are hot and dry, perennial legumes do not persist, but cool-season annual legumes are well adapted (Sheaffer and Evers 2007) and in many cases have become naturalized (Diggs et al. 1999).

Overseeding of warm-season perennial grasses with cool-season annual legumes allows 4 to 6 weeks of earlier spring grazing (Evers 2005). Commonly seeded annual legumes include arrowleaf clover, crimson clover, and hairy vetch. Arrowleaf clover has high forage yield and excellent reseeding potential, but it matures later and has less regrowth after grazing than crimson clover

Manuscript received for review, May 2011; accepted for publication, October 2011.

(Evers and Newman 2008). Crimson clover has excellent seedling vigor and early spring growth but is limited by poor reseeding ability (Evers and Smith 2006; Evers and Newman 2008). Interest in annual medics as winter pasture legumes has increased due to their ability to reseed under grazing (Muir et al. 2001; Muir et al. 2005). Cold tolerance often limits northern and western expansion of annual medics (Muir et al. 2005; Ocumpaugh et al. 2007).

Although efforts to improve adaptability of forage legumes and identify optimal management practices continue, research remains incomplete. Knowledge of winter survival of annual legume accessions and ability to provide forage during spring when overseeded or drilled into existing perennial grasses remains limited (Bow et al. 2008). To improve information available to pasture managers about which legume species to plant, winter survival and spring availability of 14 autumn-seeded legume species were evaluated across three locations in Oklahoma and Texas from 2006 to 2008. Objectives of the research were to identify legume species that survived winter with high spring standing crop and compatibility with perennial grasses.

METHODS

Experiment Locations and Establishment Methods

Legume evaluations were established at Burneyville and Ardmore, OK, and Stephenville and Vashti, TX, from 2006 to 2008 (Table 1). At Burneyville, soil was a Norwood clay loam, and legumes were seeded in separate plantings within a 10-year-old stand of eastern gamagrass (*Tripsacum dactyloides* L.), originally established in 76.2 cm rows, in September 2006 and October 2007. Legumes were broadcast seeded and lightly raked by hand within individual 3.0 by 4.5 m plots in the 2006 planting and no-till drilled with a HEGE 500 drill with 17.8 cm row spacings in 4.5 by 6.0 m plots in the 2007 planting. Before seeding each fall, the field was mowed at a 30 cm height and baled. Soil tests of the first planting in 2006 revealed pH = 8.2 and availability of P and K at 71 and 1,390 mg kg^{-1}, respectively. Soil tests of the second planting in 2007 revealed pH = 8.0 and availability of P and K at 75 and 1,436 mg kg^{-1}, respectively. Diammonium phosphate (18-46-0) was applied to each planting at 112 kg ha^{-1} in November 2006 and October 2007.

At Ardmore, legumes were drilled with tall fescue [*Lolium arundinaceum* (Schreb.) S.J. Darbyshire cv. PDF584] into a clean-tilled seedbed at a <0.6 cm depth with a HEGE 500 drill in September 2007. Plots were 4.5 by 6.0 m, and the fescue was seeded at 16.8 kg pure live seed (PLS) ha^{-1}. Soil was a Heiden clay with a pH = 7.1 and availability of P and K at 7 and 319 mg kg^{-1}, respectively. Diammonium phosphate was applied at 112 kg ha^{-1} prior to planting.

At Stephenville, legumes were no-till drilled at <0.6 cm depth with a HEGE 1000 drill with 19.0 cm row spacings within a 15-year-old stand of switchgrass (*Panicum virgatum* L. cv. Alamo) in October 2006. Before seeding, the switchgrass stand was mowed to a 5 cm height, baled, and removed. Plots were 1.5 by 7.6 m. Soil was a Windthorst fine sandy loam with a pH of 7.0 and P and K availability of 18 and 563 mg kg^{-1}, respectively. Diammonium phosphate was applied at 112 kg ha^{-1} at planting.

At Vashti, legumes were drilled with tall fescue (cv. Flecha) into a clean-tilled seedbed at a <0.6 cm depth using a HEGE 500 drill in October 2006 and September 2007. Soil was an Anocon loam with a pH = 6.7 and in which availability of P and K was 175 and 1,025 mg kg^{-1}, respectively. Plots were 1.5 by 7.6 m in the 2006 planting and 1.5 by 6.0 m in the 2007 planting. Fescue was seeded at 16.8 kg PLS ha^{-1} in both plantings. Before planting, diammonium phosphate was incorporated at 112 kg ha^{-1}.

Evaluation of Legume Adaptation and Compatibility

Freeze damage and vigor of legumes were assessed at Burneyville and Vashti in February 2007 and at Ardmore and Vashti in February 2008. Freeze damage was a visual rating by two observers on the whole-plot level, whereby 0 = no visual injury and 100 = complete plant death. The percentage of necrotic tissue on the plants is reported. Vigor was also a visual ranking of winter growth in February on a scale from 0 to 9, whereby 0 = dead plants and 9 = healthy, vigorous plants with growth. Standing crop was measured in late April at peak standing crop of the legumes. With the exception of the evaluation at Burneyville, spring standing crop of the annual legume species and associated grasses was determined by visual estimation of the proportion of standing crop in each of these groups, followed by harvest of total standing crop from two 0.2 m^2 quadrats at a 2.5 cm height. At Burneyville, only the standing crop of the legume component was determined because of the ease of harvesting each legume entry between the eastern gamagrass rows. Forage samples collected during April were dried in a forced-air oven at 60°C for 48 hr before determination of dry matter of the grass and legume components.

TABLE 1
PURE LIVE SEEDING RATES OF WINTER ANNUAL LEGUMES EVALUATED IN SOUTH-CENTRAL OKLAHOMA AND NORTH-CENTRAL TEXAS, 2006–2008

Common name	Scientific name and authority	Cultivars sown	Pure live seeding ($kg\ ha^{-1}$)
Arrowleaf clover	*Trifolium vesiculosum* Savi	Apache and Yuchi	8–10
Austrian winter pea	*Pisum sativum* L. ssp. *arvense* (L.) Poir.	Common[a]	22–39
Ball clover	*Trifolium nigrescens* Viv.	Common[a] and Overton	2–3
Burr medic	*Medicago polymorpha* L.	Ueckert and NF[b]	12–17
Button medic	*Medicago orbicularis* (L.) Bartal.	Estes and NF	4–10
Common vetch	*Vicia sativa* L.	Common[a]	33
Crimson clover	*Trifolium incarnatum* L.	Dixie and Overton	13–17
Hairy vetch	*Vicia villosa* Roth	AU and Common[a]	15
Little burr medic	*Medicago minima* (L.) L.	Devine and NF[b]	6–8
Rigid medic	*Medicago rigiduloides* E. Small	NF[b]	12–17
Rose clover	*Trifolium hirtum* All.	Overton R18	7–17
Subterranean clover	*Trifolium subterraneum* L.	Denmark	12–17
Tifton burr medic	*Medicago rigidula* (L.) All.	NF[b]	10–17
White sweetclover	*Melilotus alba* Medik.	Hubam and TX[c]	11–13

[a]Variety unknown.
[b]Experimental accession of the Samuel Roberts Noble Foundation.
[c]Experimental accession of the Texas A&M Experiment Station at Overton.

In all plantings and locations, legume entries were arranged in a randomized complete block design with four replications. An analysis of variance was conducted to determine main effects and interaction of legume species and environment (location-year) using mixed models procedure in SAS (Statistical Analysis Software, Cary, NC). Different cultivars and accessions of each legume species (Table 1) were pooled by environment in the analysis due to variation in seed availability among cultivars from year to year. Legume species and environment were considered fixed effects, and replications and their interactions were considered random effects in the analysis. Least significance differences among legume species were determined at $P \leq 0.05$.

RESULTS

Environment Effects

Legume species and environment interactions affected freeze damage, vigor, and standing crop of legumes and compatibility with perennial grasses throughout the study (Table 2). Interactions of legume species and environment were likely due in part to differences in precipitation, soil types, temperatures, and companion grasses among testing environments. Long-term precipitation (1971–2000) across the winter growing season (September to April) for Stephenville, Vashti, Burneyville, and Ardmore averaged 505, 538, 611, and 610 mm, respectively. For the 2006 to 2007 growing season, precipitation summed to 553, 617, and 430 mm at Stephenville, Vashti, and Burneyville, respectively. Thus, Burneyville had less precipitation than the long-term average and less than that of Stephenville and Vashti in the first year of these trials. During the 2007 to 2008 growing season, precipitation summed to 349, 378, and 384 mm at Vashti, Burneyville, and Ardmore, respectively. Thus, all locations had less precipitation from long-term location averages in the second year of these trials. Average annual temperatures were similar to long-term average annual temperatures (17°C) for each location, and the first fall freeze (November 30) and last spring freeze (March 5) dates were similar across locations.

TABLE 2
ANALYSIS OF VARIANCE OF FREEZE DAMAGE, VIGOR, AND SPRING STANDING CROP OF 14 ANNUAL LEGUME SPECIES OVERSEEDED WITH PERENNIAL GRASSES ACROSS SIX ENVIRONMENTS IN THE SOUTHERN GREAT PLAINS

			Standing crop	
Source of variation	**Freeze damage**	**Vigor**	**Legume**	**Grass**
	——— *P* value ———			
Environment	0.0303	<0.0001	<0.0001	<0.0001
Legume species	<0.0001	<0.0001	<0.0001	<0.0001
Environment • Legume species	<0.0001	<0.0001	<0.0001	0.0003

Freeze Damage and Early-Spring Vigor

Freeze damage varied among legume species (Table 3). Hairy vetch and rose clover did not suffer freeze damage (0%) at any of the testing environments. A few legume species on average had low levels (<8%) of freeze damage across environments. These included entries of arrowleaf clover, Austrian winter pea, ball clover, crimson clover, little burr medic, rigid medic, subterranean clover, and Tifton burr medic. Legume species that suffered freeze damage (>15%) on average across testing environments included button medic, burr medic, common vetch, and white sweetclover. Among testing environments, freeze damage was greatest at Vashti in 2008 and may have been compounded by the dry conditions at this location.

Hairy vetch, followed by Austrian winter pea, had the greatest early-spring vigor across testing environments (Table 3). Their early-spring vigor scores averaged 6.82 and 5.92, respectively. Legumes with low early-spring vigor scores, <2.15 on average, included entries of burr medic, common vetch, and white sweetclover. Most other legume species had slightly better to moderate early-spring vigor with average scores ranging from 2.70 to 3.53.

Legume Standing Crop

Spring standing crop depended on legume species and environment. Across environments, standing crop was greatest for hairy vetch and Austrian winter pea (Table 4). At Ardmore, spring standing crop averaged 3,763 and 2,982 kg DM ha^{-1} for hairy vetch and Austrian winter pea, respectively. Burr medic, little burr medic, Tifton burr medic, common vetch, white sweetclover, and subterranean clover performed poorly at Ardmore, as standing crop among these legumes ranged from 160 to 707 kg DM ha^{-1}. Arrowleaf clover, button medic, crimson clover, rigid medic, and rose clover had similar spring standing crop, ranging from 1,241 to 2,227 kg DM ha^{-1}.

At Burneyville, legume standing crop was measured in 2007 and 2008 (Table 4). Again, hairy vetch and Austrian winter pea performed well, as standing crop averaged 3,590 and 3,066 kg DM ha^{-1}, respectively, at this location in 2007. Many of the annual medics also had high spring standing crop at this environment. Standing crop ranged from 995 kg DM ha^{-1} for rigid medic to 3,755 kg DM ha^{-1} for button medic (Table 4). In 2008, Austrian winter pea and hairy vetch had the greatest standing crop, ranging from 3,387 to 4,181 kg DM ha^{-1}. Standing crop also was considerable for many of the annual medics, averaging from 1,976 kg DM ha^{-1} for little burr medic, 2,284 kg DM ha^{-1} for rigid medic, 2,439 kg DM ha^{-1} for Tifton burr medic and 2,580 kg DM ha^{-1} for button medic. Annual clovers generally performed poorly at this site in 2007 and 2008 (Table 4). Spring standing crop of crimson clover ranged from 473 to 961 kg DM ha^{-1} across years. Rose clover had the best standing crop of annual clovers, averaging 2,503 kg DM ha^{-1} in 2007 and 2,071 kg DM ha^{-1} in 2008.

Standing crop at Stephenville was highest for hairy vetch, Austrian winter pea, and rose clover, ranging from 2,818 to 3,292 kg DM ha^{-1} (Table 4). Arrowleaf clover, burr medic, and button medic had a moderate spring standing crop, ranging from 1,071 to 1,233 kg DM ha^{-1}. Across species and cultivars, forage mass of annual medics and

TABLE 3
VISUAL RATINGS OF FREEZE DAMAGE AND VIGOR OF LEGUMES
AT BURNEYVILLE AND ARDMORE, OKLAHOMA, AND VASHTI, TEXAS

	Freeze damage					**Vigor rating**				
	Burneyville	**Ardmore**	**Vashti**			**Burneyville**	**Ardmore**	**Vashti**		
Legume entry	**2007**	**2008**	**2007**	**2008**	**Average**	**2007**	**2008**	**2007**	**2008**	**Average**
	Percentage (%)					Scale 1–9				
Arrowleaf clover	0.00	0.63	0.00	0.00	0.16	1.00	3.44	4.38	2.58	2.85
Austrian winter pea	18.75	1.25	11.25	0.00	7.81	4.75	5.50	7.75	5.69	5.92
Ball clover	2.50	—	0.00	—	1.25	1.25	—	4.13	—	2.69
Button medic	0.00	2.69	1.56	55.65	14.98	3.88	2.70	3.19	1.03	2.70
Burr medic	15.00	9.42	18.75	85.17	32.09	2.75	2.71	2.75	0.38	2.15
Common vetch	—	58.75	—	15.00	36.88	—	1.00	—	3.06	2.03
Crimson clover	7.50	0.63	2.50	0.63	2.82	2.00	3.44	5.13	3.56	3.53
Hairy vetch	0.00	0.00	0.00	0.00	0.00	5.25	6.00	8.63	7.38	6.82
Little burr medic	2.50	0.63	0.00	21.88	6.25	4.00	2.46	3.00	1.66	2.78
Rigid medic	1.25	0.00	6.25	2.68	2.55	1.94	3.34	3.69	3.31	3.07
Rose clover	0.00	0.00	0.00	0.00	0.00	2.50	2.38	4.00	2.13	2.75
Subterranean clover	0.00	0.75	3.75	0.00	1.13	1.25	2.62	5.25	3.06	3.05
Tifton burr medic	4.50	0.50	1.50	2.63	2.28	3.75	2.13	3.50	2.33	2.93
White sweetclover	34.38	36.25	—	0.75	23.79	2.13	1.13	—	1.81	1.69
Average	6.17	8.58	3.80	14.18	8.39	2.80	2.98	4.62	2.92	3.31
LSD[a]	6.1	4.9	6.5	22.9	9.2	0.6	0.6	0.8	0.9	0.5

Note: Dash (—) indicates not seeded.
[a]Least significant difference (LSD) for comparison of legume species within environments.

TABLE 4
SPRING STANDING CROP OF LEGUMES AT ARDMORE AND BURNEYVILLE, OKLAHOMA, AND STEPHENVILLE AND VASHTI, TEXAS

	Ardmore	Burneyville		Stephenville	Vashti		
Legume species	2008	2007	2008	2007	2007	2008	Average
	Yield (kg DM ha^{-1})						
Arrowleaf clover	1,347	2,063	471	1,233	999	313	1,071
Austrian winter pea	2,982	3,066	4,181	3,292	3,022	2,720	3,210
Ball clover	—	963	—	76	1004	—	681
Button medic	1,367	3,755	2,580	1,169	875	216	1,660
Burr medic	684	2,429	498	1,071	1,556	38	1,046
Common vetch	160	—	1,357	—	—	369	629
Crimson clover	2,227	473	961	278	1,718	1,175	1,138
Hairy vetch	3,763	3,590	3,387	2,997	3,812	3,529	3,513
Little burr medic	698	3,658	1,976	433	1,054	126	1,324
Rigid medic	1,275	995	2,284	43	1,008	1,033	1,105
Rose clover	1,241	2,503	2,071	2,818	1,071	202	1,650
Subterranean clover	707	14	336	0	1280	600	490
Tifton burr medic	472	2,856	2,439	82	898	132	1,146
White sweetclover	186	1,576	659	—	—	120	635
Average	1,316	2,149	1,784	1,124	1,525	813	1,455
LSD[a]	733	1,092	968	694	711	617	450

Note: Dash (—) indicates not seeded.
[a]Least significant difference (LSD) for comparisons among legume species within environments.

annual clovers averaged 660 and 748 kg DM ha^{-1}, respectively. At Vashti, standing crop was best for hairy vetch and Austrian winter pea, ranging from 3,022 to 3,812 kg DM ha^{-1} in 2007 (Table 4). Spring standing crop of annual medics and annual clovers averaged 1,078 and 1,214 kg DM ha^{-1}, respectively. In 2008, standing crop averaged 2,720 kg DM ha^{-1} for Austrian winter pea and 3,529 kg DM ha^{-1} for hairy vetch, respectively. Standing crop of annual medics and annual clovers averaged 309 and 831 kg DM ha^{-1}, respectively.

Compatibility of Legumes with Forage Grasses

Although hairy vetch and Austrian winter pea had the greatest spring standing crop of legume species, they demonstrated potential to reduce standing crop of companion grasses, switchgrass and tall fescue (Table 5). At Stephenville in 2007, spring standing crop of the existing switchgrass stand averaged 1,052 kg DM ha^{-1} when mixed with Austrian winter pea or hairy vetch compared to an average of 2,512 kg DM ha^{-1} across the other legume species. At Ardmore in 2008, standing crop of seedling tall fescue was reduced from an average of 1,767 kg DM ha^{-1} across other legume species to 1,035 kg DM ha^{-1} when combined with Austrian winter pea and hairy vetch (Table 5). Hairy vetch severely limited standing crop of seedling tall fescue at Vashti in 2007 and 2008. From 2007 to 2008, seedling tall fescue standing crop ranged from 158 to 301 kg DM ha^{-1} when seeded with hairy vetch compared to an average of 1,062 to 1,238 kg DM ha^{-1} across the other legume species. Seeding arrowleaf clover, crimson clover, rigid medic, and button medic with

TABLE 5
EFFECTS OF LEGUMES ON SPRING STANDING CROP OF SWITCHGRASS AT STEPHENVILLE, TEXAS, AND TALL FESCUE AT ARDMORE, OKLAHOMA, AND VASHTI, TEXAS

	Stephenville	Ardmore	Vashti		
Legume species	**2007**	**2008**	**2007**	**2008**	**Average**
	Yield (kg DM ha^{-1})				
Arrowleaf clover	2,428	1,233	995	1,188	1,461
Austrian winter pea	990	861	1,208	604	916
Ball clover	2,225	—	1,005	—	1,562
Burr medic	1,751	1,300	1,440	1,036	1,382
Button medic	2,657	1,532	1,337	899	1,606
Common vetch	—	2,420	—	1,464	1,942
Crimson clover	2,455	996	1,230	756	1,359
Hairy vetch	1,114	1,208	158	301	695
Little burr medic	2,376	1,834	1,472	1,215	1,724
Rigid medic	2,779	1,524	1,191	813	1,577
Rose clover	2,214	2,602	877	1,651	1,835
Subterranean clover	3,264	1,401	1,434	498	1,639
Tifton burr medic	2,966	2,160	1,428	1,192	1,935
White sweetclover	—	2,434	—	1,432	1,933
Average	2,268	1,523	1,148	1,004	1,510
LSD[a]	982	732	510	616	495

Note: Dash (—) indicates not seeded.
[a]Least significant difference (LSD) for comparisons among legume species within environments.

tall fescue provided consistent standing crop of both grass and legume components at Ardmore and Vashti across years. Although only standing crop of the legume component was measured at Burneyville in 2007 and 2008, negative effects of legume species on standing crop of eastern gamagrass were not apparent as the legumes generally grew and senesced between rows of the existing stand of grass.

DISCUSSION

Annual Pasture Legumes for the Southern Plains

Hairy vetch and Austrian winter pea clearly demonstrated superior spring standing crop as autumn-seeded annual legumes across all the environments. Previous research has found hairy vetch to be adapted to a wide range of soil textures and pH (5.5 to 8.0). Bloat potential also is low, and it shows good cold tolerance. For successful overseeding of warm-season perennial grasses with winter annual legumes, it is important to reduce warm-season grass competition in autumn before seeding. Planting should occur four to six weeks before the average first killing frost at seeding rates of 22 to 34 kg ha^{-1}. Because of its large seed size, hairy vetch should be drilled 1.2 to 2.5 cm deep to result in good stands (Evers 2005). Caution is necessary when seeding legumes together with perennial grasses such as tall fescue on clean-tilled seedbeds, as competition from these legumes tended to overwhelm the grass seedlings, limiting their ability to establish. Compatibility of these legumes with established grasses such as switchgrass and eastern gamagrass, however,

is questionable. Although they did not appear to reduce standing crop of eastern gamagrass, they reduced spring standing crop of switchgrass. This may be due to winter legumes reducing available soil moisture for the warm-season grass in spring. Grazing of swards with hairy vetch and Austrian winter pea by late April may reduce their dominance over and improve their compatibility with pasture grasses.

Crimson and arrowleaf clovers have been identified as the most dependable winter annual forage legumes in the southeastern United States (Sheaffer and Evers 2007). They performed moderately well across most environments in this zone of 760 to 890 mm annual rainfall, with the exception of Burneyville. A soil pH > 8.0 may have limited clover success on this site because iron-deficiency chlorosis occurs when pH exceeds 7.5 (Sheaffer and Evers 2007). Standing crop of arrowleaf clover also may have been limited at all locations by the mid-April harvests because arrowleaf clover is a later-maturing clover (Evers and Newman 2008). Planting early in the growing season or using later-maturing cultivars can maximize production of annual legumes and lengthen the grazing season (Butler et al. 2002). Crimson clover often is used successfully in pasture-based production systems because of its early maturity and excellent seedling vigor (Evers 1999). Blends of early- and late-maturing types may provide a longer season of high-quality grazing and enhance nitrogen contribution to the pasture (Muir et al. 2005).

Rose clover performed moderately well at the high-soil-pH site at Burneyville in 2007 and 2008, Ardmore in 2008, and Stephenville in 2007, but poorly at Vashti in 2007 and 2008. Rose clover is adapted to slightly alkaline soils (Smith et al. 1992; Evers and Newman 2008), explaining why it performed better than other annual clovers on the high-soil-pH site at Burneyville. Standing crop of ball clover (*T. nigrescens* Viv.) and subterranean clovers were poor to marginal on all sites, and therefore are not recommended for planting in this 760 to 890 mm rainfall zone. Subterranean clover suffers from Fe deficiency on high pH soils and is susceptible to freeze damage during cold winters (Evers 1999).

Success of annual medics depended on the species. Little burr medic cv. Devine, as well as NF (Noble Foundation) and Estes button medics, suffered the least freeze damage and were generally the most productive. They had excellent spring standing crop on the high pH soils at Burneyville, where annual clovers suffered. Released in 2005, Devine little burr medic was developed by Texas AgriLife Research for central Texas between Dallas (32°N latitude) and San Antonio (29°N latitude). Desirable attributes included tolerance to freeze damage, better forage and hard seed production, and positive seed production under grazing (Ocumpaugh et al. 2007).

Burr medic suffered the most freeze damage, and its ability to provide consistent spring forage in north-central Texas and south-central Oklahoma appears limited. In 2008, all medics with the exception of rigid medic suffered heavy freeze damage and performed poorly at Vashti. Their persistence in the south-central US environments will depend on their ability to tolerate killing freezes and on hard seed production to develop soil seed reserves (Muir et al. 2001; Muir et al. 2005). Availability of sufficient soil moisture, high concentrations of soil P, and limited competition from grasses are necessary to ensure maximum growth. Naturalized populations of annual medics typically occur on disturbed sites without much competition from grasses (Diggs et al. 1999; Muir et al. 2001). Annual medics do not grow well with sod-forming grasses but may have a role with bunchgrasses in low summer-rainfall areas (Muir et al. 2001). Annual medics also have value if stands regenerate from year to year without additional inputs (Muir et al. 2005).

With the exception of hairy vetch and Austrian winter pea, legumes did not interfere with subsequent grass development, suggesting they may be successfully overseeded into existing pastures or seeded together with grasses in clean-tilled seedbeds. Key factors for success of legumes when overseeding or seeding with perennial grasses will include attention to proper soil pH, P, and K (Bow et al. 2008). A pH of 6.5 is considered optimum for nitrogen fixation, and legumes generally respond well to P fertilization (Snyder and Leep 2007). Seed yields and self-regeneration of annual clovers and medics also are important considerations when evaluating use of these legumes in forage systems (Muir et al. 2005). Research is needed to determine how grazing intensity affects the ability of winter annual legumes to produce sufficient seed to replenish soil seed banks and self-regenerate. Minimum volunteer reseeding stands of 100 legume seedlings m^{-2} have been noted as necessary for good stand persistence (Evers 2005). Successful reseeding of annual clovers also depends on production of an adequate seed crop with a high percentage of hard seed (Evers and Smith 2006). Hard seed is a dormancy mechanism where an impermeable seed coat prevents absorption of water and germination as opposed to soft seed, which absorbs water and germinates readily (Beuselinck et al. 1994). The rate at which hard seed in soil declines through time depends

on legume species and climatic factors. Future research on legume persistence and reseeding under grazing will improve understanding of the value of different legumes in forage-based beef production systems regionally.

ACKNOWLEDGMENTS

The authors thank Jim Stein, John R. Bow, Julie Barrick, Tabby Campbell, and Shawn Norton for their contributions to this research and the Samuel Roberts Noble Foundation and Texas AgriLife Research and Extension Service for funding these efforts.

REFERENCES

Beuselinck, P.R., J.H. Bouton, W.O. Lamp, A.G. Matches, M.H. McCaslin, C.J. Nelson, L.H. Rhodes, C.C. Sheaffer, and J.J. Volenec. 1994. Improving legume persistence in forage crop systems. *Journal of Production Agriculture* 7:311-22.

Bow, J.R., J.P. Muir, D.C. Weindorf, R.E. Rosiere, and T.J. Butler. 2008. Integration of cool-season annual legumes and dairy manure compost with switchgrass. *Crop Science* 48:1621-28.

Butler, T.J., G.W. Evers, M.A. Hussey, and L.J. Ringer. 2002. Flowering in crimson clover as affected by planting date. *Crop Science* 42:242-47.

Diggs, G.M., Jr., B.L. Lipscomb, and R.J. O'Kennon. 1999. *Shinners and Mahler's Illustrated Flora of North Central Texas*. Botanical Research Institute of Texas, Fort Worth.

Evers, G.W. 1999. Seedling growth comparisons of arrowleaf, crimson, rose, and subterranean clovers. *Crop Science* 39:433-40.

Evers, G.W. 2005. A guide to overseeding warm-season perennial grasses with cool-season annuals. *Forage and Grazinglands* doi:10.1094/FG-2004-0614-01-MG.

Evers, G.W., and Y.C. Newman. 2008. Arrowleaf, crimson, rose, and subterranean clover growth with and without defoliation in the southeastern United States. *Agronomy Journal* 100:221-30.

Evers, G.W., and G.R. Smith. 2006. Crimson clover seed production and volunteer reseeding at various grazing termination dates. *Agronomy Journal* 98:1410-15.

Heichel, G.H. 1985. Symbiosis: Nodule bacteria and leguminous plants. In *Forages: The Science of Grassland Agriculture*, ed. M.E. Heath, R.F. Barnes, and D.S. Metcalfe, 64-71. Iowa State University Press, Ames.

Muir, J.P., W.R. Ocumpaugh, and T.J. Butler. 2005. Trade-offs in forage and seed parameters of annual *Medicago* and *Trifolium* species in north-central Texas as affected by harvest intensity. *Agronomy Journal* 97:118–24.

Muir, J.P., W.D. Pitman, and D.F. Coombs. 2001. Seeding rate and phosphorous fertilization effects on "Armadillo" burr medic establishment. *Agronomy Journal* 93:1269–75.

Ocumpaugh, W.R., D.N. Ueckert, J.P. Muir, T.J. Butler, and R.L. Reed. 2007. Registration of "Devine" little burr medic. *Journal of Plant Registrations* 1:31–32.

Sheaffer, C.C., and G.W. Evers. 2007. Cool-season legumes for humid areas. In *Forages: The Science of Grassland Agriculture*, 6th ed., ed. C.J. Nelson, R.F. Barnes, K.J. Moore, and M. Collins. Blackwell Publishing, Oxford, UK.

Smith, G.R., F.M. Rouquette, Jr., G.W. Evers, M.A. Hussey, W.R. Ocumpaugh, J.C. Read, and A.M. Schubert. 1992. Registration of "Overton R18" rose clover. *Crop Science* 32:1507.

Snyder, C.S., and R.H. Leep. 2007. Fertilization. In *Forages: The Science of Grassland Agriculture*, 6th ed., ed. C.J. Nelson, R.F. Barnes, K.J. Moore, and M. Collins. Blackwell Publishing, Oxford, UK.

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

Great Plains Research 22 (Spring 2012):45–58
2012 Published by the Center for Great Plains Studies, University of Nebraska-Lincoln

A CONCEPTUAL MODEL TO FACILITATE AMPHIBIAN CONSERVATION IN THE NORTHERN GREAT PLAINS

David M. Mushet

U.S. Geological Survey
Northern Prairie Wildlife Research Center
8711 37th Street SE
Jamestown, ND 58401
dmushet@usgs.gov
and
Environmental and Conservation Science Program
North Dakota State University
Fargo, ND 58105

Ned H. Euliss, Jr.

U.S. Geological Survey
Northern Prairie Wildlife Research Center
8711 37th Street SE
Jamestown, ND 58401
ceuliss@usgs.gov

and

Craig A. Stockwell

Department of Biological Sciences and Environmental and Conservation Science Program
North Dakota State University
Fargo, ND 58105
craig.stockwell@ndsu.edu

ABSTRACT—As pressures on agricultural landscapes to meet worldwide resource needs increase, amphibian populations face numerous threats including habitat destruction, chemical contaminants, disease outbreaks, wetland sedimentation, and synergistic effects of these perturbations. To facilitate conservation planning, we developed a conceptual model depicting elements critical for amphibian conservation in the northern Great Plains. First, we linked upland, wetland, and landscape features to specific ecological attributes. Ecological attributes included adult survival; reproduction and survival to metamorphosis; and successful dispersal and recolonization. Second, we linked ecosystem drivers, ecosystem stressors, and ecological effects of the region to each ecological attribute. Lastly, we summarized information on these ecological attributes and the drivers, stressors, and effects that work in concert to influence the maintenance of viable and genetically diverse amphibian populations in the northern Great Plains. While our focus was on the northern Great Plains, our conceptual model can be tailored to other geographic regions and taxa.

Key Words: amphibian conservation, adaptive management, conceptual models, ecological attributes, ecological effects, ecosystem drivers, ecosystem stressors

INTRODUCTION

Amphibian populations have been declining worldwide largely due to anthropogenic habitat alteration (Blaustein and Wake 1990; Wyman 1990; Pechmann et al. 1991; Alford and Richards 1999; Kiesecker et al. 2001; Green 2003). In the northern Great Plains, habitat alteration has consisted primarily of wetland and grassland conversion to cropland. Approximately half the wetlands in the northern Great Plains have been lost (Tiner 1984; Dahl 1990) and 34% of the upland habitats have been

Manuscript received for review, March 2011; accepted for publication, August 2011.

converted to agricultural production (Euliss et al. 2006). Conversely, over 2,200,000 ha of wetland and grassland habitats have been restored in the northern Great Plains (Gleason et al. 2008), but many of these restored habitats are vulnerable for conversion back to agricultural production due to rising commodity prices. In order to conserve amphibian populations within agricultural landscapes, we need a better understanding of habitats important to amphibian populations in the northern Great Plains. For amphibians, these habitats consist principally of wetland, upland, and landscape features that influence a species' viability through survival, reproduction, and successful dispersal.

Conceptual ecological models are effective tools for summarizing and organizing our current understanding of ecosystem structure and function (Heemskerk et al. 2003). Through the use of illustrations, conceptual models provide a means of communicating scientific thought by visualizing the linkages among major ecosystem drivers and stressors, the ways they affect ecological outcomes, and their relationship to specific habitat components that can be purposely manipulated by management. Hence, conceptual models are not ends in themselves but are effective for developing conservation plans or establishing new policy. Specifically, conceptual models can aid communication, inquiry, and consensus building among scientists, managers, policy makers, and a diverse public (Maddox et al. 1999; Ogden et al. 2005). As an example, Ogden et al. (2005) introduce a set of conceptual models as a tool to facilitate efforts to design and assess the Everglades restoration program. To facilitate amphibian conservation and management in the northern Great Plains, we developed a similar conceptual model to better inform decision makers' conservation plans for the region's amphibian populations. Our model links important ecosystem drivers, ecosystem stressors, ecological effects, and ecological attributes (Fig. 1) influencing amphibian population viability and genetic diversity in the northern Great Plains.

To minimize semantic confusion, we followed Ogden et al. (2005) in defining ecosystem drivers, stressors, effects, and attributes. They define *ecosystem drivers* as major natural and anthropogenic forces occurring outside a system that have large-scale influence on that system. For instance, drivers of amphibian populations in the northern Great Plains are principally associated with continental and regional climate cycles, and economic or political factors that encourage or discourage habitat alteration. *Ecosystem stressors* are changes brought about by the drivers that cause changes in physical, chemical, or biotic components of an ecosystem. Droughts, tillage of soils, wetland drainage, and use of agrichemicals are examples of typical ecosystem stressors faced by amphibian populations in the northern Great Plains. *Ecological effects* are physical, chemical, or biological responses to the stressors. As an example, increased runoff, increased sedimentation, altered water depths, and altered plant communities can all be ecological effects of soil tillage (an ecosystem stressor). Lastly, *ecological attributes* are the affected components of an ecosystem that can be linked to specific processes important for system sustainability. Thus, in the example above, the effects of tillage can result in reduced dispersal and recolonization success. This ecological attribute influences the viability and genetic diversity of amphibian populations.

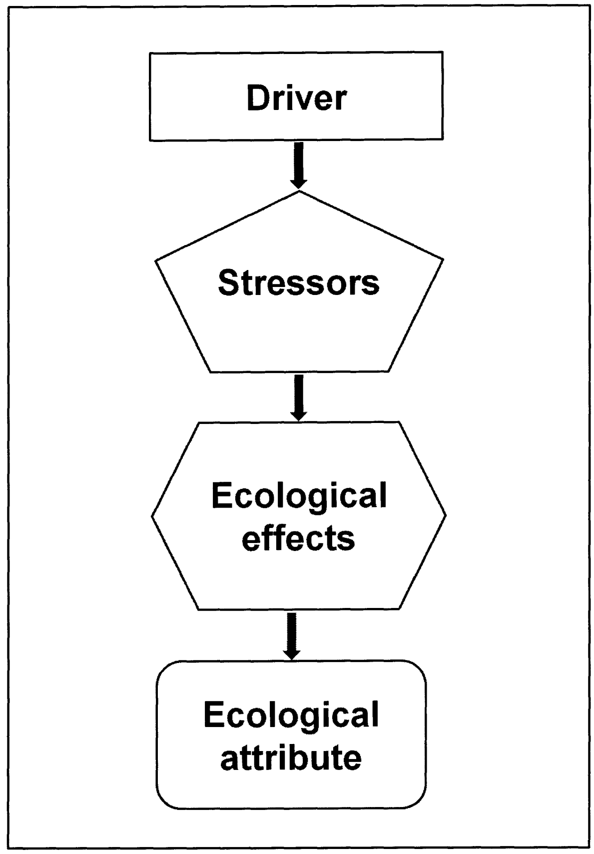

Figure 1. Simplified diagram depicting linkages between a driver and attribute through stressors and their ecological effects (modified from Ogden et al. 2005).

MODEL DESIGN AND METHODS

Tradeoffs between model generality and model realism affect the ability of a single model to adequately describe an entire system or even a part of a system (Mad-

dox et al. 1999). The generality needed to make a model applicable to an entire region would by necessity focus on broad-scale ecosystem drivers while providing few details of intricate connections. However, to obtain realism, considerable details are needed to identify important connections. Here, we attempted to find a compromise between model generality and realism through use of a two-stage process. First we used existing literature to develop a generalized model that identifies key habitat components and ecological attributes affecting amphibian populations in the northern Great Plains (Fig. 2). Using the ecological attributes as end points, we then defined linkages to major natural and anthropogenic ecosystem drivers through the identification of ecosystem stressors and their ecological effects. We organized these drivers, stressors, effects, and ecological attributes into a second, more detailed model allowing for the visualization of important linkages (Fig. 3). By linking major natural and anthropogenic drivers to key ecological attributes responsible for sustaining diverse amphibian populations in the northern Great Plains, we obtained a clearer understanding of the effects of driver-induced stressors and thus potential impacts on amphibian populations.

HABITAT COMPONENTS IMPORTANT TO NORTHERN GREAT PLAINS AMPHIBIANS

Conditions of wetlands and uplands, and the spatial arrangement of wetlands and uplands at the landscape scale, exert a synergistic influence on amphibian conservation in the northern Great Plains (Fig. 2). Amphibians use wetlands primarily for reproduction. Within wetlands, survival of eggs and larvae to metamorphosis is necessary for continued persistence in an area. However, these breeding wetlands are not spatially independent, and the production of dispersers is needed to maintain viable (Semlitsch 2000) and genetically diverse populations (Wilbur 1980). Water quality, hydroperiod, water depth, and biotic interactions (i.e., predation, competition, parasitism, and disease) affect reproduction and survival of amphibians in the wetland habitat (Semlitsch 2000).

Upland habitats contribute to the survival of adults through summer months. Important habitat components of uplands include vegetative cover, condition of substrates, and the invertebrate food resources they provide (Semlitsch 2000). Amphibian survival through winter is dependent upon components of overwintering habitat within wetlands (e.g., water depth) or uplands (e.g., insulation provided by snow or vegetative biomass), according to which amphibian species is being considered (Lannoo 2005).

At a landscape scale, density and diversity of suitable wetland habitats and the condition of the habitats between wetlands significantly affect dispersal and recolonization success (Semlitsch 2000). Thus, wetland, upland, overwintering, and landscape components can be linked to ecological attributes including reproduction and survival to metamorphosis, survival of adults, and successful dispersal and recolonization (Fig. 2).

Wetland Habitats

Amphibians of the northern Great Plains use wetland habitats primarily for mating, egg survival, and larval growth. To maintain viable amphibian populations, adequate numbers of juveniles must be produced to sustain adult breeding populations, rescue local populations, and recolonize areas where populations have become extirpated (Gill 1978). Within wetlands, hydroperiod and biotic interactions (i.e., predation, competition, parasitism, and disease) work in concert to influence the numbers of juveniles produced (Pechmann et al. 1989; Semlitsch et al. 1996).

Both extremely temporary wetlands (i.e., those with hydroperiods of less than 30 days) and permanent wetlands (i.e., those with hydroperiods greater than 1 year) are used by fewer amphibian species than wetlands with intermediate hydroperiods (Heyer et al. 1975; Wilbur 1980). If wetlands dry too quickly, only species with rapid rates of metamorphosis can occur. Additionally, inter- and intraspecific competition for food resources can reduce larval developmental rates, thereby lengthening the aquatic portion of life cycles and increasing vulnerability to desiccation in short-hydroperiod wetlands (Collins and Cheek 1983; Wilbur 1987; Newman 1987; Pfennig 1990; Wilbur and Fauth 1990). Likewise, if a wetland is too permanent, it can become populated with predators (especially fish), which can reduce or eliminate larvae of species that lack antipredator traits (Caldwell et al. 1980; Morin 1986; Kats et al. 1988; Tyler et al. 1998). The diversity and abundance of amphibians in and around wetlands can be greatly impacted by either increasing or decreasing the number of days a wetland holds water (Pechmann et al. 1989).

Wetland water quality can also have a significant impact on amphibian population processes, including egg development and larval survival (Boyer and Grue 1995). For instance, increased sedimentation rates or importation of chemical contaminants can affect amphibian egg survival, larval growth, and successful metamorphosis of young-of-the-year (Boyer and Grue 1995). In agricultural

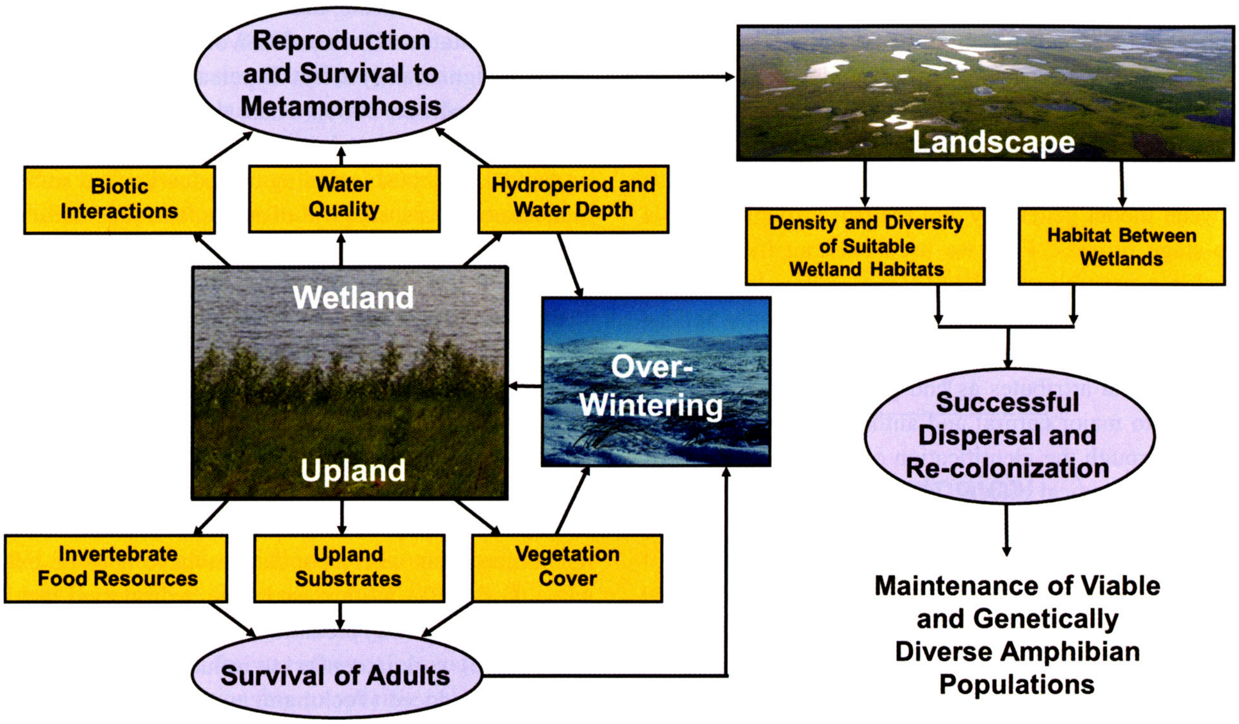

Figure 2. A generalized model depicting connections between habitats (photos), key life-history attributes (ovals), and ecosystem components (rectangles). These lead to maintenance of viable and genetically diverse populations of amphibians in the northern Great Plains.

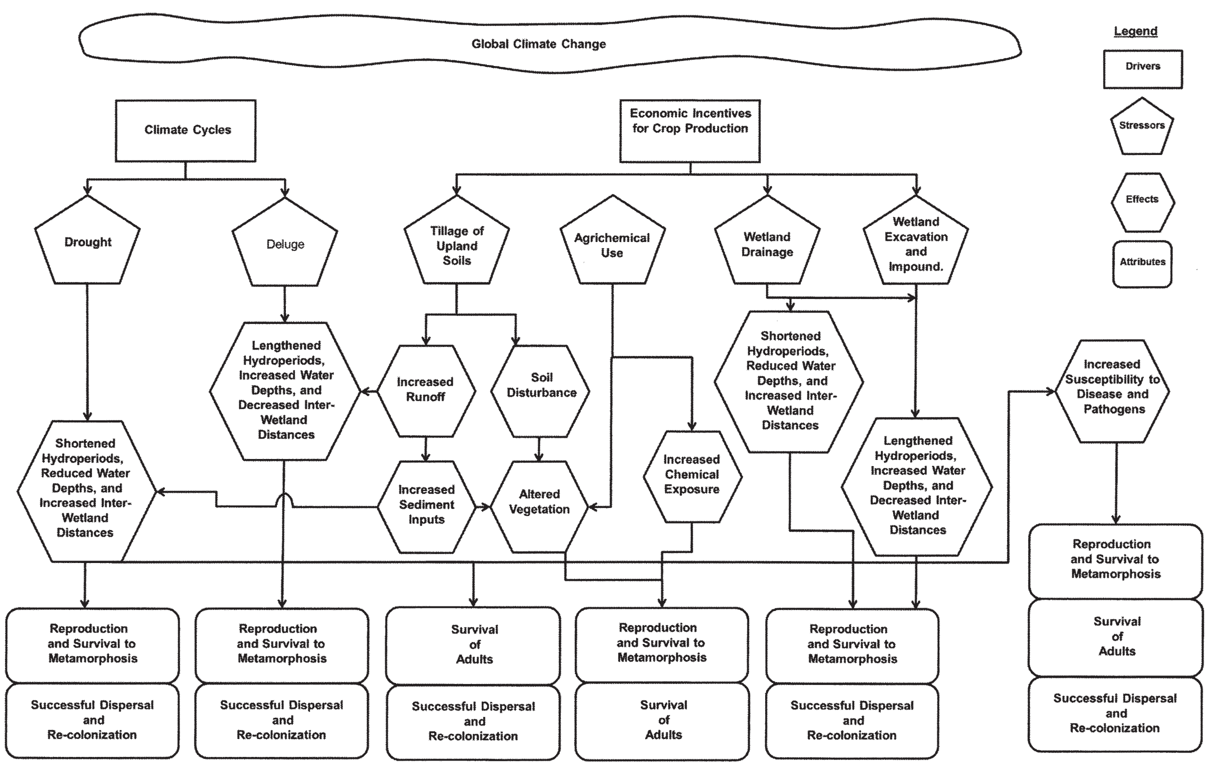

Figure 3. A conceptual model relating key drivers to ecological attributes important to amphibians in the northern Great Plains. Global climate change has the potential to affect both major drivers and therefore all stressors, effects, and life-history attributes. Thus, it is displayed as a cloud overarching the entire model.

areas such as the northern Great Plains, water quality can be an especially contentious issue (e.g., Hayes 2004) due to the potential negative impacts of agrichemicals on water quality and the dependency of the region's agricultural productivity on the use of vast quantities of these chemicals. Further, synergistic interactions of hydroperiod, predation, competition, and water quality can play an important role in amphibian population dynamics, persistence, and community structure (Wellborn et al. 1996; Semlitsch 2000).

Upland Habitats

With the exception of mudpuppies (*Necturus maculosus*), all amphibians of the northern Great Plains have complex life cycles that require both aquatic and terrestrial habitats (Wilbur 1980). Juveniles and adults live in the terrestrial habitat for much of the year (Madison 1997; Semlitsch 1998), where they feed on rich invertebrate food resources found in the upland vegetation (Stebbins and Cohen 1995). Survival in terrestrial habitats is key to ensuring viable populations (Semlitsch 2000). Many agricultural production activities impact uplands and thus adult survival probability (Gray et al. 2004a).

Amphibians can be directly exposed to harmful levels of agricultural pesticides in terrestrial habitats (Semlitsch 2000). Additionally, pesticides can directly affect both native plant and invertebrate communities by killing both target and nontarget species, altering natural food web dynamics important to amphibians. Soil cultivation can reduce live and detrital vegetation that functions as foraging, retreat, and burrow sites for amphibians (Dodd 1996; deMaynadier and Hunter 1998; Herbeck and Larsen 1999; Naughton et al. 2000). Further, cultivation can alter wetland habitats through increased sedimentation (Gleason and Euliss 1998) and water-level fluctuations (Euliss and Mushet 1996).

Overwintering Habitats

Winters in the northern Great Plains deserve special attention because overwintering strategy is a primary factor influencing amphibian distribution and abundance. To overwinter in the northern Great Plains, amphibians rely primarily on behavioral avoidance or physiological mechanisms. Species that behaviorally avoid freezing can be further subdivided into two groups, burrowers and underwater overwinterers. Burrowers, which include the plains spadefoot (*Spea bombifrons*), all the region's toad species (*Anaxyrus* spp.), and tiger salamanders (*Ambystoma* spp.), avoid freezing conditions by burrowing below the frost line in upland habitats (Lannoo 2005). In addition to digging their own burrows, some species have been recorded making use of preexisting burrows where available (e.g., Kolbe et al. 2002).

Amphibians that overwinter underwater avoid freezing temperatures by moving to deep water bodies that do not solidly freeze. The northern leopard frog (*Lithobates pipiens*) overwinters underwater in the northern Great Plains. However, ice thicknesses can approach 1 m in midwinter (Barica 1979), making shallow wetlands unsuitable because they freeze solid to the substrate in most winters. The distribution and abundance of suitable overwintering sites for northern leopard frogs can have a marked influence on the distribution of this species.

Lastly, some amphibian species (e.g., wood frogs [*Lithobates sylvatica*], boreal chorus frogs [*Pseudacris maculata*]) rely primarily on physiological means to survive winters (for a review see Storey and Storey 1992). Freeze-tolerant species transport sugars, primarily from their livers, into cells throughout their bodies, which prevents the destructive and lethal formation of ice crystals within cells, even while the extracellular fluids surrounding cells freeze solidly (Lee et al. 1992). The ability of the wood frog to not only resist but also tolerate freezing has allowed this species to occur in areas farther north than any other North American amphibian species (Lannoo 2005).

Landscape Characteristics

At the landscape scale, amphibians often can be characterized as exhibiting a metapopulation structure. Amphibian metapopulations are influenced by the number of juveniles dispersing and the probability that an individual will successfully reach and reproduce in a new breeding habitat (Hanski and Gilpin 1991; Sjögren 1991; Gibbs 1993). However, metapopulation spatial structure can be impacted by wetland drainage, which has substantially reduced the number and density of wetlands in agricultural landscapes (Tiner 1984; Dahl 1990; Dahl and Johnson 1991; Findlay and Houlahan 1997; Knutson et al. 1999; Kolozsvary and Swilhart 1999; Lehtinen et al. 1999; Gray et al. 2004b). Conservation programs that increase the number and landscape connectivity of wetlands are critical for conserving sustainable metapopulations. Increases in wetland numbers ultimately reduce interwetland distances, thereby increasing the likelihood for successful dispersal. Successful dispersal is especially important as populations frequently become extirpated

due to persistent drought or localized climate variation (Dodd 1993; Semlitsch et al. 1996; Lannoo 1998).

Understanding the spatial and temporal dynamics of amphibian metapopulations is critical to evaluating how populations respond to anthropogenic as well as natural disturbance. In most amphibian metapopulation studies, the breeding pond is considered as the basic spatial unit used to delineate subpopulations of the larger metapopulation (e.g., Gill 1978; Sjögren 1991; Sjögren-Gulve 1994; Edenhamn 1996; Hecnar and M'Closkey 1996; Skelly and Meir 1997; Trenham 1998). Interpopulation movement, population dynamics, and genetic structure are then assessed based on the delineated subpopulations. However, this "ponds-as-patches" view of amphibian metapopulations may present an oversimplification of amphibian spatial dynamics that can lead us to lose focus on other habitat components critical to amphibian conservation and metapopulation dynamics (Marsh and Trenham 2001). The adults of most pond-breeding amphibians spend the majority of their lives away from breeding ponds in terrestrial habitats (Wilbur 1984). Additionally, some amphibian species use different wetland types over the course of their life cycles. Aggregations of breeding adults at individual ponds may not represent distinct subpopulations (Marsh and Trenham 2001), and thus, breeding ponds may not be the spatial unit best suited for evaluating metapopulation dynamics.

Terrestrial habitat between wetlands also is a key habitat component influencing juvenile dispersal success (Semlitsch 2000). Although little information is available on the dispersal of amphibians through terrestrial habitats, it is likely that implementation of conservation plans that maintain continuous natural habitat cover or corridors between neighboring wetlands would reduce risks to predation, desiccation, and starvation of dispersers. In addition, the spatial distribution of overwintering habitat can be important. For example, wetlands that do not freeze solidly are critical to overwintering northern leopard frogs, especially during drought, when water depths are reduced. The spatial distribution of such "drought refugia" can affect population dynamics of this species for several years following droughts (Mushet 2010).

DRIVERS, STRESSORS, AND EFFECTS

In the northern Great Plains, major drivers affecting amphibian populations include climate cycles and economic incentives for crop production. These drivers can be linked to ecological attributes important to the maintenance of viable and genetically diverse amphibian populations through ecosystem stressors and their ecological effects (Fig. 3). Here we list ecosystem stressors tied to these major drivers and provide details on their ecological effects on amphibians.

Interannual Climate Variation

In the northern Great Plains, 10- to 20-year precipitation cycles include periods of drought (Woodhouse and Overpeck 1998) alternating with periods of average or above average rainfall (Duvick and Blasing 1981; Karl and Koscielny 1982; Diaz 1983; Karl and Riebsame 1984; Diaz 1986; Winter and Rosenberry 1998). During years of drought, wetlands in the northern Great Plains have severely shortened hydroperiods resulting in decreased wetland water depths and in some cases complete desiccation of wetlands. During persistent periods of above-average precipitation, wetlands become more permanent and fish may become established, resulting in degradation of their value as amphibian breeding sites (Semlitsch 2000). Most wetlands in the northern Great Plains were historically fish-free due to seasonally ephemeral water conditions, cyclical droughts, isolation from other wetland and riverine systems, and extreme temperatures that froze wetlands solid during winter (Peterka 1989). However, consolidation drainage, excavation of dugouts within wetlands for cattle watering, connection of wetlands through artificial drainage networks, and extended periods of above-normal precipitation all have led to more favorable conditions for fish in many of the region's wetlands. Further, active movement of fish into and among wetlands by commercial bait dealers and fishery managers has greatly expanded the presence of fish within the region's wetlands. Predatory fish feed directly upon amphibian larvae, many of which lack natural defenses to predators given the fishless habitats in which they evolved (Kats et al. 1988). Additionally, planktivorous fish can reduce the abundance of large filter-feeding invertebrates in lakes, leading to turbid waters (Spencer and King 1984; Hanson and Butler 1990) that slow the growth of submerged hydrophytes (Hanson and Butler 1990). These hydrophytes provide structure for epiphytic algae, the food base for anuran larvae. Thus, amphibian assemblages have been found to vary greatly between wetlands with and without fish (Kats et al. 1988; Hecnar and M'Closkey 1996).

Wetland Drainage

Wetland drainage in the northern Great Plains can have ecological effects similar to those expressed during

periods of natural drought (i.e., significantly reducing hydroperiod length, often to the point that the wetlands can no longer provide for reproduction of amphibians). However, wetland drainage can also effectively lengthen the hydroperiod of lower-elevation terminal wetlands into which other wetlands have been drained, potentially mimicking the ecological effects expressed during natural periods of abundant precipitation (Fig. 3). Additionally, the increased connectivity among wetlands due to the creation of artificial drainage networks allows for the increased movement of aquatic organisms, including fish, among wetlands, having potential negative impacts on amphibians. Thus, when we consider the effects of wetland drainage on amphibians of the northern Great Plains, we must also take into account not only the loss of wetlands from drainage but also the effect of drainage water on wetlands receiving it and also the increased interconnectivity among wetlands.

Tillage of Upland Soils

Conversion of grasslands to agriculturally productive croplands in the northern Great Plains has fundamentally changed the nature of the landscape in which the region's amphibians exist. For example, the dominance of agriculture has resulted in an increase in the import of sediments from surrounding uplands into wetland basins (Adomaitis et al. 1967; Martin and Hartman 1987; Gleason 1996; Gleason and Euliss 1998; Gleason 2001). This chronic filling of wetlands has resulted in altered water depths and storage volumes (Gleason and Euliss 1998; Gleason 2001). Chronic reduction in depth has effectively shortened the hydroperiod and as a consequence has reduced the number and distribution of overwintering refuge sites for the northern leopard frog. Sedimentation has been shown to influence the composition of the plant and invertebrate communities (Jurik et al. 1994; Wang et al. 1994; Gleason and Euliss 1998; Gleason et al. 2003), which can alter food web dynamics important to amphibians (Stebbins and Cohen 1995).

Agrichemical Use

Amphibian populations of the northern Great Plains are affected by both inorganic and organic contaminants. Rouse et al. (1999) reported that nitrate in concentrations found in many surface waters is one of the most widespread contaminant threats to North American amphibians. Nitrogen from nitrogen-based fertilizers and livestock waste accumulates in wetlands (Goolsby et al. 1991) where it typically occurs in the form of nitrate. Nitrate at concentrations found in many agricultural wetlands (>1 mg/L) has been shown to cause both acute and toxic effects in amphibians (Berger 1989; Baker and Waights 1993, 1994; Bishop et al. 1999). Agricultural fertilization can also lead to the accumulation of phosphates in wetlands, which can affect amphibians by enhancing snail populations, the intermediate hosts of many amphibian parasites.

Amphibians are also often exposed to a diverse array of organic agricultural pesticides, which can have significant effects on amphibian populations (Bishop 1992; Hall and Henry 1992; Berrill et al. 1993, 1997; Smith 2001; Hayes 2004; Howe et al. 2004; Relyea 2005a, 2005b) and their aquatic food resources (Relyea 2005a, 2009). Studies have shown even extremely low concentrations of pesticides such as atrazine can have important effects on amphibians (e.g., 0.1 ppb for atrazine, Hayes et al. 2003). Additionally, multiple agricultural chemicals can act synergistically in aquatic environments (Howe et al. 1998; Relyea 2004a, 2009), and these chemicals can also act synergistically with predatory stress (Boone and Semlitsch 2001; Relyea 2004b; Rohr et al. 2006). Given these ecological effects, conservation efforts should include mechanisms for reducing exposure of amphibians to these chemicals.

Wetland Excavation and Impoundment

In efforts to increase the agricultural and waterfowl productivity of drier portions of the northern Great Plains in the west, thousands of wetlands with relatively long hydroperiods have been created primarily by damming low-order surface flows (Ruwaldt et al. 1979; Willis 2001) or excavating existing wetlands (Euliss and Mushet 2004) (Fig. 4). Excavated and impounded wetlands often are stocked with predatory fish that can have a negative impact on amphibian communities. As with natural climate cycles and wetland drainage, wetlands that are excavated or impounded will have altered hydroperiods, which in turn can either favor or disfavor certain amphibian species (Fig. 3). As an example, Euliss and Mushet (2004) documented an increase in the distribution and abundance of tiger salamanders across western North Dakota in response to altered wetland hydroperiods. However, increases in this and other predatory species (e.g., predatory aquatic insects) have the potential to negatively affect amphibian species adapted to the naturally short hydroperiods of this region. Additionally, natural barriers that once existed in the form of great distances between permanent water sources may have been broken down by the abundance of newly created water sources on the region's landscape.

Figure 4. A natural wetland habitat (top) and an excavated and impounded wetland (bottom) in western North Dakota.

DISEASE AND PATHOGENS

All the ecosystem stressors and ecological effects discussed above can contribute to increased susceptibility of amphibians to disease and pathogens (Fig. 3). Infectious disease such as *Ranavirus* (Hyatt et al. 2000) and chytrid fungus (*Batrachochytrium dendrobatidis*) (Annis et al. 2004) is one of the contributing factors to worldwide declines of amphibian populations (Crawshaw 1992; Daszak et al. 1999; Collins et al. 2001; Kiesecker et al. 2001; Collins et al. 2003). *Ranavirus* is a lethal pathogen that affects both amphibians and fish, and therefore it has been suggested that fish may serve as reservoirs for amphibian viruses of this genus (Bollinger et al. 1999). Once established in an amphibian population, *Ranavirus* can persist through intraspecific reservoirs in the absence of fish (e.g., terrestrial adult amphibians may serve as a reservoir reinfecting larval populations in wetlands) and cause recurrent die-offs (Brunner et al. 2004). *Ranavirus* outbreaks have been implicated in several large-scale die-offs of tiger salamanders, northern leopard frogs, and wood frogs in the northern Great Plains (Bollinger et al. 1999; National Wildlife Health Center 2001; Green et al. 2002).

CLIMATE CHANGE

Global climate change adds a new dimension of complication affecting multiple aspects of the conservation and management of amphibians in the northern Great Plains. Climate change will likely affect all the drivers, stressors, effects, and ecological attributes previously discussed (Fig. 3). For instance, extended droughts are expected under various climate change models (Schneider et al. 2007), which will likely result in severely reduced numbers of drought refugia for the northern leopard frog. Thus, climate change scenarios should also be considered by researchers, policy makers, and managers as they examine management practices that could impact amphibian populations. Will key habitat components shift in location or function due to changing frequency of severe events (Johnson et al. 2005; Neimuth et al. 2010)? How will changes in precipitation patterns affect hydroperiods of amphibian breeding wetlands (Johnson et al. 2010)? Will warmer temperatures allow additional diseases to become established in the northern Great Plains? These are just a few of the questions that will need to be considered, and any conservation plan developed for amphibians in the region or elsewhere should address adaptive mechanisms for dealing with the largely unknown effects of a changing climate. Only through the use of conservation plans that have mechanisms for detecting and adapting actions to changing environmental conditions can these plans provide for the persistence of populations given uncertain environmental futures.

CONCLUSIONS

The conversion of the northern Great Plains to support agricultural production has great implications for the conservation of the region's amphibians. The majority of the land within the northern Great Plains is privately owned and managed, and thus in most cases monetary decisions drive the decision-making process. While changes associated with dynamic commodity markets may seem daunting to the manager charged with the task of maintaining or improving amphibian populations, the conceptual models described here reveal significant opportunities to influence vast tracts of the landscape through the implementation of federal and state conservation programs. In short, conservation programs on private lands are critical in amphibian conservation efforts in the northern Great Plains. As an example, the Conservation Reserve Program (CRP) of the U.S. Department of Agriculture (USDA) Farm Service

Agency helps to maintain perennial cover on 2.5 million acres of land in North Dakota alone. This incentive to return croplands to grasslands stops the tillage of soils in areas enrolled in the program and greatly reduces agrichemical usage. An examination of linkages identified in Figure 3 shows that in addition to the positive benefits of reduced sediment inputs into wetland habitats and reduced exposure of amphibians to chemicals, changing the upland plant community from annual crops to perennial vegetation creates intact upland habitat for foraging adult and dispersing juvenile amphibians, and provides numerous options for amphibians seeking overwinter cover. However, further examination of this model also reveals that halting the tillage of upland soils may lead to a decrease in runoff water entering wetland basins. Thus, if sediment inputs have been substantial prior to restoration, returning uplands surrounding a wetland to grassland may result in substantial drying of that wetland. Such a scenario was documented by van der Kamp et al. (1999) when wetlands within an area were unintentionally dried as a result of converting croplands to perennial grasslands. Thus, if maintaining water depth for a particular species is identified as a management goal (e.g., to maintain overwintering habitat for northern leopard frogs), a manager may need to consider the removal of excessive accumulations of sediments from wetlands to mitigate for decreased water inputs. Returning degraded wetlands to their original depths through sediment removal would also help restore original hydroperiods, another effect identified by an examination of our model (Fig. 3).

The conceptual models described here are designed to facilitate conservation of viable and genetically diverse amphibian populations in the northern Great Plains by helping to focus communication among scientists, managers, and policy makers through the visual depiction of linkages between major system drivers, stressors, effects, and ecological attributes important to the region's amphibians. Our models also highlight the need to consider multiple factors and their linkages in efforts to conserve amphibian populations in the region. Given that the needs of amphibians vary by species, care should be taken to identify potential and synergistic effects on multiple species. Conceptual models such as those presented here can facilitate these efforts. Additionally, identification of ecosystem drivers and stressors and their effects on ecological attributes of amphibians will enhance our ability to allow for changes in conservation and management actions in response to an uncertain future.

ACKNOWLEDGMENTS

We greatly appreciate support received for this effort from the U.S. Department of Agriculture's Natural Resources Conservation Service Conservation Effects Assessment Project (CEAP–Wetlands). We also thank Sharon Kahara and Robert Newman for providing helpful reviews of earlier versions of this manuscript.

REFERENCES

Adomaitis, V.A., H.A. Kantrud, and J.A. Shoesmith. 1967. Some chemical characteristics of aeolian deposits of snow-soil on prairie wetlands. *Proceedings of the North Dakota Academy of Science* 21:65–69.

Alford, R.A., and S.J. Richards. 1999. Global amphibian declines: A problem in applied ecology. *Annual Review of Ecology and Systematics* 30:133–65.

Annis S.L., F.P. Dastoor, H. Ziel, P. Daszak, and J.E. Longcore. 2004. A DNA-based assay identifies *Batrachochytrium dendrobatidis* in amphibians. *Journal of Wildlife Diseases* 40:420–28.

Baker, J.M., and V. Waights. 1993. The effects of sodium nitrate on the growth and survival of toad tadpoles (*Bufo bufo*) in the laboratory. *Herpetology Journal* 3:147–48.

Baker, J.M., and V. Waights. 1994. The effects of nitrate on tadpoles of the tree frog (*Litoria caerulea*). *Herpetology Journal* 4:106–8.

Barica, J. 1979. *Some Biological Characteristics of Plains Aquatic Ecosystems and Their Effect on Water Quality.* 1979 PARC Symposium, Regina, SK, Canada.

Berger, L. 1989. Disappearance of amphibian larvae in the agricultural landscape. *Ecology International Bulletin* 17:65–73.

Berrill, M., S. Bertram, and B. Pauli. 1997. Effects of pesticides on amphibian embryos and larvae. *Herpetological Conservation* 1:233–45.

Berrill, M., S. Bertram, A. Wilson, S. Louis, D. Brigham, and C. Stromberg. 1993. Lethal and sublethal impacts of pyrethroid insecticides on amphibian embryos and tadpoles. *Environmental Toxicology and Chemistry* 12:525–39.

Bishop, C.A. 1992. The effects of pesticides on amphibians and the implications for determining causes of declines in amphibian populations. *Canadian Wildlife Service, Occasional Paper* 76:67–70.

Bishop, C.A., N.A. Mahoney, J. Struger, P. Ng, and K.E. Pettit. 1999. Anuran development, density and diversity in relation to agricultural activity in the Holland River watershed, Ontario, Canada

(1990–1992). *Environmental Monitoring and Assessment* 59:21–43.

Blaustein, A.R., and D.B. Wake. 1990. Declining amphibian populations: a global phenomenon? *Trends in Ecology and Evolution* 5:203–4.

Bollinger, T.K., J. Mao, D. Schock, R.M. Brigham, and V.G. Chinchar. 1999. Pathology, isolation, and preliminary molecular characteristics of a novel Iridovirus from tiger salamanders in Saskatchewan. *Journal of Wildlife Diseases* 35:413–29.

Boone, M.D., and R.D. Semlitsch. 2001. Interactions of an insecticide with larval density and predation in experimental amphibian communities. *Conservation Biology* 15:228–38.

Boyer, R. and C.E. Grue. 1995. The need to develop water quality criteria for frogs. *Environmental Health Perspectives* 103:352–57.

Brunner, J.L., D.M. Schock, E.W. Davidson, and J.P. Collins. 2004. Intraspecific reservoirs: complex life history and the persistence of a lethal ranavirus. *Ecology* 560–66.

Caldwell, J.P., J.H. Thorp, and T.O. Jervey. 1980. Predator-prey relationships among larval dragonflies, salamanders, and frogs. *Oecologia* 46:285–89.

Collins, J.P., J.L. Brunner, V. Miera, M.J. Parris, D.M. Schock, and S. Storfer. 2003. Ecology and evolution of infectious diseases. In *Amphibian Conservation,* ed. R. Semlitsch, 137–51. Smithsonian Institution Press, Washington, DC.

Collins, J.P., and J.E. Cheek. 1983. Effect of food and density on development of typical and cannibalistic salamander larvae in *Ambystoma tigrinum nebulosum. American Zoologist* 23:77–84.

Collins, J.P., N. Cohen, E.W. Davidson, J. Longcore, and A. Storfer. 2001. Global amphibian declines: An interdisciplinary research challenge for the 21st century. In *Status and Conservation of US Amphibians,* vol. 1: *Conservation Essays,* ed. M.J. Lannoo, 43–52. University of California Press, Berkeley.

Crawshaw, G.J. 1992. The role of disease in amphibian decline. *Canadian Wildlife Service Occasional Paper* 76:60–62.

Dahl, T.E. 1990. *Wetland Losses in the United States, 1780's to 1980's.* US Department of the Interior, Fish and Wildlife Service, Washington, DC.

Dahl, T.E., and C.E. Johnson. 1991. *Status and Trends of Wetlands in the Coterminous United States, Mid-1970's to Mid-1980's.* US Department of the Interior, Fish and Wildlife Service, Washington, DC.

Daszak, P., L. Berger, A.A. Cunningham, A.D. Hyatt, D.E. Grees, and R. Speare. 1999. Emerging infectious diseases and amphibian population declines. *Emerging Infectious Diseases* 5:735–48.

deMaynadier, P.G., and M.L. Hunter, Jr. 1998. Effects of silvicultural edges on the distribution and abundance of amphibians in Maine. *Conservation Biology* 12:340–52.

Diaz, H.F. 1983. Some aspects of major dry and wet periods in the contiguous United States, 1895–1981. *Journal of Climate and Applied Meteorology* 22:3–16.

Diaz, H.F. 1986. An analysis of twentieth century climate fluctuations in northern North America. *Journal of Climate and Applied Meteorology* 25:1625–57.

Dodd, C.K., Jr. 1993. Cost of living in an unpredictable environment: the ecology of striped newts *Notophthalmus perstriatus* during a prolonged drought. *Copeia* 1993:605–14.

Dodd, C.K., Jr. 1996. Use of terrestrial habitats by amphibians in the sandhill uplands of north-central Florida. *Alytes* 14:42–52.

Duvick, D.N., and T.J. Blasing. 1981. A dendroclimatic reconstruction of annual precipitation amounts in Iowa since 1680. *Water Resource Research* 17:1183–89.

Edenhamn, P. 1996. *Spatial Dynamics of the European Tree Frog (Hyla arborea L.) in a Heterogeneous Landscape.* PhD diss., Uppsala University, Uppsala, Sweden.

Euliss, N.H., Jr., and D.M. Mushet. 1996. Water-level fluctuations in wetlands as a function of landscape condition in the prairie pothole region. *Wetlands* 16:587–93.

Euliss, N.H., Jr., and D.M. Mushet. 2004. Impacts of water development on aquatic macroinvertebrates, amphibians, and plants in wetlands of a semi-arid landscape. *Aquatic Ecosystem Health and Management* 7:73–84.

Euliss, N.H., Jr., R.A. Gleason, A. Olness, R.L. McDougal, H.R. Murkin, R.D. Robarts, R.A. Bourbonniere, and B.G. Warner. 2006. North American prairie wetlands are important nonforested land-based carbon storage sites. *Science of the Total Environment* 361:179–88.

Findlay, C.S., and J. Houlahan. 1997. Anthropogenic correlates of species richness in southeastern Ontario wetlands. *Conservation Biology* 11:1000–1009.

Gibbs, J.P. 1993. Importance of small wetlands for the persistence of local populations of wetland-associated animals. *Wetlands* 13:25–31.

Gill, D.E. 1978. The metapopulation ecology of the red-spotted newt, *Notophthalmus viridescens* (Rafinesque). *Ecological Monographs* 48:145–66.

Gleason, R.A. 1996. *Influence of Agricultural Practices on Sedimentation Rates, Aquatic Invertebrates, and Bird-use in Prairie Wetlands*. Master's thesis, Humboldt State University, Arcata, CA.

Gleason, R.A. 2001. *Invertebrate Egg and Plant Seed Banks in Natural, Restored, and Drained Wetlands in the Prairie Pothole Region (USA) and Potential Effects of Sedimentation on Recolonization of Hydrophytes and Aquatic Invertebrates*. PhD diss., South Dakota State University, Brookings, SD.

Gleason, R.A., and N.H. Euliss, Jr. 1998. Sedimentation of prairie wetlands. *Great Plains Research* 8:97–112.

Gleason, R.A., N.H. Euliss, Jr., D.E. Hubbard, and W.G. Duffy. 2003. Effects of sediment load on emergence of aquatic invertebrates and plants from wetland soil egg and seed banks. *Wetlands* 23:26–34.

Gleason, R.A., M.K. Laubhan, and N.H. Euliss, Jr., ed., 2008. *Ecosystem Services Derived from Wetland Conservation Practices in the United States Prairie Pothole Region with an Emphasis on the US Department of Agriculture Conservation Reserve and Wetlands Reserve Programs*. US Geological Professional Paper 1745, Reston, VA.

Goolsby, D.A., R.H. Coupe, and D.J. Markovchick. 1991. *Distribution of Selected Herbicides and Nitrate in the Mississippi River and its Major Tributaries*. Report No. 91-4163, US Geological Survey, Denver.

Gray, M.J., L.M. Smith, and R. Brenes. 2004a. Effects of agricultural cultivation on demographics of Southern High Plains amphibians. *Conservation Biology* 18:1368–77.

Gray, M.J., L.M. Smith, and R.I. Leyva. 2004b. Influence of agricultural landscape structure on a Southern High Plains, USA, amphibian assemblage. *Landscape Ecology* 19:719–29.

Green, D.E., K.A. Converse, and A.K. Schrader. 2002. Epizootiology of sixty-four amphibian morbidity events in the USA, 1996–2001. *Annals of the New York Academy of Sciences* 969:323–39.

Green, D.M. 2003. The ecology of extinction: Population fluctuation and decline in amphibians. *Biological Conservation* 111:331–43.

Hall, R.J., and P.P. Henry. 1992. Assessing effects of pesticides on amphibians and reptiles: status and needs. *Herpetological Journal* 2:65–71.

Hanski, I., and M.E. Gilpin. 1991. *Metapopulation Dynamics*. Academic Press, London.

Hanson, M.A., and M.G. Butler. 1990. Early responses of plankton and turbidity to bioaccumulation in a shallow prairie lake. *Hydrobiologia* 200/201:317–27.

Hayes, T.B. 2004. There is no denying this: Defusing the confusion about Atrazine. *BioScience* 54:1138–49.

Hayes, T.B., K. Haston, M. Tsui, A. Hoang, C. Haeffele, and A. Vonk. 2003. Atrazine-induced hermaphroditism at 0.1 ppb in American leopard frogs (*Rana pipiens*): Laboratory and field evidence. *Environmental Health Perspectives* 111:568–75.

Hecnar, S.J., and R.T. M'Closkey. 1996. The effects of predatory fish on amphibian species richness and distribution. *Biological Conservation* 79:123–31.

Heemskerk, M., K. Wilson, and M. Pavao-Zuckerman. 2003. Conceptual models as tools for communication across disciplines. *Conservation Ecology* 7:8. http://www.consecol.org/vol7/iss3/art8/.

Herbeck, L.A., and D.R. Larsen. 1999. Plethodontid salamander response to silvicultural practices in Missouri Ozark forests. *Conservation Biology* 13:623–32.

Heyer, W.R., R.W. McDiarmid, and D.L. Weigmann. 1975. Tadpoles, predation, and pond habitats in the tropics. *Biotropica* 7:100–111.

Howe, C.M., M. Berrill, B.D. Pauli, C.C. Helbing, K. Werry, and N. Veldhoen. 2004. Toxicity of Glyphosate-based pesticides to four North American frog species. *Environmental Toxicology and Chemistry* 23:1928–38.

Howe, G.E., R. Gillis, and R.C. Mowbray. 1998. Effect of chemical synergy and larval stage on the toxicity of atrazine and alachlor to amphibian larvae. *Environmental Toxicology and Chemistry* 17:519–25.

Hyatt, A.D., A.R. Gould, Z. Zupanivic, A. Cunningham, S. Hengstberger, R.J. Whittington, J. Kattenbely, and B.E.H. Coupar. 2000. Comparative studies of amphibian and piscine iridoviruses. *Archives of Virology* 145:301–31.

Johnson, W.C., B.V. Millett, T. Gilmanov, R.A. Voldseth, G.R. Guntenspergen, and D.E. Naugle. 2005. Vulnerability of northern prairie wetlands to climate change. *Bioscience* 55:863–72.

Johnson, W.C., B. Werner, G.R. Guntenspergen, R.A. Voldseth, B. Millett, D.E. Naugle, M. Tulbure, R.W.H. Carroll, J. Tracy, and C. Olawsky. 2010.

Prairie wetland complexes as landscape functional units in a changing climate. *Bioscience* 60:128–40.

Jurik, T.W., S.-C. Wang, and A.G. van der Valk. 1994. Effects of sediment load on seedling emergence from wetland seed banks. *Wetlands* 14:159–65.

Karl, T.R., and A.J. Koscielny. 1982. Drought in the United States: 1895–1981. *Journal of Climatology* 2:313–29.

Karl, T.R., and W.E. Riebsame. 1984. The identification of 10 to 20 year temperature and precipitation fluctuations in the contiguous United States. *Journal of Climate and Applied Meteorology* 23:950–66.

Kats, L.B., J. Petranka, and A. Sih. 1988. Antipredator defenses and the persistence of amphibian larvae with fishes. *Ecology* 69:1865–70.

Kiesecker, J.M., A.R. Blaustein, and L.K. Belden. 2001. Complex causes of amphibian population declines. *Nature* 410:681–84.

Knutson, M.G., J.R. Sauer, D.A. Olsen, M.J. Mossman, L.M. Hemesath, and M.J. Lannoo. 1999. Effects of landscape composition and wetland fragmentation on frog and toad abundance and species richness in Iowa and Wisconsin, USA. *Conservation Biology* 13:1437–46.

Kolbe, J.J., B.E. Smith, and D.M. Browning. 2002. A large aggregation of tiger salamanders (*Ambystoma tigrinum melanostictum*) at a black-tailed prairie dog (*Cynomys ludovicianus*) town in southwestern South Dakota. *Herpetological Review* 33:95–99.

Kolozsvary, M.B., and R.K. Swilhart. 1999. Habitat fragmentation and the distribution of amphibians: patch and landscape correlates in farmland. *Canadian Journal of Zoology* 77:1288–99.

Lannoo, M.J., ed. 1998. *Status and Conservation of Midwestern Amphibians*. University of Iowa Press, Ames.

Lannoo, M.J., ed. 2005. *Amphibian Declines: The Conservations Status of United States Species*. University of California Press, Berkeley.

Lee, R.E., Jr., J.P. Costanzo, E.C. Davidson, and J.R. Layne, Jr. 1992. Dynamics of body water during freezing and thawing in a freeze-tolerant frog *(Rana sylvatica). Journal of Thermal Biology* 17:263–66.

Lehtinen, R.M., S.M. Galatowitsch, and J.R. Tester. 1999. Consequences of habitat loss and fragmentation for wetland amphibian assemblages. *Wetlands* 19:1–12.

Maddox, G.D., K.E. Poiani, and R.E. Unnasch. 1999. Evaluating management success: Using ecological models to ask the right monitoring questions. In *The Ecological Stewardship Project: A Common Reference for Ecosystem Management*, ed. N. Johnson, 563–84. Elsevier Science, Oxford.

Madison, D.M. 1997. The emigration of radio-implanted spotted salamanders, *Abmystoma maculatum. Journal of Herpetology* 31:542–52.

Marsh, D.M., and P.C. Trenham. 2001. Metapopulation dynamics and amphibian conservation. *Conservation Biology* 15:40–49.

Martin, D.B., and W.A. Hartman. 1987. The effect of cultivation on sediment and deposition in prairie pothole wetlands. *Water, Air, and Soil Pollution* 34:45–53.

Morin, P.J. 1986. Interactions between intraspecific competition and predation in an amphibian predator-prey system. *Ecology* 67:713–20.

Mushet, D.M. 2010. *From Earth-Observing Space Satellites to Nuclear Microsatellites: Amphibian Conservation in the Northern Great Plains*. PhD diss., North Dakota State University, Fargo.

National Wildlife Health Center. 2001. *Amphibian Diseases*. NWHC Information Sheet. US Geological Survey, Madison, WI.

Naughton, G.P., C.B. Henderson, K.R. Foresman, and R.L. McGraw II. 2000. Long-toed salamanders in harvested and intact Douglas-fir forests of western Montana. *Ecological Applications* 10:1681–89.

Neimuth, N.D., B. Wangler, and R.E. Reynolds. 2010. Spatial and temporal variation in wet area of wetlands in the prairie pothole region of North Dakota and South Dakota. *Wetlands* 30:1053–64.

Newman, R.A. 1987. Effects of density and predation on *Scaphiopus couchi* tadpoles in desert ponds. *Oecologia* 71:301–7.

Ogden, J.C., S.M. Davis, K.J. Jacobs, T. Barnes, and H.E. Fling. 2005. The use of conceptual ecological models to guide ecosystem restoration in south Florida. *Wetlands* 25:795–809.

Pechmann, J.H.K., D.E. Scott, J.W. Gibbons, and R.D. Semlitsch. 1989. Influence of wetland hydroperiod on diversity and abundance of metamorphosing juvenile amphibians. *Wetlands Ecology and Management* 1:3–11.

Pechmann, J.H.K., D.E. Scott, R.D. Semlitsch, J.P. Caldwell, L.J. Vitt, and J. Whitfield Gibbons. 1991. Declining amphibian populations: the problem of separating human impacts from natural fluctuations. *Science* 253:892–95.

Peterka, J.J. 1989. Fishes in northern prairie wetlands. In *Northern Prairie Wetlands*, ed. A. van der Valk, 302–15. Iowa State University Press, Ames.

Pfennig, D.W. 1990. The adaptive significance of an environmentally-cued developmental switch in an anuran tadpole. *Oecologia* 85:101–7.

Relyea, R.A. 2004a. Predator cues and pesticides: A double dose of danger for amphibians. *Ecological Applications* 13:1515–21.

Relyea, R.A. 2004b. Synergistic impacts of malathion and predatory stress on six species of North American tadpoles. *Environmental Toxicology and Chemistry* 23:1080–84.

Relyea, R.A. 2005a. The impact of insecticides and herbicides on the biodiversity and productivity of aquatic communities. *Ecological Applications* 15:618–27.

Relyea, R.A. 2005b. The lethal impact of Roundup on aquatic and terrestrial amphibians. *Ecological Applications* 15:1118–24.

Relyea, R.A. 2009. A cocktail of contaminants: How mixtures of pesticides at low concentrations affect aquatic communities. *Oecologia* 159:363–76.

Rohr, J., J. Kerby, and A. Sih. 2006. Community ecology as a framework for predicting contaminant effects. *Trends in Ecology and Evolution* 21:606–13.

Rouse, J.D., C.A. Bishop, and J. Struger. 1999. Nitrogen pollution: An assessment of its threat to amphibian survival. *Environmental Health Perspectives* 107:799–803.

Ruwaldt, J.J., L.D. Flake, and J.M. Gates. 1979. Waterfowl pair use of natural and man-made wetlands in South Dakota. *Journal of Wildlife Management* 43:375–83.

Schneider, S.H., S. Semenov, A. Patwardhan, I. Burton, C.H.D. Magadza, M. Oppenheimer, A.B. Pittock, A. Rahman, J.B. Smith, A. Suarez and F. Yamin. 2007. Assessing key vulnerabilities and the risk from climate change. In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* ed. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson, 779–810. Cambridge University Press, Cambridge.

Semlitsch, R.D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. *Conservation Biology* 12:1113–19.

Semlitsch, R.D. 2000. Principles for management of aquatic-breeding amphibians. *Journal of Wildlife Management* 64:615–31.

Semlitsch, R.D., D.E. Scott, J.H.K. Pechmann, and J.W. Gibbons. 1996. Structure and dynamics of an amphibian community: Evidence from a 16-year study of a natural pond. In *Long-term Studies of Vertebrate Communities,* ed. M.L. Cody and J.A. Smallwood, 217–48. Academic Press, San Diego.

Sjögren, P. 1991. Extinction and isolation gradients in metapopulations: The case of the pool frog (*Rana lessonae*). *Biological Journal of the Linnean Society* 42:135–47.

Sjögren-Gulve, P. 1994. Distribution and extinction patterns within a northern metapopulation of the pool frog, *Rana lessonae*. *Ecology* 75:1357.

Skelly, D.K., and E. Meir. 1997. Rule-based models for evaluating mechanisms of distributional change. *Conservation Biology* 11:531–38.

Smith, G.R. 2001. Effects of acute exposure to a commercial formulation of Glyphosate on the tadpoles of two species of anurans. *Bulletin of Environmental Contamination and Toxicology* 67:483–88.

Spencer, C.N., and D.L. King. 1984. Role of fish in regulation of plant and animal communities in eutrophic ponds. *Canadian Journal of Fisheries and Aquatic Science* 41:1851–55.

Stebbins, R.C., and N.W. Cohen. 1995. *A Natural History of Amphibians*. Princeton University Press, Princeton, NJ.

Storey, K.B., and J.M. Storey. 1992. Natural freeze tolerance in ectothermic vertebrates. *Annual Review of Physiology* 54:619–37.

Tiner, R.W. 1984. *Wetlands of the United States: Current Status and Recent Trends*. US Fish and Wildlife Service, Washington, DC.

Trenham, P.C. 1998. *Demography, Migration and Metapopulation Structure of Pond Breeding Salamanders*. PhD diss., University of California, Davis.

Tyler, T., W.J. Liss, L.M. Ganio, G.L. Larson, R. Hoffman, E. Deimling, and G. Lomnicky. 1998. Interaction between introduced trout and larval salamanders (*Ambystoma macrodactylum*) in high-elevation lakes. *Conservation Biology* 12:94–105.

van der Kamp, G., W.J. Stolte, and R.G. Clark. 1999. Drying out of small prairie wetlands after conversion of their catchments from cultivation to permanent brome grass. *Hydrological Sciences* 44:387–97.

Wang, S.-C., T.W. Jurik, and A.G. van der Valk. 1994. Effects of sediment load on various stages in the life and death of cattail (*Typha* x *glauca*). *Wetlands* 14:166–73.

Wellborn, G.A., D.K. Skelly, and E.E. Werner. 1996. Mechanisms creating community structure across a freshwater habitat gradient. *Annual Review of Ecology and Systematics* 27:337–63.

Wilbur, H.M. 1980. Complex life cycles. *Annual Review of Ecology and Systematics* 11:67–93.

Wilbur, H.M. 1984. Complex lifecycles and community organization in amphibians. In *A New Ecology: Novel Approaches to Interactive Systems,* ed. P.W. Price, C.N. Slobodchikoff, and W.S. Gaud, 195–224. Wiley, New York.

Wilbur, H.M. 1987. Regulation of structure in complex systems: experimental temporary pond communities. *Ecology* 68:1437–52.

Wilbur, H.M., and J.E. Fauth. 1990. Experimental aquatic food webs: Interactions between two predators and two prey. *American Naturalist* 135:176–204.

Willis, K. 2001. 73 new wetlands created in southwestern North Dakota. *Birdscapes* 2001 (Fall): 12.

Winter, T.C., and D.O. Rosenberry. 1998. Hydrology of prairie pothole wetlands during drought and deluge: A 17-year study of the Cottonwood Lake wetland complex in North Dakota in the perspective of longer term measured and proxy hydrological records. *Climatic Change* 40:189–209.

Woodhouse, C.A., and J.T. Overpeck. 1998. 2000 years of drought variability in the central United States. *Bulletin of the American Meteorological Society* 79:2693–2714.

Wyman, R.L. 1990. What's happening to the amphibians. *Conservation Biology* 4:350–52.

Great Plains Research 22 (Spring 2012):59–67

CHANNEL WIDTH AND LEAST TERN AND PIPING PLOVER NESTING INCIDENCE ON THE LOWER PLATTE RIVER, NEBRASKA

Joel G. Jorgensen

Nongame Bird Program
Nebraska Game and Parks Commission
Lincoln, NE 68503
joel.jorgensen@nebraska.gov

Mary Bomberger Brown

Tern and Plover Conservation Partnership
School of Natural Resources
University of Nebraska–Lincoln
Lincoln, NE 68583

and

Andrew J. Tyre

School of Natural Resources
University of Nebraska–Lincoln
Lincoln, NE 68583

ABSTRACT—Endangered interior least terns (*Sternula antillarum athalassos*) and threatened northern Great Plains piping plovers (*Charadrius melodus*) nest together on midstream sandbars in large rivers in the interior of North America. We investigated the relationship between river channel width and tern and plover nesting incidence on the lower Platte River, Nebraska, using a model-based logistic regression analysis. Multiple channel width measurements and a long-term nesting data set were used in the analysis. Nesting incidence was positively associated with increasing river channel width proximal to the nesting site. At a greater distance, up to 802 m away from the nesting site, there was no relationship with channel width. Managers and regulators should use these results to aid decisions pertaining to habitat creation and assessing impacts of future projects. Future research should address whether relationships exist between river channel width and nest counts and reproductive rates of interior least tern and piping plovers on the lower Platte River.

Key Words: channel width, *Charadrius melodus*, interior least tern, lower Platte River, piping plover, *Sternula antillarum athalassos*

INTRODUCTION

Effective management of threatened and endangered species occupying human-altered ecosystems in the Great Plains often relies on the creation, renovation, and preservation of habitats that are critical to their survival. Because broad-scale restoration of ecosystems is often physically or economically impractical, habitat managers are now being challenged to replicate components of complex and dynamic natural ecosystems within limits and constraints and at small geographic scales. They are further challenged to do their work with incomplete information on important relationships between species and their habitats. For threatened and endangered species management efforts to be successful, it is critical to develop and refine information about species–habitat relationships and make it available to conservation practitioners and habitat managers.

Nearly all midcontinental river systems in North America have been altered by human activities such as

Manuscript received for review, September 2011; accepted for publication, December 2011.

dam construction, channelization, bank stabilization, and water diversion (National Research Council 2002, 2005). These alterations serve human interests by providing services such as irrigation, navigation, and flood control, but they often disrupt ecosystem services and hydrological and geomorphological processes. The consequence of these alterations can be substantial loss of habitat for riverine-dependent species, which in turn may put certain species at risk of extinction. The endangered interior least terns (*Sternula antillarum athalassos*) and threatened northern Great Plains piping plovers (*Charadrius melodus*) are two such species whose decline in the United States is largely attributed to nesting habitat loss (US Fish and Wildlife Service 1988, 1990). For both species, the critically important nesting habitat includes midstream macroform sandbars and sandbar complexes in large sediment-rich rivers (Thompson et al. 1997; Elliott-Smith and Haig 2004). A recent rangewide survey showed that approximately 90% of all interior least tern nests (Lott 2006) and 21% of all piping plover nests (Elliott-Smith et al. 2009) located in the Great Plains in 2006 were found on river sandbars.

While full restoration of human-altered river systems is generally not a politically viable or economically feasible option, water project managers and users in the United States must comply with the Endangered Species Act. For example, they may be required to mitigate for the negative environmental impacts resulting from their projects and provide necessary habitat for threatened and endangered species. The comprehensive scope of mitigation necessary to meet recovery objectives in these human-altered rivers has led to the development of two major programs in the central Great Plains that are focused on the mechanical creation of nesting habitat: the US Army Corps of Engineers Emergent Sandbar Habitat program on the Missouri River (US Fish and Wildlife Service 2003) and the three-state Platte River Recovery Program on the central Platte River in Nebraska (Nebraska, Colorado, and Kansas; Platte River Recovery Implementation Program 2006).

As recovery of tern and plover populations in the Great Plains is increasingly dependent on targeted habitat projects, a critical aspect is determining where habitat construction projects will be most effective. Tern and plover nesting habitat appears, superficially, to be easily created, as it consists of expanses of sparsely vegetated sand located near water (Thompson et al. 1997; Elliott-Smith and Haig 2004). However, nesting habitat selection by terns and plovers is complex, and key species–habitat relationships are poorly understood. Terns and plovers may choose not to use sandbars that are created as part of these habitat projects or, even worse, they may be drawn into unsuitable nesting habitat that become population sinks (Pulliam 1988; Battin 2004).

The width of the river active channel (channel width) is a variable known to influence tern and plover nest site selection. Two studies on the Platte River, Nebraska, showed that mean channel width at tern and plover nesting sites was greater than the mean width of the channel at unused sites (Kirsch 1992; Ziewitz et al. 1992). These studies made important contributions to our understanding of tern and plover habitat relationships; however, both are limited in usefulness for habitat projects. The studies only showed that mean channel width differed between used and unused nesting sites; neither study provided insight on how nesting incidence changed as channel width changed. Both studies also used only one measure of channel width, that at the nesting site. However, we know that nesting habitat use by terns and plovers may be influenced by habitat variables at multiple scales (Orians and Wittenberger 1991; Pribil and Picman 1997).

The goal of this study was to expand upon earlier studies that examined the relationship between channel width and interior least tern and piping plover nesting incidence and to provide information that has practical applications to habitat projects. We addressed this by using a model-based logistic regression approach to estimate the probability of nesting incidence across a set of channel width measurements, using a long-term (ten-year) data set of tern and plover nesting habitat selection, and evaluating habitat use on the lower Platte River. Compared to other large rivers in the Great Plains, such as the Missouri and central Platte, the lower Platte River is relatively dynamic and physically unmodified.

METHODS

The Platte River drainage covers approximately 223,000 km^2 in Colorado, Wyoming, and Nebraska (National Research Council 2005). The lower Platte River extends from the Loup–Platte River confluence (near Columbus, Platte County) 166 km downstream to where it joins the Missouri River (near Plattsmouth, Cass County; Fig. 1). The lower Platte River is distinct from the portion upstream of the Loup–Platte River confluence, generally referred to as the central Platte River, because of contributions to the river flow from the Loup River (Schaepe and Alexander 2011). The lower Platte River is a dynamic, braided river system characterized by broad channels, anabranches (sections of the river that divert from and

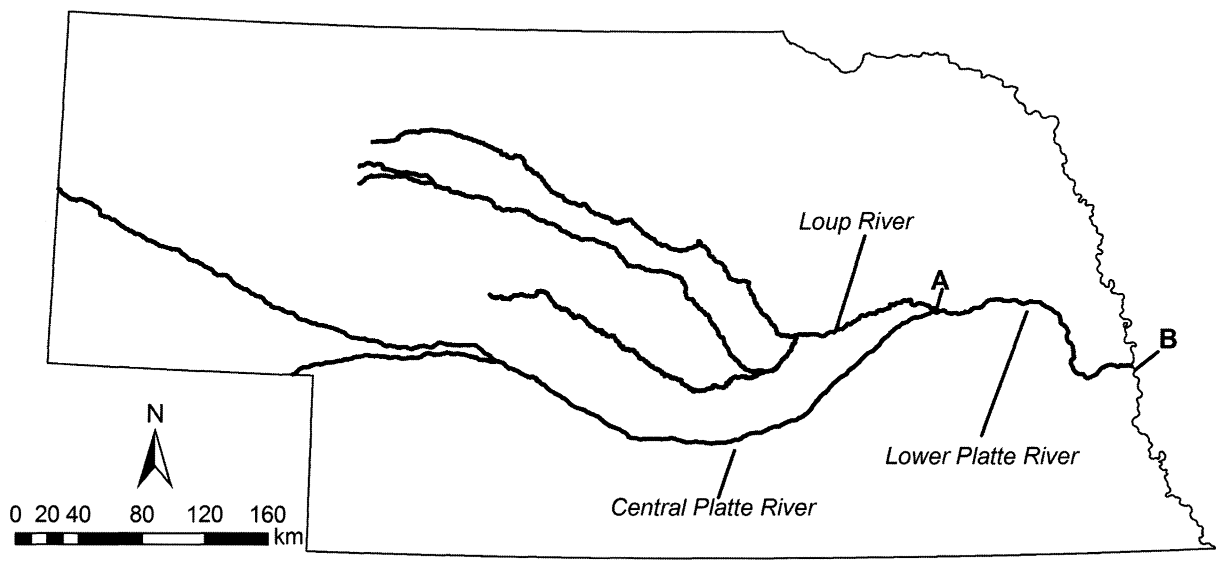

Figure 1. Lower Platte River, Nebraska, extending from the Loup–Platte River confluence near Columbus, Platte County (A) to the Platte–Missouri River confluence near Plattsmouth, Cass County (B).

rejoin the main channel in areas where river flows were divided by stabilized islands), sandbars, islands, a high sediment load of sand and gravel, and erodible banks (Blodgett and Stanley 1980). The amount and availability of sandbar tern and plover nesting habitat is variable from year to year.

We measured active channel width for 1999, 2003, and 2006 using digital ortho-photo quadrangle aerial photographs from the Farm Service Agency's National Agricultural Imagery Program. Our working definitions and analytical approach of defining the channel boundary was similar to that of Elliot et al. (2009). We defined active channel width as the unstabilized riverbed that possesses geomorphic features such as moving water and sandbars lying between stabilized steep banks that confine stream flow. Active channel width remains stable under variable water discharge and flow regimes. Ephemeral sandbars are considered part of the active channel because they lie between the stabilized banks, and river flows frequently reshape these features. Islands stabilized by early-successional or gallery forests are not considered part of the active channel. We measured both main channels and anabranches. Channel width measurements did not vary among the three years for which we had aerial photographs.

We used the aerial photographs to digitize polylines, here referred to as individual channel measurements, in ArcGIS (ESRI Inc. 2006, Version 9.2, Redlands, CA, www.esri.com). Individual channel measurements were drawn perpendicular to the active channel every 402 m beginning at the mouth of the Platte (river mile 0) and moving upstream to the Platte–Loup River confluence (near river mile 102). We followed the methods of Ziewitz et al. (1992) in using 402 m so that results of the two studies would be comparable. We used an ArcMap utility to estimate the length of each polyline.

We assessed multiple active channel width measurements by creating a series of 1,206-m-long segments consisting of four consecutive channel width measurements (Fig. 2). We refer to each unit as a unique river segment. Each unique river segment consists of three areas or sections between channel width measurements. From the middle section, measures of channel width are located immediately upstream and downstream and also 804 m upstream and downstream of the middle section (Fig. 2). The 804-m-long channel widths were included to assess not only channel width in the immediate vicinity of the sandbar but also the relationship between channel widths located some distance away. We labeled the four channel width measurements by their relative location to the middle section, thus the labels were distal upstream, proximal upstream, proximal downstream, and distal downstream. We started at the downstream terminal channel width measurement; we then moved upstream 402 m and repeated the process, creating another unique river segment. In this way, each 402-m-long segment of

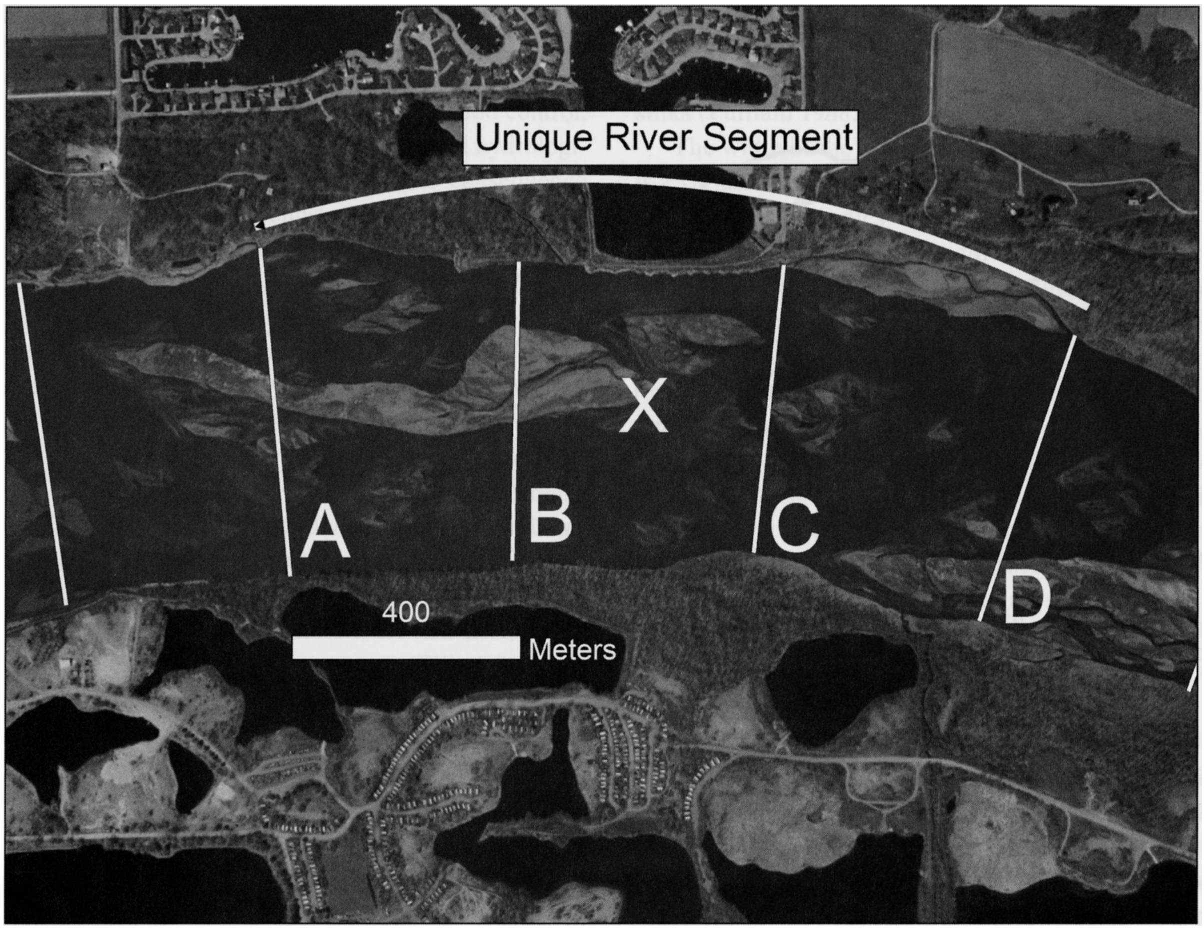

Figure 2. Relative locations of channel width measurements that comprise a unique river segment: distal upstream (A), proximal upstream (B), proximal downstream (C), and distal downstream (D). Success or failure in logistic regression models was determined by whether a nest was present in the area between the locations of the proximal channel measurements (location denoted by "X").

the river was associated with four channel width measurements. In areas of divided flow, we created multiple unique river segments.

To identify nesting sites, we used nest location data collected during annual Nebraska Game and Parks Commission tern and plover surveys from 1999 to 2008. Terns and plovers commonly nest together in loose aggregations (*sensu* Alexander 1974). Annual surveys were conducted by airboat or canoe at least once during the nesting season and covered the entire lower Platte River. All sandbars were surveyed for tern and plover presence and nesting activity. Sandbars where birds were detected were inspected on foot and nests were counted. We define a nesting site as a location in which one or more interior least tern or piping plover nests were found. We considered nesting incidence (presence or absence) rather than number of nests because survey effort was unbalanced among all river segments and among years. We used data across all years to account for extremes in nesting habitat variation and availability. A location was considered a nesting site if nesting occurred there at least once during the ten-year period.

We used logistic regression in a generalized linear model that uses binary response data (here, success or failure) to predict the probability of nesting incidence (Hilbe 2009) and to model the relationship between nesting incidence and the four channel-width measurements for each unique river segment. We also included nest site location on the lower Platte River, identified by river mile, in candidate models. In our analysis, the presence of a nesting site in the middle section of a sandbar, between the proximal downstream and proximal upstream channel widths, was scored as a success for each unique river segment. Absence of nesting at this location was scored as a failure. We rescaled channel width values by subtracting the mean channel width and dividing by 100 (Draper and Smith 1998). This analytical approach allowed us to interpret the intercept of the top model as representing the

average probability of nesting at a site and each unit increase in the model coefficient as the increase in the odds (log scale) of nesting at a site for every 100 m increase in channel width.

Adjacent channel widths are not independent, because the width measurements overlap, that is, the proximal upstream width for a given river segment is the proximal downstream width for the next river segment. Prior to conducting the analyses, we determined whether individual channel width measurements were correlated. We used correlation analysis to determine relationships among the four measurements in each unique river segment. If two variables were strongly correlated ($r_s > 0.80$; Franzblau 1958), only one of the correlated variables would be included in subsequent analyses.

We used Akaike's information criterion (AIC) and model weights (w_i) to select the best-fitting model(s) (Burnham and Anderson 1998). We used t-statistics to determine whether the maximum likelihood parameter estimates for the top model differed from zero. Unless otherwise noted, means are presented ±1 SE. All statistical analyses were performed in Program R 2.9.2 (R Development Core Team 2009).

RESULTS

We identified 589 individual channel measurements and 610 unique river segments. Of the 610 unique river segments, 420 were classified as main channel segments and 190 were classified as anabranches. Individual channel widths varied from 21 to 743 m (mean = 327.4 ± 6.1 m). From 1999 to 2008, 82 tern and plover nesting sites were recorded on the lower Platte River in 64 unique river segments. All nesting areas were located in main channel segments.

Several channel width measurements were correlated. Channel width measurements adjacent to one another were moderately correlated (r_s = 0.57–0.60, P-values < 0.01). Nonadjacent channel width measurements were less strongly correlated ($r_s < 0.40$, P-values < 0.01). Channel width measurements were weakly correlated with river mile ($r_s < 0.25$, P-values < 0.01). Based on these correlation coefficients (see "Methods"), all variables were included in the analysis.

Our model selection procedure indicated little support for the simplest models that included two or fewer parameters or complex models that included interaction terms (Table 1). A model that included only proximal upstream and proximal downstream channel widths had the lowest AIC (306.5; see Table 1) and had the highest model weight (0.49). Models that included the interaction between proximal upstream and proximal downstream channel widths or river miles were not markedly better than the top model. The three best-fitting models had a total of 87% support, and the point estimates and standard error for parameters were very similar.

Nesting incidence increased with proximal upstream and proximal downstream channel widths (see Table 2). Parameter estimates from the top model, which showed the relationship between increased nesting incidence and both proximal upstream and proximal downstream channel widths, are shown in Figure 3. Our model shows that nesting incidence is rare (<0.03) when values of both proximal upstream and proximal downstream channel widths are equal to or less than the mean channel width (327 m) of the study area.

DISCUSSION

Our results show a strong relationship between interior least tern and piping plover nesting incidence and channel width on the lower Platte River. Nesting incidence increased sharply with increased channel width; wide river channels are more attractive to nesting terns and plovers. Channel width at the smaller spatial scales (proximal upstream and proximal downstream to nesting areas) was the best predictor of colony incidence. These two imperiled species avoid nesting in narrow channels and anabranches.

These results have implications for the lower Platte River, which, being largely unregulated, remains a relatively dynamic system. The lower Platte River currently creates and maintains sandbar habitat that support nesting interior least terns and piping plovers. There is increasing pressure from economic interests and policy makers to develop river infrastructure, such as bank stabilization structures and levees, to protect private and industrial property and investments. Agencies responsible for the protection of threatened and endangered species have raised concerns about impacts to terns and plovers resulting from these developments. Decision makers charged with evaluating these developments have been hindered by limited information on the consequences of these developments for protected species. Several studies have been commissioned recently to provide this information and help rectify this problem (Ginting et al. 2008; Elliot et al. 2009; Schaepe and Alexander 2011). However, these studies are largely descriptive in nature and have not established and quantified specific species–habitat relationships. By explicitly quantifying the species–habitat relationship

TABLE 1
MODEL SELECTION SUMMARY OF INTERIOR LEAST TERN AND NORTHERN GREAT PLAINS PIPING PLOVER NESTING INCIDENCE AS A FUNCTION OF CHANNEL WIDTH AND LOCATION ON THE LOWER PLATTE RIVER

Model	Deviance	K	ΔAIC*	w_i
Intercept	409.6	1	105.1	0.00
Location	388.8	2	86.3	0.00
Distal downstream	386.4	2	83.8	0.00
Proximal downstream	328.9	2	26.4	0.00
Proximal upstream	331.6	2	29.1	0.00
Distal upstream	382.4	2	79.9	0.00
Distal downstream × location	373.4	4	74.8	0.00
Proximal downstream × location	321.9	4	23.3	0.00
Proximal upstream × location	326.2	4	27.6	0.00
Distal upstream × location	371.2	4	72.7	0.00
Distal downstream + proximal downstream	328.9	3	28.4	0.00
Distal upstream + proximal upstream	331.2	3	30.7	0.00
Proximal downstream + proximal upstream	300.5	3	0.0	0.49
Proximal downstream × proximal upstream	300.4	4	1.9	0.19
Distal downstream × distal upstream	365.4	3	64.9	0.00
Distal downstream + proximal downstream × location	321.6	5	25.1	0.00
Distal upstream + proximal upstream × location	324.6	5	28.0	0.00
Proximal downstream + proximal upstream × location	298.5	5	1.9	0.19
Distal downstream + distal downstream × location	359.3	5	62.7	0.00
Distal downstream + proximal downstream + proximal upstream + distal upstream	300.4	5	3.8	0.07
Distal downstream + proximal downstream + proximal upstream + distal upstream + location	298.8	6	4.4	0.09
(Distal downstream + proximal downstream + proximal upstream + distal upstream + location)^2	290.1	16	15.5	0.00
Distal downstream × proximal downstream × proximal upstream × distal upstream × location	283.9	32	41.3	0.00

*Akaike's information criterion (AIC) for the best-fitting model was 306.5.

TABLE 2
ESTIMATES (LOGIT SCALE) OF MAXIMUM-LIKELIHOOD PARAMETERS AND SIGNIFICANT DEVIATION FROM 0 FOR THE BEST-FITTING MODEL DESCRIBING THE PROBABILITY OF NESTING ON SANDBARS

Parameter	Estimate ± SE	*z*-value	*P* > Z
Intercept	–3.28 ± 0.27	–12.06	<0.001
Proximal downstream	0.75 ± 0.15	4.99	<0.001
Proximal upstream	0.72 ± 0.15	4.75	<0.001

Note: Values were rescaled prior to analysis.

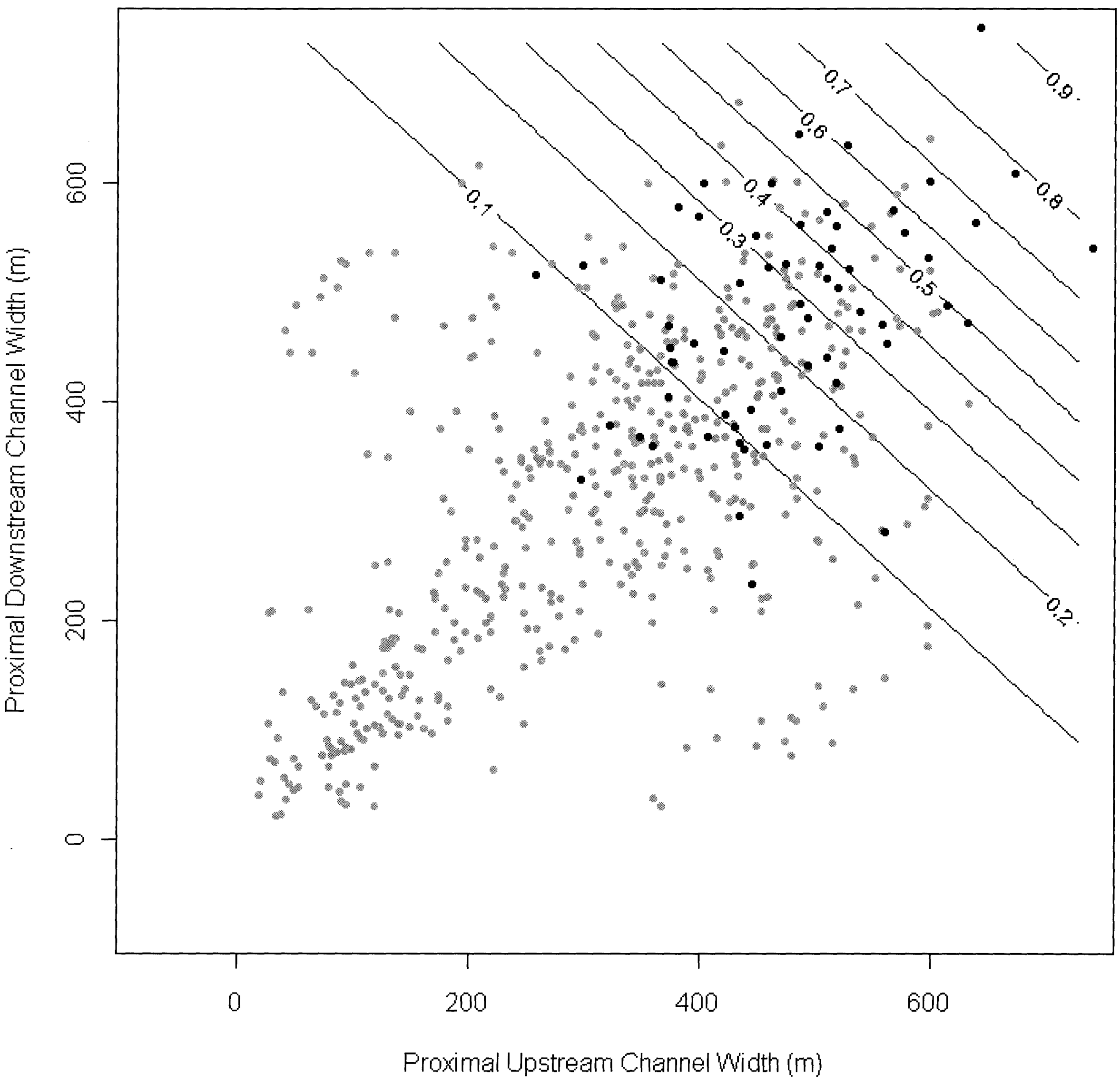

Figure 3. Contour plot from the top model showing a positive relationship between increased proximal upstream (*x*-axis) and proximal downstream (*y*-axis) channel width against increased nesting incidence by interior least terns and piping plovers on the lower Platte River. Diagonal contour lines at 0.1 m intervals in the plot area show increases in the probability of nesting incidence. Dots are unique river segments data points; black dots are nesting (presence) and gray dots are no nesting (absence).

between channel width and nesting terns and plovers, our results will be useful to decision makers assessing project designs and prioritizing project implementation.

A possible explanation for the relationship between wide channels and nesting involves predator avoidance. Interior least tern and northern Great Plains piping plover nests and chicks are frequently attacked by predators. Numerous studies have demonstrated that shorebird site use and behavior is affected by the presence of avian predators (Cresswell 1994; Cresswell and Whitfield 1994) and shorebird site use is known to change in response to the presence of certain raptors (Ydenberg et al. 2004). Sandbars located in wide river channels are less accessible to terrestrial predators such as coyotes (*Canis latrans*) and raccoons (*Procyon lotor*). Avian predators such as American kestrel (*Falco sparverius*; Kruse et al. 2001),

great horned owl (*Bubo virginianus*; Kruse et al. 2001), and American crow (*Corvus brachyrhynchos*; Kruse et al. 2001) prey on tern and plover nests and chicks. It seems plausible that terns and plovers select nesting sites further from stabilized banks that have large trees and other structures that avian predators use for perching.

In addition to reduced predation, wider portions of rivers may provide an advantage to nesting interior least terns because of proximity to food resources for these fish-eating birds. Wider portions of braided rivers, such as the lower Platte River, possess an array of shallow-water habitat complexes (Schumm 1985) that are attractive to small fish. Higher fish densities are known to influence the behavior of fish-eating birds and their breeding success (Jodice et al. 2006). Adult interior least terns themselves feed on and feed their chicks the small-bodied fish that occur in high abundance in these shallow-water habitats (Callam 1989; Stucker et al. 2011).

Terns and plovers respond to a suite of variables when selecting nesting sites. However, some of these other variables, such as sandbar size and elevation, are ephemeral and ever-changing due to variable river flows. As a result, they are challenging to measure reliably and effectively. Consequently, channel width may serve as a useful and easy-to-measure indicator of the suitability of the lower Platte River for nesting terns and plovers. We recommend future tern and plover surveys be refined to include channel width measurements along with nest counts and productivity measures. This information would allow a more complex suite of variables to be included in analyses, making results more informative and species–habitat relationships more predictive.

In the future, interior least tern and piping plover recovery and management will increasingly rely on effective human decision making, whether through proactive habitat creation or regulatory action. In either case, there is a need to explicitly quantify the ecological relationships that apply to management decisions. Defining these relationships and understanding their consequences will provide decision makers the opportunity to consider the trade-offs of future development against potential impacts to interior least terns and piping plovers, as well as to evaluate the likelihood of success of habitat projects intended to benefit these two imperiled species.

ACKNOWLEDGMENTS

We thank Sonya Steckler, Jeff Runge, Rachel Simpson, Gene Zurlein, and two anonymous reviewers for comments that improved this manuscript.

REFERENCES

Alexander, R.D. 1974. The evolution of social behavior. *Annual Review of Ecology and Systematics* 5:325–83.

Battin, J. 2004. When good animals love bad habitats: Ecological traps and the conservation of animal populations. *Conservation Biology* 18:1482–91.

Blodgett, R.H., and K.O. Stanley. 1980. Stratification, bedforms, and discharge relations of the Platte braided river system, Nebraska. *Journal of Sedimentary Petrology* 50:139–48.

Burnham, K.P., and D.R. Anderson. 1998. *Model Selection and Inference: A Practical Information Theoretic Approach*. Springer-Verlag, New York.

Callam, M.A. 1989. Use of prepositioned electrofishing grids to assess habitat availability, utilization, preference, and suitability for *Notropis stramineus*, *N. lutrensis*, and *N. blennius* in the Lower Platte River, Nebraska. Master's thesis, University of Nebraska–Lincoln, Lincoln, NE.

Cresswell, W. 1994. Age-dependent choice of redshank (*Tringa tontanus*) feeding location: Profitability or risk? *Journal of Animal Ecology* 63:589–600.

Cresswell, W., and D.P. Whitfield. 1994. The effect of raptor predation on wintering wader populations at the Tyninghame Estuary, southeast Scotland. *Ibis* 136:223–32.

Draper, N.R., and H. Smith. 1998. *Applied Regression Analysis*. Wiley and Sons, New York.

Elliot, C.M., B.L. Huhmann, and R.B. Jacobson. 2009. *Geomorphic Classification of the Lower Plate River, Nebraska*. US Geological Survey Scientific Investigations Report 2009-5198.

Elliott-Smith, E., and S.M. Haig. 2004. Piping plover (*Charadrius melodus*). In *The Birds of North America*, ed. A. Poole. Academy of Natural Sciences, Philadelphia, and the American Ornithologists' Union, Washington, DC.

Elliott-Smith, E., S.M. Haig, and B.M. Powers. 2009. *Data from the 2006 International Piping Plover Census*. US Geological Survey Data Series 426.

Franzblau, A.N. 1958. *A Primer of Statistics for Non-statisticians*. Harcourt, New York.

Ginting, D., R.B. Zelt, and J.I. Linard. 2008. *Temporal Differences in the Hydrologic Regime of the Lower Platte River, Nebraska, 1895–2006*. US Geological Survey Scientific Investigations Report 2007-5267.

Hilbe, J.M. 2009. *Logistic Regression Models*. Chapman and Hall Publishers, London.

Jodice, P.G.R., D.D. Roby, R.M. Suryan, D.B. Irons, K.R. Turco, E.D. Brown, J.F. Thedinga, G.H. Visser. 2006. Increased energy expenditure by a seabird in response to higher food abundance. *Marine Ecology Progress Series* 306:283–93.

Kirsch, E. 1992. Habitat selection and productivity of least terns (*Sterna antillarum*) on the Lower Platte River, Nebraska. PhD diss., University of Montana, Missoula, MT.

Kruse, C.D., K.F. Higgins, and B.A. Vander Lee. 2001. Influence of predation on piping plover (*Charadrius melodus*), and least tern (*Sterna antillarum*), productivity along the Missouri River in South Dakota. *Canadian Field-Naturalist* 115:480-86.

Lott, C.A. 2006. Distribution and abundance of the interior population of least tern (*Sterna antillarum*), 2005: A review of the first complete range-wide survey in the context of historic and ongoing monitoring efforts. Dredging Operations and Environmental Research Program Technical Notes Collection, US Army Engineer Research and Development Center, Vicksburg, MS. http://www.abcbirds.org/abcprograms/science/ternsurvey.pdf (accessed August 15, 2010).

National Research Council. 2002. *The Missouri River Ecosystem: exploring the prospects for recovery.* National Academy Press, Washington, DC.

National Research Council. 2005. *Endangered and Threatened Species of the Platte River.* National Academy Press, Washington, DC.

Orians, G.H., and J.F. Wittenberger. 1991. Spatial and temporal scales in habitat selection. *American Naturalist Supplement* 137:29–49.

Platte River Recovery Implementation Program. 2006. Final Platte River Recovery Implementation Program. Platte River Recovery Implementation Program, Kearney, NE. http://www.platteriverprogram.org/PubsAndData/ProgramLibrary/Platte%20River%20Recovery%20Implementation%20Program%20Document.pdf (accessed September 4, 2010).

Pribil, S., and J. Picman. 1997. The importance of using the proper methodology and spatial scale in the study of habitat selection by birds. *Canadian Journal of Zoology* 75:1835–44.

Pulliam, H.R. 1988. Sources, sinks and population regulation. *American Naturalist* 132:652–61.

R Development Core Team. 2009. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0. http://www.R-project.org (accessed November 9, 2010).

Schaepe, N.J., and J.S. Alexander. 2011. Sediment SAMPLES and channel-geometry data, lower Platte River watershed, Nebraska. 2010. US Geological Survey Data Series 572.

Schumm, S.A. 1985. Patterns of alluvial rivers. *Annual Review of Earth and Planetary Sciences* 13:5–27.

Stucker, J.H., D.A. Buhl, and M.H. Sherfy. 2011. Emergent sandbar construction for least terns on the Missouri River: Effects of forage fishes in shallow-water habitats. *River Research and Applications*, doi: 10.1002/rra.1525.

Thompson, B.C., J.A. Jackson, J. Burger, L.A. Hill, E.M. Kirsch, and J.L. Atwood. 1997. Least tern (*Sterna antillarum*). In *The Birds of North America*, ed. A. Poole and F. Gill. Academy of Natural Sciences, Philadelphia, and the American Ornithologists' Union, Washington, DC.

US Fish and Wildlife Service. 1988. Great Lakes and northern Great Plains piping plover recovery plan. US Fish and Wildlife Service, Twin Cities, MN.

US Fish and Wildlife Service. 1990. Recovery plan for the interior population of the least tern (*Sterna antillarum*). US Fish and Wildlife Service, Twin Cities, MN.

US Fish and Wildlife Service. 2003. Amendment to the 2000 biological opinion on the operation of the Missouri River Main Stem Reservoir System, operation and maintenance of the Missouri River Bank Stabilization and Navigation Project, and operation of the Kansas River Reservoir System. US Fish and Wildlife Service, Minneapolis, MN.

Ydenberg, R.C., R.W. Butler, D.B. Lank, B.D. Smith, and J. Ireland. 2004. Western sandpipers have altered migration tactics as peregrine falcon populations have recovered. *Proceedings of the Royal Society B: Biological Sciences* 271:1263–69.

Ziewitz, J.W., J.G. Sidle, and J.J. Dinan. 1992. Habitat conservation for least terns and piping plovers on the Platte River, Nebraska. *Prairie Naturalist* 24:1–20.

Great Plains Research 22 (Spring 2012):69–78

WETLAND HYDRODYNAMICS AND LONG-TERM USE OF SPRING MIGRATION AREAS BY LESSER SCAUP IN EASTERN SOUTH DAKOTA

Sharon N. Kahara[1]

Department of Natural Resource Management
South Dakota State University
Brookings, SD 57007

and

Steven R. Chipps

U.S. Geological Survey
South Dakota Cooperative Fish and Wildlife Research Unit
South Dakota State University
Brookings, SD 57007
Steven.Chipps@sdstate.edu

ABSTRACT—Lesser scaup (*Aythya affinis* [Eyton]) populations remain below their long-term average despite improved habitat conditions along spring migration routes and at breeding grounds. Scaup are typically associated with large, semipermanent wetlands and exhibit regional preferences along migration routes. Identifying consistently used habitats for conservation and restoration is complicated by irregular wetland availability due to the dynamic climate. We modeled long-term wetland use by lesser scaup in eastern South Dakota based on surveys conducted during below-average (1987–1989) and above-average (1993–2002) water condition years. Wetland permanence, longitude, and physiographic region were all significant determinants of use ($P < 0.01$). Long-term use was best described by a quadratic equation including wetland surface area variability, an index of wetland hydrodynamics that is linked to productivity, biodiversity, and value to waterfowl. Contrary to previous findings, our study shows that over the long term, lesser scaup are more than twice as likely to use permanent wetlands as they are semipermanent wetlands. The northern region of South Dakota's Prairie Coteau, which holds the highest density of hydrologically dynamic permanent wetlands, should be considered an area of conservation concern for lesser scaup. The criteria we identified may be used to identify important lesser scaup habitats in other regions of the Prairie Pothole Region.

Key Words: lesser scaup, Prairie Coteau, Prairie Pothole Region, wetland hydrodynamics, wetland surface area

INTRODUCTION

North America's Prairie Pothole Region encompasses approximately 800,000 km^2 and is characterized by millions of wetland depressions. The Prairie Pothole Region provides multiple ecosystem services; however, since the 1780s it has suffered drastic wetland losses primarily to agricultural production (Dahl 1990). The heaviest losses occurred in the southeast portion of the region, with Iowa reportedly losing 99% of its wetlands. By comparison, South Dakota has fared marginally better, retaining 65% of its original wetlands (Dahl 1990). However, many of the remaining wetlands continue to undergo changes due to adjacent agricultural practices, resulting in drainage, increased sediment, nutrient, and chemical inputs (Neely and Baker 1989; Gleason and Euliss 1998). Identifying areas of conservation concern is a critical need, especially given the spatial scale of the region, distribution of wetland basins, variable climate, and projected habitat changes due to climate change (Euliss et al. 2004; Johnson et al. 2005; Millett et al. 2009; Johnson et al. 2010).

[1] Current address: Humboldt State University, Arcata, CA 95521, email: snk6@humboldt.edu

Manuscript received for review, August 2011; accepted for publication, January 2012.

The Prairie Pothole Region has long been recognized as an important breeding area for waterfowl and a critical staging ground for spring migrants. Overall, the region supports over 300 bird species (Prairie Pothole Joint Venture 2003). Lesser scaup (*Aythya affinis* [Eyton]), a species of diving duck whose populations have declined significantly since the 1970s (USFWS 2010), migrate through eastern South Dakota's Prairie Pothole Region in large numbers each spring. The combined greater and lesser scaup populations remain 16% below their long-term average (5.1 ± 0.05 million; USFWS 2010). Recent studies attribute lesser scaup declines to changes in spring migration and breeding habitat quality (Austin et al. 1999). Availability and quality of wetlands throughout the upper Midwest play an important role in lesser scaup body condition (Anteau and Afton 2004), which may influence subsequent breeding success. Declines in the 1970s and 1980s were initially attributed to poor water conditions in the Prairie Pothole Region, when precipitation fell below long-term averages leading to widespread drought and temporary loss of wetland habitat. However, their populations continued to decline in the 1990s, which was, on average, the second-wettest decade of the century (Garbrecht and Rossel 2002; Millet et al. 2009). During this period, wetlands increased in size and number across the Prairie Pothole Region, became less isolated and in some instances, may have merged forming larger, deeper ponds (Kahara et al. 2009). Increased wetland availability is generally associated with increased waterfowl production (USFWS 2010); therefore, the reasons for the decline remain unclear, and it is imperative that we identify important habitat areas for further investigation.

Numerous studies of lesser scaup associate them with large, semipermanent wetlands (Holland 1997; Lindeman and Clark 1999; Mockler 2004; Anteau 2006), while others have found higher densities on permanent wetlands (Kantrud and Stewart 1977). One study observed that lesser scaup relied heavily on permanent wetlands in dry years (Allen 1986). We sought to identify the most important wetlands to migrating lesser scaup based on long-term records, as most of the previous studies based their results on relatively brief observation periods. Studies based on less than 10 years of observation may be inadequate for determining priority areas for conservation, as wetlands in the Prairie Pothole Region often exhibit drastic hydrologic variability that influences depth, size, permanence, abundance, and even spatial distribution in response to the cyclical dry-wet climate (Tiner 2003; Kahara et al. 2009). Phases of these climate cycles usually persist for 10–20 years (Diaz 1986), influencing water chemistry, vegetation, and biota (Euliss et al. 2004).

The temporary disappearance of shallow temporary and seasonal wetlands during extended droughts limits the use of these wetland types by most waterfowl (Euliss et al. 1999). However, these are rarely used by diving ducks such as lesser scaup. In extreme droughts, temporary loss of semipermanent wetlands may occur, as was observed during a severe dry period between 1988 and 1993 at the Cottonwood Lake study area in North Dakota (LaBaugh et al. 1996).

Lesser scaup also exhibit regional preferences (Holland 1997; Anteau 2006). In eastern South Dakota, more scaup were observed on wetlands in the Missouri and Prairie Coteaus than other physiographic regions (Holland 1997; Mockler 2004). Identifying consistently used spring migration habitat in the variable landscape of the Prairie Pothole Region would help focus conservation efforts on maintaining habitat quality and food availability in those habitats (Anteau and Afton 2004).

We examined long-term records of lesser scaup habitat associations in eastern South Dakota as influenced by wetland size, hydrology, location, and areal variability over a period of 16 years during which both below-average and above-average water conditions were experienced (Winter and Rosenberry 1998). These variables were used to prioritize areas for migrating lesser scaup.

MATERIALS AND METHODS

Study Area

The study was conducted in eastern South Dakota's Prairie Pothole Region, which encompasses about 91,700 km^2 east of the Missouri River. Approximately 10% of South Dakota's Prairie Pothole Region is comprised of depressional wetlands, mainly freshwater marshes formed by glaciation events during the Pleistocene era (Flint 1971; Johnson and Higgins 1997). We assessed five major physiographic regions in eastern South Dakota (Fig. 1). Physiographic regions differ in climate, soil types, hydrology, elevation, and relative proportion of wetland classes (Johnson and Higgins 1997). Hydrological conditions vary with cyclical dry-wet climate events. Average annual precipitation data from 25 stations across the study area were obtained from the South Dakota State University Climate Data website (http://climate.sdstate.edu/climate_site/climate.htm). Average precipitation during the survey period (1987–2002) was 486 mm, with the driest period occurring

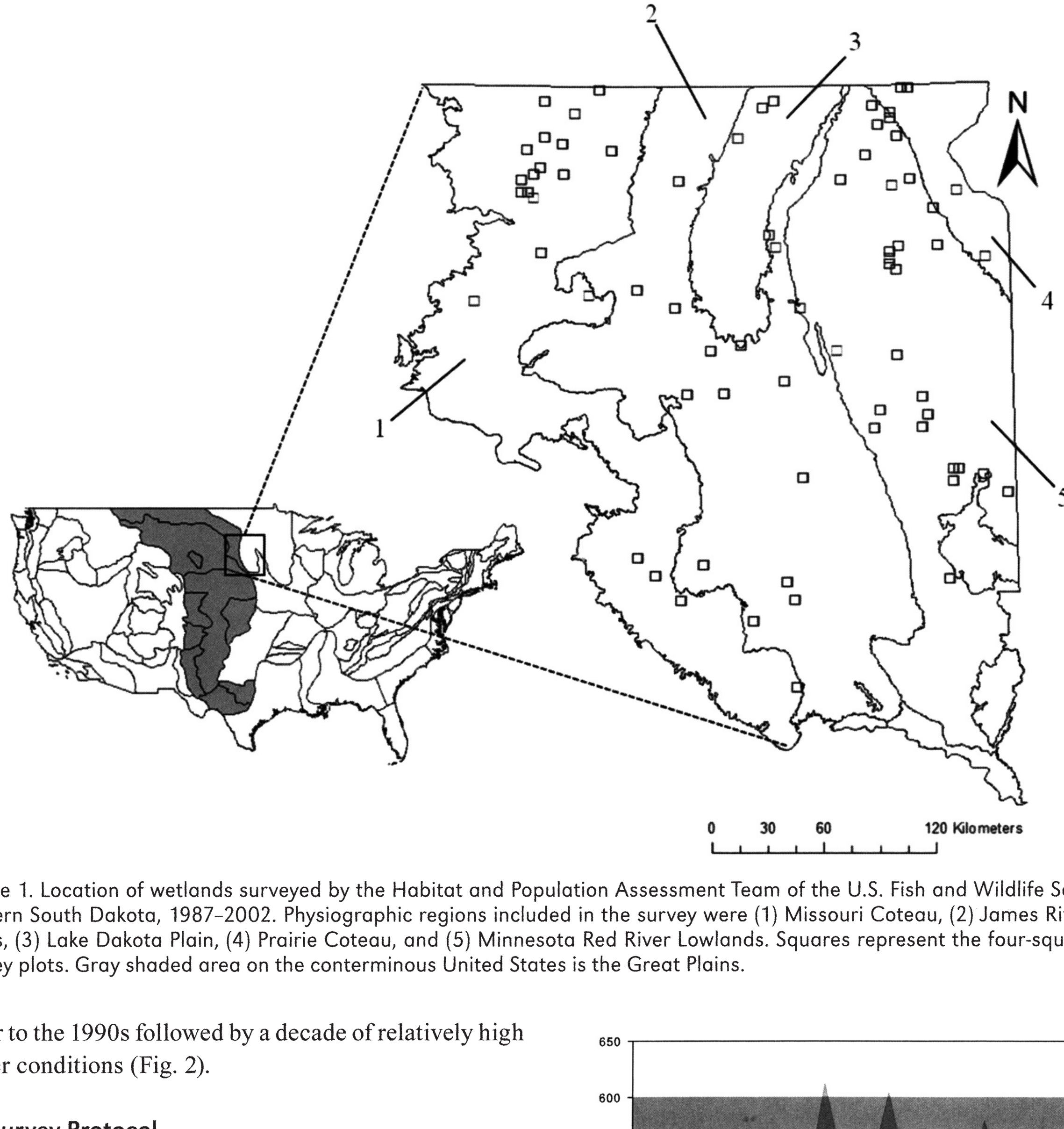

Figure 1. Location of wetlands surveyed by the Habitat and Population Assessment Team of the U.S. Fish and Wildlife Service in eastern South Dakota, 1987–2002. Physiographic regions included in the survey were (1) Missouri Coteau, (2) James River Lowlands, (3) Lake Dakota Plain, (4) Prairie Coteau, and (5) Minnesota Red River Lowlands. Squares represent the four-square-mile survey plots. Gray shaded area on the conterminous United States is the Great Plains.

prior to the 1990s followed by a decade of relatively high water conditions (Fig. 2).

Survey Protocol

We used survey data collected by the U.S. Fish and Wildlife Service Habitat and Population Assessment Team (USFWS-HAPET, Bismarck, ND) in eastern South Dakota from 1987 to 2002. During the survey period, 73 four-square-mile plots (approximately 10.4 km^2; Fig. 1) were randomly selected within five Fish and Wildlife Service Wetland Management Districts (Fig. 1). Over 17,000 surveys were conducted on 954 ponds from 1987 to 2002. Multiple ponds of varying hydrologic regime and size were selected within each four-square-mile plot. Surveys are conducted twice a year, the first from May 1 to May 15 and the second from May 20 to June 5. Observations of waterfowl and general wetland

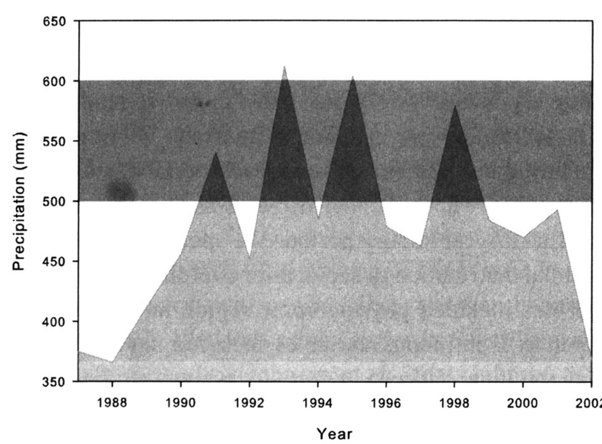

Figure 2. Average annual precipitation (mm) in eastern South Dakota (1987–2002), based on data from 25 weather stations (South Dakota Office of Climatology). Shaded area indicates annual average precipitation range based on data from 30-year climate normals, 1961–1990 (after Millet et al. 2009).

morphometry were made from vehicles using spotting scopes mounted on the window. Observers selected a set of vantage points from which they could view each wetland in its entirety, and recorded waterfowl numbers by species. General wetland morphometry (i.e., basin area, wet area, percentage of vegetation cover) was estimated in the field by surveyors. Surveys were conducted from morning to midafternoon, and time of day did not significantly influence numbers of birds observed (Mockler 2004). Surveyors classified wetlands into one of four categories based on water permanence following Stewart and Kantrud (1971), using the vegetative zone occupying the deepest or central part of the wetland basin to infer degree of water retention. These categories were (1) temporary, (2) seasonal, (3) semipermanent, and (4) permanent.

Statistical Analysis

Scaup Use vs. Non-use. We assessed scaup presence using a generalized linear mixed model specified for logistic distribution (SAS PROC GLIMMIX; SAS Institute 2004). Generalized linear mixed models are designed to perform estimation where data are nonparametric, autocorrelated, and nested. The model accounted for repeated measures over 16 years and overdispersion of the data. The response variable was scaup use vs. non-use; a binary variable. Continuous descriptive variables included wetland area, wetland wet area, and latitude and longitude. Class variables included survey period, wetland class, and physiographic region.

Long-Term Wetland Use. Long-term use of wetlands by lesser scaup was assessed using generalized linear mixed models. Our data included repeated measures made on multiple ponds within plots. Only those wetlands used by lesser scaup were included in analysis. We fit models explaining the number of years each pond was used by lesser scaup where number of years used was averaged over the 16-year survey period. We specified a negative binomial distribution to account for overdispersion. Class variables included physiographic region and water permanence. Continuous variables included survey period (May vs. June), latitude, longitude, average surface area, and wetland surface area variability. Wetland surface area variability was calculated as the difference between minimum and maximum surface area values for each wetland over the survey period. We modeled scaup use as a function of all possible combinations of the variables including interactions and quadratic effects.

Model fit was determined using a scaled Pearson's chi-square parameter. Pearson's chi-square is a goodness-of-fit measure that compares the predicted values of the outcome variable with the actual values where a value close to one was considered indicative of model adequacy (Pedan 2001). Models were then ranked using Akaike's Information Criterion (AIC), where AIC values were calculated from the negative log likelihood derived from each regression model (Burnham and Anderson 2002). Model weights (w_i) were then calculated as a measure of the support for each model. The relative importance of predictor variables was estimated by summing the AIC weights ($\sum w_i$) across the top 10 models in the candidate set where the variable occurred (Burnham and Anderson 2002).

We performed logistic regression (SAS PROC LOGISTIC) to specify the proportion of years each wetland was used by scaup. An odds ratio was calculated to provide an estimate of the relative likelihood of scaup using the Prairie Coteau compared to all other physiographic regions. Odds ratios compare odds of one event occurring relative to one specified response event (Equation 1). The value of the odds ratio may vary from 0 to infinity, with values equal to or around 1, indicating similar odds of both events occurring. We also estimated the odds of scaup using permanent wetlands compared to temporary, seasonal, and semipermanent wetland classes using a generalized linear mixed model procedure (SAS PROC GLIMMIX) specified for binary variables and repeated measures.

$$Odds\ ratio = \left(\frac{p_i}{1-p_i}\right) \Big/ \left(\frac{p_j}{1-p_j}\right) \qquad \text{(Equation 1)}$$

where:

$\frac{p_i}{1-p_i}$ represents the odds of event i occurring, and

$\frac{p_j}{1-p_j}$ represents the odds of event j occurring.

We used the nearest neighbor interpolation tool in ArcGIS (version 9.3) to interpolate average change in wetland surface area, average years used by lesser scaup, and average number of lesser scaup counted over the survey period.

RESULTS

Average annual precipitation over the survey period included both below-average and above-average water conditions (Fig. 2) and was positively correlated with wetland area (Fig. 3; $r = 0.69$, $P < 0.01$). Average annual lesser scaup counts over the survey area were positively

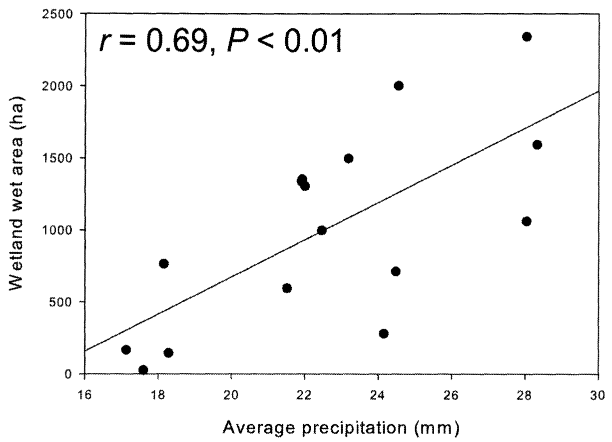

Figure 3. Average precipitation (mm) vs. average wetland wet area (ha) in eastern South Dakota, 1987–2002.

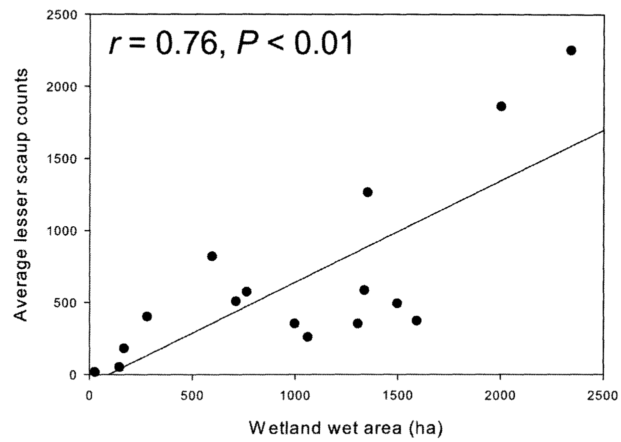

Figure 4. Average wetland wet area (ha) vs. average lesser scaup counts in eastern South Dakota, 1987–2002.

correlated with average wetland surface area (Fig. 4; r = 0.73, $P < 0.01$).

Scaup Use vs. Non-Use

Survey period ($P < 0.0001$), wetland class (water permanence) ($P < 0.01$), longitude ($P = 0.007$), and physiographic region ($P < 0.01$) were all significant determinants of scaup presence. Scaup presence, unlike scaup abundance, was not significantly related to wetland area ($P = 0.104$) or wetland wet area ($P = 0.479$). We found a significant difference between survey periods ($P < 0.01$), and so only data from the second survey was excluded from subsequent analysis. Furthermore, surveys conducted from May 1 to May 15 have been found to correspond best to peak scaup migration (Naugle et al. 2000; Austin et al. 2002; Mockler 2004).

Long-Term Wetland Use

The best-supported model explaining number of years a wetland was used by scaup included the quadratic term for change in surface area (Table 1). The next best model was physiographic region and wetland class, which had an ΔAIC of 9.1. Parameter estimates are given in Table 2. AIC weights indicated that the most important variable was wetland variability ($w_i = 0.99$), whereas physiographic region ($w_i = 0.01$) and average wetland area ($w_i = 0.001$) provided little explanatory value to the data (Table 3). Average change in wetland surface area ranged from 0 to 89 ha. The most variable wetlands were located in the Prairie Coteau physiographic region (Fig. 5A). The highest numbers of scaup and most frequently used areas were in the northern Prairie Coteau and northern Missouri Coteau (Figs. 5B and 5C).

The odds of migrating lesser scaup using the Prairie Coteau and Missouri Coteau were similar (Table 4). The odds of other physiographic regions being used by migrant scaup was less than half that of the Prairie Coteau. Semipermanent wetlands were only a third as likely to be used as permanent wetlands. Temporary wetlands were the least likely to be used by migrating scaup (Table 5).

CONCLUSIONS

Numerous studies have demonstrated the importance of spring migration habitat on waterfowl body condition, with implications for breeding success (e.g., Raveling and Heitmeyer 1989; Mainguy et al. 2002; Anteau and Afton 2004; Haukos et al. 2006). Drought conditions along migration routes and breeding grounds can influence migration chronology (Baar et al. 2008), force broods to move greater distances (Krapu et al. 2006), extend spring migration (Hupp et al. 2011), and reduce waterfowl carrying capacity (Smith 1971). The climate of the Prairie Pothole Region is semiarid, with considerable variations in rainfall (Winter 1989). Wetlands of the region are very sensitive to climate variability (Johnson et al. 2004; Johnson et al. 2005; Johnson et al. 2010). During severe droughts, many wetlands dry up completely, resulting in fewer available wetlands for waterfowl use and increased isolation among remaining basins (Shapley et al. 2005; Kahara et al. 2009).

Habitat conditions encountered along spring migration routes can impact body condition, timing of nesting,

TABLE 1
BEST-SUPPORTED MODELS BASED ON AKAIKE'S INFORMATION CRITERION VALUES OF FACTORS AFFECTING NUMBER OF YEARS USED BY LESSER SCAUP IN EASTERN SOUTH DAKOTA, 1987–2002

Variables	Scaled Pearson's χ^2	AIC
Change in surface area Change in surface area^2	1.09	872.7
Physiographic region • Wetland class	1.08	881.8
Global model	1.08	885.8

Note: Pearson's chi-square statistics are from a generalized linear mixed model specified for a negative binomial distribution.

TABLE 2
FACTORS AFFECTING NUMBER OF YEARS USED BY LESSER SCAUP IN EASTERN SOUTH DAKOTA, 1987–2002

Variables	df	β	P
Intercept	204	1.0634	<0.0001
Change in surface area	204	0.017	<0.0001
Change in surface area^2	204	-0.00004	<0.0001

Note: Parameter estimates and test statistics are from a generalized linear mixed model specified for a negative binomial distribution.

TABLE 3
AKAIKE'S INFORMATION CRITERION MODEL WEIGHTS OF FACTORS AFFECTING LONG-TERM WETLAND USE BY LESSER SCAUP IN EASTERN SOUTH DAKOTA, 1987–2002

Variable	AIC ω_i
Change in surface area	0.99
Physiographic region	0.01
Average wetland area	0.001

breeding success, and survival (e.g., Ebbinge and Spaans 1995; Mainguy et al. 2002). Brasher (2010) reported that duck use decreased as wetlands became more isolated. Greater isolation may increase distances between stopover wetlands, increasing flight paths and placing additional energetic burdens on birds en route to breeding grounds. However, effects of longer flight paths on birds' ability to sequester sufficient food and maintain body condition remain uninvestigated. Nonetheless, it is likely that waterfowl populations have adapted to the variable dry-wet climate of the Prairie Pothole Region, and population numbers have been observed to respond accordingly.

The relationship between breeding ducks and wetland availability in the Prairie Pothole Region (indexed as "May Ponds") is well documented (Batt et al. 1989), but it is rarely applied to spring migrant use. During wet periods, wetlands in the Prairie Pothole Region expand in surface area and even overflow their basins (Leibowitz and Vining 2003; Tiner 2003; Shapley et al. 2005). Precipitation generally increased across the Prairie Pothole Region during the 20th century, with the highest recorded rainfall in the southeastern region. Analysis of climate trends indicate that average annual rainfall in eastern South Dakota varied within a range of 500–600 mm/yr with the highest precipitation occurring in the mid- to late 1990s (Garbrecht and Rossel 2002; Millet et al. 2009). We demonstrated that lesser scaup numbers in eastern South Dakota were positively related to wetland size and that wetland size was positively related to precipitation.

The relationship between lesser scaup numbers and wetland variability was quadratic, indicating a preference for wetlands that exhibited intermediate levels of surface area fluctuation. We found that permanent wetlands exhibited higher surface area variability than semipermanent, seasonal, and temporary wetlands, which may be linked to the fact that they are generally larger than other wetland classes. The relatively large size may also ensure longer hydroperiods and thus provide refugia during droughts. Longer hydroperiods are critical to the survival of specific aquatic invertebrates (e.g., amphipods) that constitute a large proportion of scaup diets during migration (Anteau and Afton 2004; Strand et al. 2007). We suggest that studies conducted in regions where semipermanent wetlands are more common, and during average or above-average water condition years, may overestimate their importance to lesser scaup.

Over the 16-year survey period, permanent wetlands in the Prairie Coteau experienced the greatest variation in size from dry to wet periods. High wetland density and

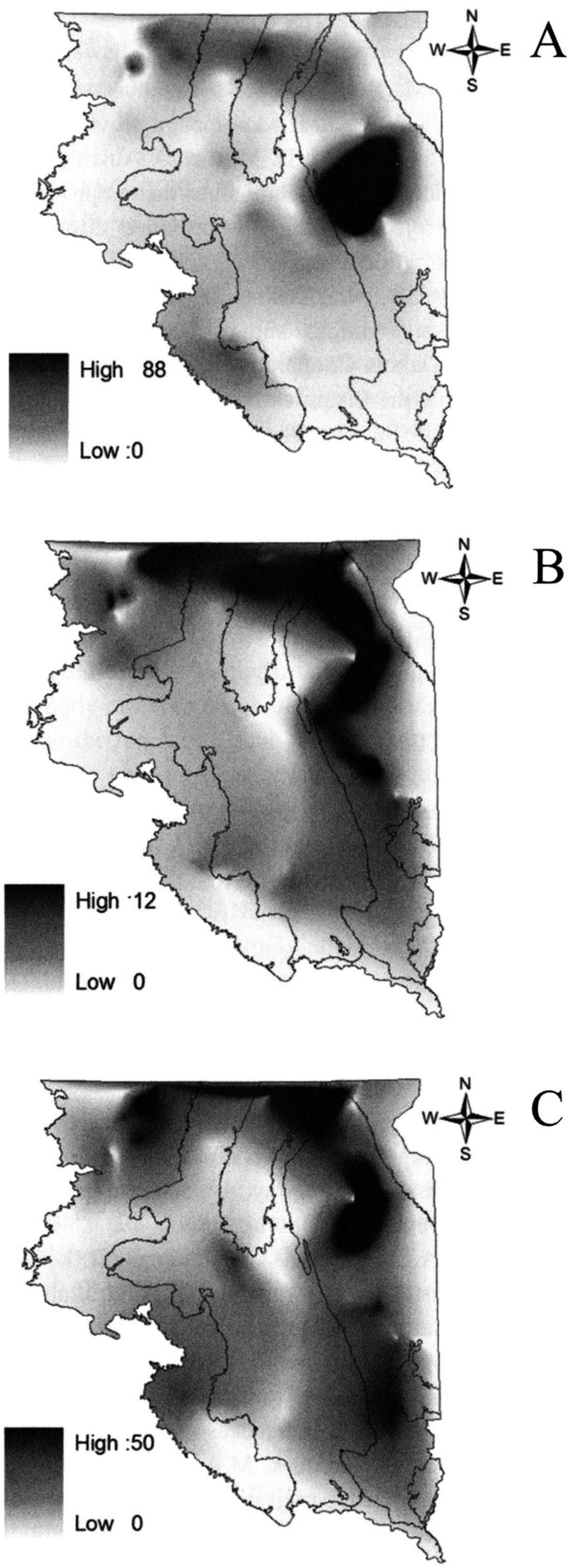

Figure 5. Spatial distribution showing (A) average change in surface area (ha) at each four-square-mile plot surveyed from 1987 to 2002 in eastern South Dakota, (B) average number of years used by migrant lesser scaup, and (C) average number of lesser scaup counted.

TABLE 4
ODDS RATIO ESTIMATES OF LONG-TERM USE OF PHYSIOGRAPHIC REGIONS BY LESSER SCAUP IN EASTERN SOUTH DAKOTA, 1987–2002

Effect	Point estimate	95% confidence limits	
Missouri Coteau vs. Prairie Coteau	0.966	0.697	1.337
Minnesota Red River Lowland vs. Prairie Coteau	0.503	0.206	1.229
Lake Dakota Plain vs. Prairie Coteau	0.431	0.137	1.358
James River Lowland vs. Prairie Coteau	0.488	0.292	0.816

Note: Estimates are based on a logistic model of the proportion of years used.

TABLE 5
ODDS RATIO ESTIMATES OF LONG-TERM USE OF WETLAND CLASSES BY LESSER SCAUP IN EASTERN SOUTH DAKOTA, 1987–2002

Effect	Point estimate	95% confidence limits	
Temporary vs. permanent	0.057	0.033	0.097
Seasonal vs. permanent	0.143	0.113	0.181
Semipermanent vs. permanent	0.28	0.233	0.336

Note: Estimates are based on a logistic model of used vs. unused wetlands.

hydrodynamics have been linked to increased productivity (van der Valk 1989; Johnson et al. 2004). Dynamic surface water levels increase sediment exposure and reinundation, thereby facilitating nutrient cycling and productivity (Mitsch and Gosselink 2007). The period of flooding after sediment exposure is usually followed by rapid and prolific plant growth fueled by the increased nutrient availability (van der Valk and Davis 1978), which contributes to increased secondary and tertiary productivity farther up the food chain (Euliss et al. 2004). Our study also determined that contrary to previous research (e.g., Lindeman and Clark 1999; Mockler 2004), permanent wetlands were more likely to be used by migrant scaup than semipermanent wetlands over the long term.

Observed differences in wetland use may be an artifact of sampling location and timing, as wetland hydroperiods tend to shift depending on local climate. Also, wetland resources and types are not evenly distributed across the Prairie Pothole Region (Kahara et al. 2009). Few lesser scaup breed in South Dakota; however, it is major stopover site for spring migrants (Holland 1997). Our study suggests that dynamic permanent wetlands may provide more benefits to migrating lesser scaup over the long term.

We suggest that the northern portions of the Prairie Coteau be considered an area of conservation concern for migrating lesser scaup. This region is not only rich in large, aerially dynamic permanent wetlands but also has large numbers of semipermanent wetlands favored by lesser scaup in average and above-average water condition years. This area is also an important staging and brood-rearing area for other diving duck species including ring-necked ducks (*Aythya collaris*), redheads (*Aythya americana*), and buffleheads (*Bucephala albeola*) (Holland 1997). Conservation programs such as the Conservation Reserve Program (CRP) and the Wetlands Reserve Program (WRP) have enrolled millions of hectares of land since their inception in the early 1990s. These programs have reportedly significantly boosted waterfowl productivity (Reynolds et al. 2001) resulting in millions of new ducks each year. Although wetland losses in the Dakotas have been relatively small compared to other regions of the Prairie Pothole Region (35% in South Dakota and 49% in North Dakota), these regions also likely provide the most productive waterfowl habitats in the region (Johnson et al. 2005). Therefore, the weight of these wetland losses may be more ecologically severe.

Hydrodynamics are not currently considered as part of the criteria for conservation prioritization in the Prairie Pothole Region and warrant further investigation. Our data support studies that link dynamic climate conditions to habitat suitability for waterfowl (e.g., Johnson et al. 2005). Under current global climate change scenarios, hydrologically dynamic wetland areas could shift farther east in the Prairie Pothole Region to areas that have already lost the majority of their wetlands (Dahl 1990). In addition to focusing on breeding sites, the inclusion of wetlands located along spring migration routes should be considered as part of conservation planning to improve lesser scaup survival and breeding success. The criteria we identified may be used to identify important lesser scaup habitats in other regions in the Prairie Pothole Region.

ACKNOWLEDGMENTS

We thank M. Bouchard for assistance with maps and GIS data. S. Vaa and P. Mammenga provide technical assistance in the field. D. Mushet, J. Austin, and R. Murano provided helpful comments that improved the manuscript. Project funding was provided through the Wildlife Restoration Program (W-75-R-150-75110) administered by the South Dakota Department of Game, Fish, and Parks. Additional support was provided by the USGS South Dakota Cooperative Fish and Wildlife Research Unit and the Bismarck HAPET Office of the U.S. Fish and Wildlife Service. The South Dakota Cooperative Fish and Wildlife Research Unit is jointly supported by the U.S. Geological Survey, South Dakota State University, South Dakota Department of Game, Fish, and Parks, the Wildlife Management Institute, and the U.S. Fish and Wildlife Service. Any use of trade names is for descriptive purposes only and does not imply endorsement by the federal government.

REFERENCES

Allen, A.W. 1986. *Habitat suitability index models: lesser scaup (breeding).* U.S. Fish and Wildlife Service. Biological Report. Department of the Interior, Washington, DC.

Anteau, M.J. 2006. Ecology of lesser scaup and amphipods in the upper Midwest: Scope and mechanisms of the spring condition hypothesis and implications for migration habitat conservation. PhD diss., Louisiana State University, Baton Rouge.

Anteau, M.J., and A.D. Afton. 2004. Nutrient reserves of lesser scaup *Aythya affinis* during spring migration in the Mississippi Flyway: A test of the spring condition hypothesis. *The Auk* 121:917–29.

Austin, J.E., A.D. Afton, M.G. Anderson, R.G. Clark, C.M. Custer, J.S. Lawrence, J.B. Pollard, and J.K. Ringleman. 1999. Declines of Greater and Lesser scaup populations: Issues, hypotheses, and research directions. http://www.npwrc.usgs.gov/resource/birds/blubill/index.htm (accessed January 1, 2009).

Austin, J.E., D.A. Granfors, M.A. Johnson, and S.C. Kohn. 2002. Scaup migration patterns in North Dakota relative to temperatures and water conditions. *Journal of Wildlife Management* 66:874–82.

Baar, L., R.S. Matlack, W.P. Johnson, and R.B. Barron. 2008. Migration chronology of waterfowl in the southern High Plains of Texas. *Waterbirds* 31:394–401.

Batt, B.D.J., M.G. Anderson, C.D. Anderson, and F.D. Caswell. 1989. The use of prairie potholes by North American ducks. In *Northern Prairie Wetlands,* ed. A. Van der Valk, 204–27. Iowa State University Press, Ames.

Brasher, M.G. 2010. Duck use and energetic carrying capacity of actively and passively managed wetlands in Ohio during autumn and spring migration. PhD diss., Ohio State University, Columbus.

Burnham, K.P., and D.R. Anderson. 2002. *Model Selection and Multimodel Inference: A Practical-Theoretic Approach*, 2nd ed. Springer-Verlag, New York.

Dahl, Thomas E. 1990. Wetlands losses in the United States 1780s to 1980s. http://www.npwrc.usgs.gov/resource/wetlands/wetloss/index.htm (accessed August 1, 2010).

Diaz, H.F. 1986. An analysis of twentieth century climate fluctuations in northern North America. *Journal of Climate and Applied Meteorology* 25:1625–57.

Ebbinge, B.S., and B. Spaans. 1995. The importance of body reserves accumulated in spring staging areas in the temperate zone for breeding in dark-bellied brent geese *Branta b. bernicla* in the high Arctic. *Journal of Avian Biology* 26:105–13.

Euliss, N.H., Jr., J.W. LaBaugh, L.H. Fredrickson, D.M. Mushet, G.A. Swanson, T.C. Winter, D.O. Rosenberry, and R.D. Nelson. 2004. The wetland continuum: A conceptual framework for interpreting biological studies in the prairie pothole region of North America. *Wetlands* 24:448–58.

Euliss, N.H., Jr., D.M. Mushet, and D.A. Wrubleski. 1999. Wetlands of the prairie pothole region: Invertebrate species composition, ecology, and management. In *Invertebrates in Freshwater Wetlands of North America: Ecology and Management*, ed. D.P. Batzer, R.B. Rader, and S.A. Wissinger, 471–514. John Wiley and Sons, New York.

Flint, R.F. 1971. *Glacial and Quaternary Geology.* John Wiley and Sons, New York.

Garbrecht, J.D., and F.E. Rossel. 2002. Decade-scale precipitation increase in Great Plains at the end of the 20th century. *Journal of Hydrological Engineering* 7:64–75.

Gleason, R.A., and N. Euliss. 1998. Sedimentation of prairie wetlands. *Great Plains Research* 8:97–112.

Haukos, D.A., M.R. Miller, D.L. Orthmeyer, J.Y. Takekawa, J.P. Fleskes, M.L. Casazza, W.M. Perry, and J.A. Moon. 2006. Spring migration of northern pintails from Texas and New Mexico, USA. *Waterbirds* 29:127–36.

Holland, M.M. 1997. Characteristics of wetlands used by breeding diving ducks in eastern South Dakota. Master's thesis, South Dakota State University, Brookings.

Hupp, J.W., N. Yamaguchi, P.L. Flint, J.M. Pearce, K. Tokita, T. Shimada, A.M. Ramey, S. Kharitonov, and H. Higuchi. 2011. Variation in spring migration routes and breeding distribution of northern pintails *Anas acuta* that winter in Japan. *Journal of Avian Biology*, http://onlinelibrary.wiley.com/doi/10.1111/j.1600-048X.2011.05320.x/full (accessed August 1, 2010).

Johnson, R.R., and K.F. Higgins. 1997. Wetland resources of eastern South Dakota. PhD diss., South Dakota State University, Brookings.

Johnson, W.C., B. Werner, G.R. Guntenspergen, R.A. Voldseth, B. Millett, D.E. Naugle, M. Tulbure, R.W.H. Carroll, J. Tracy, and C. Olawsky. 2010. Prairie wetland complexes as landscape functional units in a changing climate. *BioScience* 60:128–40.

Johnson, W.E., S.E. Boettcher, K.A. Poiani, and G.R. Guntenspergen. 2004. Influence of weather extremes on the hydrology of glaciated prairie wetlands. *Wetlands* 24:385–98.

Johnson, W.E., B.V. Millett, T. Gilmanov, R.A. Voldseth, G.R. Guntenspergen, and D.E. Naugle. 2005. Vulnerability of northern prairie wetlands to climate change. *BioScience* 55:863–72.

Kahara, S.N., R.M. Mockler, K.F. Higgins, S.R. Chipps, and R.R. Johnson. 2009. Spatiotemporal patterns of wetland occurrence in the Prairie Pothole Region of eastern South Dakota. *Wetlands* 29:678–89.

Kantrud, H.A., and R.E. Stewart. 1977. Use of natural basin wetlands by breeding waterfowl in North Dakota. *Journal of Wildlife Management* 41:243–53.

Krapu, G., P. Pietz, D. Brandt, and R. Cox, Jr. 2006. *Mallard Brood Movements, Wetland Use, and Duckling Survival During and Following a Prairie Drought.* Northern Prairie Wildlife Research Center, USGS, Jamestown, ND.

LaBaugh, J.W., T.C. Winter, G.A. Swanson, D.O. Rosenberry, R.D. Nelson, and N.H. Euliss, Jr. 1996. Changes in atmospheric circulation patterns affect mid-continent wetlands sensitive to climate. *Limnology and Oceanography* 41:864–70.

Leibowitz, S.G., and K.C. Vining. 2003. Temporal connectivity in a prairie pothole complex. *Wetlands* 23(1):13–25.

Lindeman, D.H., and R.G. Clark. 1999. Amphipods, land–use impacts, and lesser scaup *Aythya affinis*

distribution in Saskatchewan wetlands. *Wetlands* 19:627–38.

Mainguy, J., J. Bêty, G. Gauthier, and J.-F. Giroux. 2002. Are body condition and reproductive effort of laying greater snow geese affected by the spring hunt? *Condor* 104:156–61.

Millett, B., W.C. Johnson, and G. Guntenspergen. 2009. Climate trends of the North American prairie pothole region, 1906–2000. *Climatic Change* 93:243–67.

Mitsch, W.J., and J.G. Gosselink. 2007. *Wetlands,* 4th ed. John Wiley and Sons, New York.

Mockler, R.E. 2004. Lesser scaup use of wetlands in eastern South Dakota. Master's thesis, South Dakota State University, Brookings.

Naugle, D.E., R.R. Johnson, T.R. Cooper, M.M. Holland, and K.F. Higgins. 2000. Temporal distribution of waterfowl in eastern South Dakota: Implications for aerial surveys. *Wetlands* 20:177–183.

Neely, R.K., and J.L. Baker. 1989. Nitrogen and phosphorus dynamics and the fate of agricultural runoff. In *Northern Prairie Wetlands*, ed. A. van der Valk, 92–131. Iowa State University Press, Ames.

Pedan, A. 2001. Analysis of count data using the SAS system. In *Proceedings of the Twenty-Sixth Annual SAS Users Group International Conference*. SAS Institute, Cary, NC.

Prairie Pothole Joint Venture. 2003. Prairie Pothole Joint Venture. http://www.ppjv.org/pdf/15year.pdf (accessed August 1, 2010).

Raveling, D.G., and M.E. Heitmeyer. 1989. Relationships of population size and recruitment of pintails to habitat conditions and harvest. *Journal of Wildlife Management* 53:1088–1103.

Reynolds, R.E., T.L. Shaffer, R.W. Renner, W.E. Newton, and B.D.J. Batt. 2001. Impact of the Conservation Reserve Program on duck recruitment in the U.S. Prairie Pothole Region. *Journal of Wildlife Management* 65:765–80.

SAS Institute. 2004. The SAS system for windows. SAS Institute, Cary, NC.

Shapley, M.D., W.C. Johnson, D.R. Engstrom, and W.R. Osterkamp. 2005. Late-Holocene flooding and drought in the Northern Great Plains, USA, reconstructed from tree rings, lake sediments, and ancient shorelines. *Holocene* 15:29–41.

Smith, A.G. 1971. *Ecological Factors Affecting Waterfowl Production in the Alberta Parklands*. Resource Publication Number 98. U.S. Fish Wildlife Service, Washington, DC.

Stewart, R.E., and H.A. Kantrud. 1971. *Classification of Natural Ponds and Lakes in the Glaciated Prairie Region*. Resource Publication Number 92. U.S. Fish and Wildlife Service, Washington, DC.

Strand, K.A., S.R. Chipps, S.N. Kahara, K.F. Higgins, and S. Vaa. 2007. Patterns of prey use by lesser scaup *Aythya affinis* (Aves) and diet overlap with fishes during spring migration. *Hydrobiologia* 598:389–98.

Tiner, R.W. 2003. Geographically isolated wetlands of the United States. *Wetlands* 23:494–516.

USFWS (U.S. Fish and Wildlife Service). 2010. *Waterfowl Population Status, 2010*. U.S. Department of the Interior, Washington, DC.

van der Valk, A.G. 1989. *Northern Prairie Wetlands*. Iowa State University Press, Ames.

van der Valk, A.G., and C.B. Davis. 1978. The role of the seed bank in the vegetation dynamics of prairie glacial marshes. *Ecology* 59:322–35.

Winter, T.C. 1989. Hydrologic studies of wetlands in the Northern Prairie. In *Northern Prairie Wetlands*, ed. A. van der Valk, 16–54. Iowa State University Press, Ames.

Winter, T.C., and D.O. Rosenberry. 1998. Hydrology of prairie pothole wetlands during drought and deluge: A 17-year study of the cottonwood lake wetland complex in North Dakota in the perspective of longer term measured and proxy hydrological records. *Climatic Change* 40:189–209.

Great Plains Research 22 (Spring 2012):79–86

REPRODUCTION AND POPULATION CHARACTERISTICS OF WHITE-TAILED JACKRABBITS IN SOUTH DAKOTA

Charles Dieter

Department of Natural Resource Management
South Dakota State University
Brookings, SD 57007
charles.dieter@sdstate.edu

and

Dustin Schaible

Utah Division of Wildlife Resources
P.O. Box 606
Cedar City, UT 84721-0606

ABSTRACT—We evaluated the reproductive biology of 314 white-tailed jackrabbits (*Lepus townsendii*) in 44 counties throughout South Dakota from June 2004 to September 2005. We classified jackrabbits as juveniles or adults based on the closure of the proximal epiphysis of the humerus using X-ray analysis. We determined annual reproductive activity through fluctuations in measured weights of reproductive organs for both sexes. The 2005 breeding season started in late February and proceeded until mid-July, approximately 142 days, allowing for females to potentially produce 3.3 litters. We found four distinct breeding periods by the overlap of estimated conception and parturition dates. Mean litter size was 4.6 per female (range 1–8). Prenatal mortality from preimplantation and postimplantation loss was highest (32%) in the first littering period in 2005.

Key Words: fecundity, population characteristics, reproduction, South Dakota, white-tailed jackrabbit

INTRODUCTION

Many researchers have suggested that *Lepus* spp. have cyclic populations (Rowman and Keith 1956; Donoho 1972; Gross et al. 1974; Nowak and Paradiso 1983; Anderson and Shumar 1986). Recently, however, Shaible and Dieter (2011) have discovered a general downward trend in jackrabbit populations in the northern Great Plains. There have been many suggestions for the cause of fluctuations in lagomorph populations, but most of the research has been done on snowshoe hares (*Lepus americanus*) (Hik 1995; Boonstra et al. 1998; Hodges et al. 1999; Krebs et al. 2001; Sheriff et al. 2009). Little data exist to evaluate the current status of white-tailed jackrabbits (*Lepus townsendii*). We wanted to examine the reproductive potential of white-tailed jackrabbits to determine if reproductive output may influence fluctuations in jackrabbit populations.

Manuscript received for review, October 2011; accepted for publication, January 2012.

As with most leporids, white-tailed jackrabbits are capable of producing multiple litters per season, and reproductive output may vary geographically (Flux 1971; Conaway et al. 1974; Keith 1981; Dunn et al. 1982; Rogowitz 1992). Jackrabbits have a tendency for postpartum breeding, which may lead to synchronous breeding (Lechleitner 1959; Kline 1963; James and Seabloom 1969; Dunn et al. 1982; Rogowitz 1992).

White-tailed jackrabbits typically reach reproductive maturity after one year of age. The breeding season begins in late February and extends through mid-July (Dunn et al. 1982). In Iowa and North Dakota, the breeding season lasted 148 days (Kline 1963; James and Seabloom 1969) while a 146-day breeding season was noted in southwestern Wyoming (Rogowitz 1992). White-tailed jackrabbits produce three to four litters per year in both North Dakota (James and Seabloom 1969) and Iowa (Kline 1963). The gestation period for white-tailed jackrabbits is typically 42–43 days (Kline 1963).

Since jackrabbits serve an important niche in grassland ecosystems, it is important to understand population demographic composition and fecundity. This information may allow managers to evaluate population fluctuations and understand predator-prey relationships. White-tailed jackrabbits have received little attention with respect to demographic composition within their distribution, and no attention has been given to reproductive parameters in South Dakota (Schaible and Dieter 2011). The objective of this research was to determine population characteristics and reproductive potential of white-tailed jackrabbits in South Dakota.

STUDY AREA

We collected white-tailed jackrabbits throughout South Dakota from June 2004 to September 2005. The eastern portion of the state lies within the Prairie Plains, which was created through glaciation and is characterized by low hills, marshes, and lakes (Visher 1918). Most of the western portion of the state lies within the Great Plains, which includes a more rugged landscape of rolling hills. Tallgrass prairie dominates much of the area in eastern South Dakota and makes a transition to northern mixed-grass prairie to the west (Johnson and Nichols 1982). The northeast quarter of South Dakota tends to be the coldest and the southwestern portions the warmest (Visher 1918). The growing season generally averages 130 days, and annual precipitation averages approximately 50.8 cm for the state (Visher 1918).

Land use is typically for agricultural purposes, especially in eastern South Dakota (Hogan and Fouberg 1998). The most commonly cultivated crops include corn (*Zea* spp.), soybeans (*Glycine max*), alfalfa (*Medicago sativa*), and several small grains including oats (*Avena sativa*), wheat (*Triticum aestivum*), and barley (*Hordeum vulgare*). Livestock production is also prevalent throughout South Dakota. Portions of western South Dakota still contain large areas of grassland.

METHODS

We collected 15–20 jackrabbits each month using a .22 caliber rifle. We also received jackrabbits from personnel of the South Dakota Department of Game, Fish and Parks and Ellsworth Air Force Base. We fit each jackrabbit with an individual identification tag, and the animals were either frozen or necropsied immediately.

We estimated the age of jackrabbits using X-ray analysis (0.15 s exposure time) of the proximal epiphysis of the left humerus (Hale 1949; Lechleitner 1959; James and Seabloom 1969). We classified jackrabbits as juveniles (2–12 months) where the epiphyseal area had a definite groove or as adults (over one year old) where there was no evidence of an epiphyseal line (Lechleitner 1959).

Postmortem examinations involved assessing the reproductive condition of both sexes using methods described by James and Seabloom (1969) and Gross et al. (1974). We determined sexual activity by measuring the mass of paired testes after the epididymides were removed for males, and by measuring the mass of paired ovaries for females. We determined reproductive potential by examination of fetuses that were removed and counted from gravid females. Litter size was defined as the total number of viable fetuses per female (Rogowitz 1992). Following methods similar to James and Seabloom (1969), we approximated fetal age by comparing developmental and morphological characteristics to those of the snowshoe hare (Bookhout 1964) since there were no similar references for white-tailed jackrabbits. We approximated the date of conception by backdating the estimated fetal age from the date of collection. Parturition dates were determined by adding the gestation period of 43 days to conception dates (James and Seabloom 1969; Rogowitz 1992). The breeding season was defined as the length of time between the first conception date and the last conception date. We calculated the annual potential number of litters by dividing the length of the breeding season by the 43-day gestation period. Proc GLM Least Square Means (SAS Institute, Gary, IN) was used to determine seasonal differences in ovarian and testicular weights.

We preserved ovaries removed from gravid female jackrabbits in a 10% formalin solution and then sectioned them to macroscopically count corpora lutea, which represented the number of ova shed per ovary for individual litters (James and Seabloom 1969). We estimated prenatal mortality from the amount of litter loss experienced from preimplantation and postimplantation loss (Lechleitner 1959). Preimplantation loss was defined as failure of ova to implant within the uterine wall, and we estimated the loss by subtracting the number of corpora lutea from the number of implantation sites. We measured postimplantation loss as resorption of implanted embryos, and we calculated it by subtracting the number of implantation sites from the number of viable fetuses (Lechleitner 1959). Resorbing fetuses were identified as swellings that appeared distinctly smaller than viable fetuses (Bookhout 1964). Both causes of prenatal mortality were then incorporated as

$$(\text{Prenatal loss per litter}) / (\text{Number of ova shed}) \times 100$$

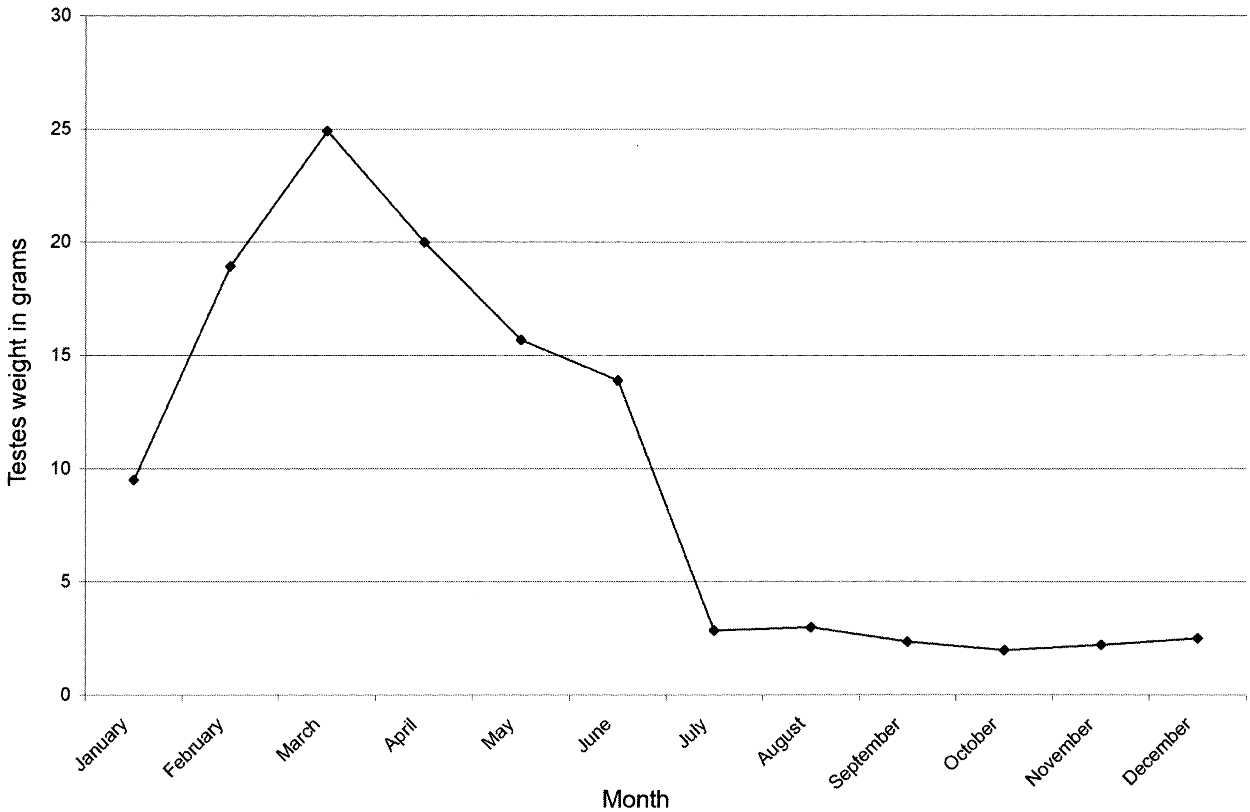

Figure 1. Monthly fluctuation in testes weights of male white-tailed jackrabbits in South Dakota, 2004 and 2005.

to calculate a percentage prenatal mortality for each littering period (Lechleitner 1959).

RESULTS

We collected 314 white-tailed jackrabbits in 44 counties throughout South Dakota. The number of jackrabbits collected monthly ranged from six to 44 ($\bar{x}$ = 19). There were 161 males and 153 females, which was not different than an expected 1:1 sex ratio ($\chi^2 = 0.204$).

We were able to estimate the age of 264 white-tailed jackrabbits. The remaining 50 animals were not included due to damage of the humerus in the collection process. There were 171 adults, which were present in all months of collection. The remaining 93 jackrabbits were classified as juveniles and were collected from June to December 2004 and from May to September 2005.

An annual pattern of reproductive activity was demonstrated by testicular weight fluctuations in male white-tailed jackrabbits (Fig. 1). There was a monthly difference in testicular weights ($F_{11} = 56.38$, $P < 0.001$). The highest testicular weight occurred in March (24.92 g; SE = 1.16) followed by April (19.98 g; SE = 0.74) and February (18.93 g; SE = 1.06). These data indicate that male white-tailed jackrabbits were most sexually active during early spring. Testicular weights were lowest in October (1.95 g; SE = 1.84) and November (2.21 g; SE = 1.39).

Annual fluctuations were also apparent in monthly female ovarian weights ($F_{11} = 14.34$, $P < 0.001$) (Fig. 2). Ovarian weights were highest in May (2.98 g; SD = 0.28) followed by March (2.16 g; SE = 0.18). Ovarian weights in April (1.78 g; SE = 0.18) and June (1.90 g, SE = 0.15) were also high, indicating that females were most sexually active from March to June. Ovarian weights were lowest in October (0.27 g; SE = 0.38) and November (0.23 g; SE = 0.28).

Breeding synchrony was evident as indicated by an overlap of estimated conception and parturition dates (Table 1). In June 2004 eight of the 10 adult female jackrabbits were pregnant. From the estimated conception dates, females collected in June likely represented the third littering period. Conception dates for each female were estimated from May 22 to May 27, and subsequent parturition dates were estimated from July 3 to July 8.

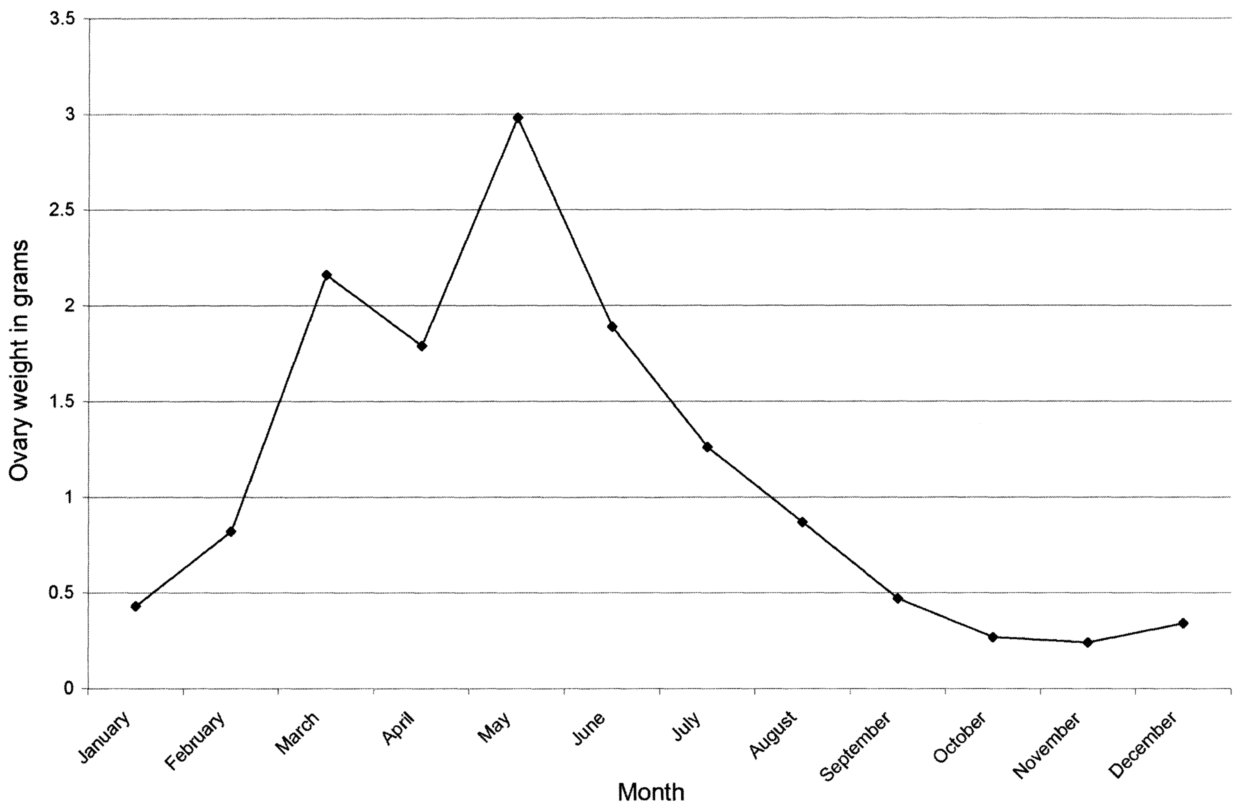

Figure 2. Monthly fluctuations in ovarian weights of female white-tailed jackrabbits in South Dakota, 2004 and 2005.

Litter size ranged from four to eight and averaged 5.5 (SE = 0.50) per female.

In July 2004 two of seven adult females were pregnant and one of 10 adult females was pregnant in August. Estimated conception dates for these females were July 4, July 6, and July 17. Since the estimated conception dates overlap with parturition dates of the third littering period, these three females likely represented the fourth litter in 2004. Litter size ranged from four to seven and averaged 5.0 (SE = 1.0) per female during the fourth littering period. Due to timing of collection, the length of the 2004 breeding season was not determined.

In 2005 the breeding season started in February, based on the first pregnant female's estimated conception date (February 24). Further support for an increase in reproductive activity was demonstrated by the progression of ovarian and testicular weight during this time period. In March, all 13 collected adult female jackrabbits were pregnant, with conception dates estimated from February 24 to March 6. Parturition dates were estimated from April 7 to April 17. Litter size for the first littering period ranged from one to seven and averaged 4.2 (SE = 0.46) per female.

The second littering period in 2005 was determined by an overlap of conception dates demonstrated by three gravid females collected in April and one collected in May. Estimated conception dates for these four females were from March 29 to April 16. There were approximately two weeks of overlap between the first littering period parturition dates and the second littering period conception dates. Parturition dates for the second littering period were from May 10 to May 28. Litter size ranged from five to eight and averaged 6.0 (SE = 0.71) during the second littering period.

The estimated conception dates of six gravid females collected in June 2005 and one in July were from May 27 to June 9. These conception dates were approximately two weeks after parturition of females in the second littering period and likely represented the third littering period. Parturition dates for these females were estimated from July 8 to July 21. Litter size for the third littering period ranged from three to six and averaged 4.7 (SE = 0.42) per female.

In August 2005 two of the 11 adult females collected were gravid, with estimated conception dates of June 30

TABLE 1
REPRODUCTIVE OUTPUT AND ESTIMATED CONCEPTION AND PARTURITION DATES OF FEMALE WHITE-TAILED JACKRABBITS IN SOUTH DAKOTA, 2004 AND 2005

Littering period	No. shot	Gravid females (%)	Mean litter size (SE)	Viable fetuses (SE)	Ova shed*	Prenatal mortality (%)	Conception dates	Parturition dates
2004	3	10	8 (80)	5.5 (0.5)	40, 41	2	22–25 May	3–8 July
	4	17	3 (17)	5.0 (1.0)	15, 15	0	4–17 July	16–29 August
2005	1	13	13 (100)	4.2 (0.46)	54, 79	32	24 February–6 March	7–17 April
	2	5	4 (80)	6.0 (0.71)	24, 25	4	29 March–16 April	10–28 May
	3	10	7 (70)	4.7 (0.42)	33, 35	6	27 May–9 June	8–21 July
	4	11	2 (18)	3.0 (0)	6, 7	14	30 June–15 July	12–26 August

*First number indicates implantation sites and second number represents ova shed.

and July 15. These females likely represented the fourth littering period since conception dates overlap with parturition dates of the third littering period. Parturition dates for the fourth littering period were estimated to be August 12 and 26. Both females were carrying three viable fetuses. The length of the breeding season was estimated from February 24 to July 15, which was 142 days, allowing for 3.3 litters.

In 2004 prenatal mortality occurred in one gravid female white-tailed jackrabbit collected in June (third littering period) that demonstrated resorption of one fetus resulting in 2% prenatal mortality. There were no instances of prenatal mortality during the fourth littering period.

In 2005 prenatal mortality was greatest (32%) in the first littering period. There were 79 ova shed from the 13 collected females with only 54 implantation sites. Two females also showed evidence of resorption at one implantation site during the first littering period. In the second littering period, 25 ova were shed with 24 viable fetuses, since one female exhibited resorption of one fetus (4% prenatal mortality). During the third littering period there were 35 ova shed with only 33 implantation sites. Preimplantation loss of one ova and one instance of resorption resulted in 6% prenatal mortality in the third littering period. Prenatal mortality was 14% in the fourth littering period. Preimplantation loss was the only source of prenatal mortality, with seven ova shed and only six implantation sites. There were 26 gravid females collected in 2005 that shed 146 ova over four littering periods, so the potential annual production was 22.5 per female (Table 1). Overall, higher fecundity was observed during the second littering period as indicated by a large litter size and a low prenatal mortality.

DISCUSSION

Since leporids have a high reproductive rate, demographic stochasticity is expected. There is a paucity of information on sex ratios of white-tailed jackrabbits, but our data indicate that sex ratios are similar to those of black-tailed jackrabbits, which have been reported to be 1:1 throughout much of their range (Lechleitner 1959; Tiemeier 1965; Gross et al. 1974; Dunn et al. 1982; Plettner 1984).

Juvenile jackrabbits are generally not collected until they are about three months old due to their secretive behavior (Lechleitner 1959). Juvenile jackrabbits were present during April in Nebraska (Plettner 1984) and during May in California (Lechleitner 1959). Approximately 35% of the jackrabbits we collected were juveniles and were found from May to December. Adults represented 65% of the total number of white-tailed jackrabbits collected. All jackrabbits collected in March and April were adults. Lechleitner (1959) and Plettner (1984) also found a high percentage of adults during April.

Prolific breeding capabilities in lagomorphs may aid in sudden population increases. White-tailed jackrabbit populations are composed mostly of adults in winter, while juveniles dominate in other seasons (James and Seabloom 1969; Rogowitz and Wolfe 1991). In Wyoming, Rogowitz and Wolfe (1991) reported a rapid rate of population replacement of adults by juveniles, which may have prevented a population decline during times with low survival. Since juveniles reached sexual maturity by March or April in 2005, the entire population may potentially be capable of breeding during the second littering period.

Adult male white-tailed jackrabbits appeared to be reproductively active from January to July during the

2005 breeding season. Female activity was similar to that of males, but there appeared to be a time difference of one month in the onset and cessation of breeding between the sexes. Ovaries of female jackrabbits increased in mass one month after the increase in testes mass and remained at their maximum until one month after male testes began to regress in mass. This breeding strategy assures that males are ready to breed as soon as females ovulate during spring. During the fourth littering period, females may still be able to find some reproductively capable males.

Rogowitz (1992) implied that cues other than ambient temperature stimulate reproductive activity and suggested that snow cover and food accessibility may play a role in the onset of reproduction in white-tailed jackrabbits. The characteristic postpartum heat demonstrated by *Lepus* spp. may increase the instances of breeding synchrony, but synchrony must be present within the first littering period (James and Seabloom 1969). We observed synchronous breeding in the first littering period in 2005, as has been previously reported in North Dakota (James and Seabloom 1969). Since most males are essentially reproductively active when females first become receptive, breeding synchrony of the first littering period is likely to occur. Cues that result in an initial synchronous estrous cycle of females and their tendency for postpartum breeding are likely responsible for synchrony of subsequent litters.

White-tailed jackrabbits may annually produce three to four litters in South Dakota, but only a small percentage of females actually produced four litters per season. In both 2004 and 2005, data indicate that 18% of the adult females that were collected experienced a fourth littering period. James and Seabloom (1969) found that only 29% of female white-tailed jackrabbits in North Dakota produced a fourth litter. Stefan and Krebs (2001) found that snowshoe hares also had the lowest pregnancy rates in the fourth littering period. Lower fecundity rates of the last littering period may be explained by the difference in reproductive cessation for males and females. As male hares cease breeding, testicular weights diminish, causing a loss of libido and potency (Meslow and Keith 1968; James and Seabloom 1969). Since most males become reproductively inactive approximately one month before females, it is likely that only a small percentage of males maintain reproductive potency for a receptive female during the potential fourth littering period. Future research should include counting corpora lutea for nonpregnant parous females throughout the breeding season to determine the percentage of receptive females that are capable of producing a fourth litter.

Prenatal mortality may affect overall reproductive output of female white-tailed jackrabbits. For the last two littering periods during the 2004 breeding season, we found only one mortality from postimplantation loss. There were 56 ova shed among 11 gravid white-tailed jackrabbits, indicating postimplantation loss affected 1.8% of all ova shed and 9.1% of females collected in 2004. Bronson and Tiemeier (1958) reported that resorption was a result of stress such as weather conditions, which if great enough may result in entire litter loss.

Instances of prenatal mortality varied among littering periods throughout the 2005 breeding season. Prenatal mortality was greatest in the first littering period in 2005 (32%), sharply decreased during the second (4%) and third (6%) littering periods, and rose during the fourth littering period (14%). The high incidence of prenatal mortality during the first littering period may have been due to severe weather (Rogowitz 1992). Spring weather was unusually severe, with numerous snowstorms during our study, which likely affected prenatal mortality. During the second and third littering period, conditions were ideal, with warm weather and abundant food supplies. It is unclear why there was high prenatal mortality during the fourth littering period, but variable prenatal mortality in littering periods in lagomorphs is not uncommon (Stefan and Krebs 2001).

Reproductive output of female white-tailed jackrabbits may vary between littering periods. In North Dakota the average number of ova shed by female white-tailed jackrabbits steadily decreased throughout the breeding season (James and Seabloom 1969). The mean number of ova shed by female white-tailed jackrabbits in South Dakota was greatest during the first two littering periods. In Wyoming, Rogowitz (1992) found that reproductive output among white-tailed jackrabbits varied with environmental conditions, and energy expenditure for fetal production was greater when suitable forage became available.

White-tailed jackrabbits in South Dakota are capable of having four litters in each breeding season. However, the incidence of this reproductive output is unclear and may be related to food abundance or predator pressure. We do not believe that the current reproductive characteristics of white-tailed jackrabbits are contributing to their downward population trend. Wildlife managers will need to continue to monitor the population to determine what is causing the apparent continuing population decline of white-tailed jackrabbits.

ACKNOWLEDGMENTS

Funding for this research project was provided by the South Dakota Department of Game, Fish, and Parks (SDGFP), South Dakota State University, and the Federal Aid to Wildlife Fund (Project W-75-R, No. 75) administered by SDGFP. This study was approved as #04-A020 by the South Dakota State Institutional Animal Care and Use Committee. We would like to express our gratitude to Alyssa Kiesow and all the people involved in donating and collecting animals for this research, as well as SDGFP for providing a special permit allowing the collection of jackrabbits throughout the year.

REFERENCES

Anderson, J.E., and M.L. Shumar. 1986. Impacts of black-tailed jackrabbits at peak population densities on sagebrush-steppe vegetation. *Journal of Range Management* 39:152–56.

Bookhout, T.A. 1964. Prenatal development of snowshoe hares. *Journal of Wildlife Management* 28:338–45.

Boonstra, R., D. Hik, G.R. Singleton, and A. Tinnikov. 1998. The impact of predator-induced stress on the snowshoe hare cycle. *Ecological Monographs* 79:317–94.

Bronson, F.H., and O.W. Tiemeier. 1958. Reproduction and age distribution of black-tailed jack rabbits in Kansas. *Journal of Wildlife Management* 22:409–14.

Conaway, C.H., K.C. Sadler, and D.H. Hazelwood. 1974. Geographic variation in litter size and onset of breeding in cottontails. *Journal of Wildlife Management* 38:473–81.

Donoho, H.S. 1972. Dispersion and dispersal of white-tailed and black-tailed jackrabbits, Pawnee National Grasslands. Master's thesis, Colorado State University, Fort Collins.

Dunn, J.P., J.A. Chapman, and R.E. Marsh. 1982. Jackrabbits: *Lepus californicus* and allies. In *Wild Mammals of North America: Biology, Management, and Economics*, J.A. Chapman and G.A. Feldhamer, eds. 124–45. Johns Hopkins University Press, Baltimore.

Flux, J.E.C. 1971. Validity of the kidney fat index for estimating the condition of hares: A discussion. *New Zealand Journal of Science* 14:238–44.

Gross, J.E., L.C. Stoddart, and F.H. Wagner. 1974. Demographic analysis of a northern Utah jackrabbit population. *Wildlife Monographs* 40:1–68.

Hale, J.B. 1949. Aging cottontail rabbits by bone growth. *Journal of Wildlife Management* 13:216–25.

Hik, D.S. 1995. Does risk of predation influence population dynamics? Evidence from the cyclic decline of snowshoe hares. *Wildlife Research* 22:115–29.

Hodges, K.E., C.I. Stefan, and E.A. Gillis. 1999. Does body condition affect fecundity in a cyclic population of snowshoe hares? *Canadian Journal of Zoology* 77:1–6.

Hogan, E.P., and E.H. Fouberg. 1998. *The Geography of South Dakota.* Center for Western Studies, Sioux Falls, SD.

James, T.R., and R.W. Seabloom. 1969. Reproductive biology of the white-tailed jack rabbit in North Dakota. *Journal of Wildlife Management* 33:558–68.

Johnson, J.R., and J.T. Nichols. 1982. *Plants of South Dakota Grasslands.* South Dakota State University Agricultural Experiment Station Bulletin 566. Brookings, SD.

Keith, L.B. 1981. Population dynamics of hares. In *Proceedings of the World Lagomorph Conference, 1979*, ed. K. Meyers and C.D. MacInnes, 395–440. University of Guelph, Ontario.

Kline, P.D. 1963. Notes on the biology of the jackrabbit in Iowa. *Iowa Academy of Science* 70:196–204.

Krebs, C.J., R. Boonstra, S. Boutin, and A.R.E. Sinclair. 2001. What drives the 10-year cycle of snowshoe hares? *Bioscience* 51:25–35.

Lechleitner, R.R. 1959. Sex ratio, age classes, and reproduction of the black-tailed jack rabbit. *Journal of Mammalogy* 40:63–81.

Meslow, E.C., and L.B. Keith. 1968. Demographic parameters of a snowshoe hare population. *Journal of Wildlife Management* 32:812–34.

Nowak, R.M., and J.L. Paradiso. 1983. *Walker's Mammals of the World*, 4th ed. Johns Hopkins University Press, Baltimore.

Plettner, R.G. 1984. Vital characteristics of the black-tailed jack rabbit in east-central Nebraska. Master's thesis, University of Nebraska–Lincoln.

Rogowitz, G.L. 1992. Reproduction of white-tailed jackrabbits on semi-arid range. *Journal of Wildlife Management* 56:676–84.

Rogowitz, G.L., and M.L. Wolfe. 1991. Intraspecific variation in life-history traits of the white-tailed jackrabbit (*Lepus townsendii*). *Journal of Mammalogy* 72:796–806.

Rowman, W., and L.B. Keith. 1956. Reproductive potential and sex ratios of snowshoe hares in northern Alberta. *Canadian Journal of Zoology* 34:273–81.

Schaible, D., and C.D. Dieter. 2011. Health and fertility implications related to seasonal changes in kidney fat index of white-tailed jackrabbits in South Dakota. *Great Plains Research* 21:89–94.

Sheriff, M.J., C.J. Krebs, and R. Boonstra. 2009. The sensitive hare: Sublethal effects of predator stress on reproduction in snowshoe hares. *Journal of Animal Ecology* 28:1249–58.

Stefan, C.I., and C.J. Krebs. 2001. Reproductive changes in a cyclic population of snowshoe hares. *Canadian Journal of Zoology* 79:2101–8.

Tiemeier, O.W. 1965. *The Black-Tailed Jackrabbit in Kansas.* Kansas State University Agricultural Experiment Station Technical Bulletin 140. Manhattan, KS.

Visher, S.S. 1918. *The Geography of South Dakota.* South Dakota State Geological and Natural History Survey Bulletin 8. Vermillion, SD.

BOOK REVIEWS

Gathering Places: Aboriginal and Fur Trade Histories. Edited by Carolyn Podruchny and Laura Peers. Vancouver: UBC Press, 2010. xi + 324 pp. Maps, illustrations, photographs, tables, notes, bibliography, index. $99.00 cloth, $37.95 paper.

Gathering Places honors Jennifer S.H. Brown, a leading figure in the Aboriginal history of the Hudson Bay drainage basin. The ten essays and introduction deal with Natives and Native history in the region of Hudson Bay, and *there* is the influence of Professor Brown; otherwise the topics are diverse. The papers have been grouped into several themes, but broadly speaking there are two types of essays. Some use novel as well as more traditional approaches to shed light on aspects of the Aboriginal experience; the others are methodological, dealing with the writing of First Nations histories.

Brown has urged historians to move beyond traditional archival sources; and "Putting up Poles" (Podruchny, Gleach, and Roulette) and "Dressing for the Homeward Journey" (Willmott and Brownlee) do just that. "Putting up Poles" explores the role of lopsticks in the fur trade and Native culture. Lopsticks are trees that have been denuded of their branches except for a tuft left near the top of the trunk. Although it was Indians who formed them, lopsticks acted as route markers for European traders. From their work in the field, the authors have identified the location of surviving lopsticks; they also discuss the place of poles in Native culture. By the time of the fur trade, a central pole was part of Native gift-giving and other ceremonies. Intriguing but left unresolved is the extent to which this aspect of Native culture was domestic or adapted from European practice.

"Dressing for the Homeward Journey" makes use of a special find, the coffins of two young men who died sometime in the late 18th or early 19th century. These youths came from prominent families and were buried in their finery. Willmott and Brownlee itemize the clothing material and other goods found in the coffins, including a variety of silver works, rings, and, at one of the sites, thousands of beads. The remarkable array speaks to the wealth of the Great Lakes Ojibwe and Odawa during the height of the fur trade, and the detail reveals how the items of the fur trade became part of Native cultural life.

Heidi Bohaker's "Anishinaabe Toodaims" is more in the tradition of archival research, but its emphasis is new. Toodaims (totems) have various interpretations, but essentially they are tribes, clans, or other groups below the "nation" level. Taking Peter Jones's 1861 *History of the Ojebway Indians* as her starting point, Bohaker traces the group connections using a variety of approaches: diet, language, stories; but especially novel are the pictographs that became a feature of treaties and other contracts. Rather than mark "x" next to their printed names, Native leaders drew a figure that represented their clan. This could be a bison, a fish (usually pike), or a bird of a specific type. By analyzing these "signatures" in a range of documents, Bohaker provides another mechanism for tracing toodaims.

The other chapters deal mainly with the writing of Native American history. In an autobiographical essay, "Being and Becoming Métis," Heather Devine retraces her personal journey of discovery. Born of a Métis mother and non-Native father, Devine as a child was unaware of her Aboriginal heritage. Her mother had been adopted by non-Natives and was only vaguely aware of her origins. Devine describes how she and her mother traced their ancestry, including their moving interactions with their relatives and the sad failure of the Métis community to accept Devine as one of their own and take full advantage of her abilities. The essay provides frank insights about Natives and Native politics, more compelling because of their source.

Also compelling, but in a way disheartening, is "Edward Ahenakew's Tutelage by Paul Wallace" (David Miller). Ahenakew, a Cree born in Saskatchewan in 1885, was an Anglican missionary priest, but his importance to Aboriginal history is as a chronicler and translator of Native stories. "Cree Trickster Tales" (1929) and *Voices of the Plains Cree* (1973, published posthumously) are part of the canon of Native American folklore. The focus of the chapter, though, is on the correspondence between Ahenakew and Wallace, an English professor at a college in Pennsylvania and champion of Ahenakew's work. Wallace, over a period of many years, urged, advised, and even cajoled Ahenakew to produce more. Ultimately, though, the relationship broke down. Wallace did not understand Native society sufficiently, and Ahenakew's priorities lay elsewhere: with his missionary work, his political activity, and the Cree newsletter he published regularly.

In an afterword, Jennifer Brown describes her approach to Native history and offers advice to researchers. Although some essays deal with specific aspects of Anishinaabe, Cree, Ojibwe, and Métis history, the insights about the interactions between scholars and First Nations communities, and the variety of evidence available for the study of Aboriginal history, will be the principal legacies of this intriguing and useful volume.

Frank D. Lewis
Department of Economics
Queen's University, Kingston, Ontario

Federal Fathers and Mothers: A Social History of the United States Indian Service, 1869–1933. By Cathleen D. Cahill. Chapel Hill: University of North Carolina Press, 2011. xv + 368 pp. Photographs, maps, graph, table, notes, bibliography, index. $45.00 cloth.

Cathleen Cahill's *Federal Fathers and Mothers* is an excellent contribution to the literature on social provision, American state development, and Indian affairs. It should be essential reading for scholars using Theda Skocpol's classic *Protecting Soldiers and Mothers* (1992), and it is a fine addition to the

growing number of titles critiquing the traditional view of the 19th-century American state as simple, small, and unobtrusive.

Cahill offers a social history of the U.S. Indian Service, especially the School Service, from Reconstruction to the New Deal, focusing on the lives and relationships of Indian and non-Indian men and women in the Service, and how their careers and activities interacted with the "intimate colonialism" of the assimilation and allotment eras. Making brilliant use of a trove of primary materials in Indian Office personnel records, Cahill, in the core of the book, scrutinizes the experiences of single women and married couples in the Service, including examinations of leisure, friendships, romantic relationships, interracial marriages, and professional interactions. Notably, the Indian Service employed thousands of women in the decades after the Civil War, and Cahill reveals important information about women in the federal bureaucracy.

Putting its focus in context, the book begins with a review of Indian affairs up to Reconstruction and ends with an analysis of the Indian Service as it transitioned from Reconstruction to the Progressive Era and into the New Deal. Cahill's snappy writing is sharp and clear, with an engaging balance of case histories, anecdotes, humor, and analysis. There is no particular focus on the Great Plains, but many of Cahill's examples are relevant to Great Plains research.

The book has three main limitations. First, Cahill frequently employs words like "new" and "novel" to describe policy and administration in the years after the Civil War, obscuring the prewar foundations of many of the programs and administrative mechanisms under review. Second, she too easily categorizes social provision for American Indians as "compensatory"—payments rectifying past wrongs. Many of the programs and benefits provided by the United States are the price the U.S. paid—and continues to pay—for land cessions and trading commitments made generations ago. Cahill's study would be stronger had she examined in greater detail the nature of the programs she discussed, and grappled with controversies surrounding their categorization. Finally, she largely avoids the role of Indian Service personnel in creating and maintaining abusive conditions at Indian Service schools, skating too quickly past evidence of beatings, confinement, humiliation, and exploited labor.

Still, this is an excellent book. Cahill maintains clarity amid extraordinary detail and provides a wealth of information for scholars of Indian affairs and, more broadly, U.S. social provision, public administration, and state development.

STEPHEN J. ROCKWELL
Department of Social Sciences
St. Joseph's College, New York

Alberta's Day Care Controversy: From 1908 to 2009—and Beyond. By Tom Langford. Edmonton, AB: AU Press, 2011. xviii + 406 pp. Tables, appendices, notes, references, index. C$34.95 paper.

This is a carefully crafted, meticulously researched gem of a book exploring the history and intrigues of Alberta's controversies and struggles concerning child care, focused on the period since the 1960s. It is a work of historical sociology analyzing the interaction of social and political forces in Alberta clashing over the effects of child care in promoting changes in women's roles, over the negative effects of commercial child care on quality, and over the appropriate amount and type of support that governments vs. families should provide for child care. That description may make it sound too analytical and boring, but what is wonderful about Tom Langford's account is how it makes these controversies lively, detailed, and personal, through the use of archival research and contemporary interviews with historical figures.

As befits a study supported by the Social Sciences and Humanities Research Council of Canada, the book's first chapter presents its themes and research strategy. A second chapter foreshadows many of the gender-role controversies to come in detailing how Alberta decided not to accept federal 50/50 funding of wartime day nurseries. The story of the child care policy innovations and reversals in the remaining chapters would be bewildering in less deft hands. First, supply-side funding of good-quality nonprofit and municipal centers under the Preventive Social Services Act in the 1960s and most of the 1970s (encouraged by federal cost-sharing). Next, the replacement of this funding with modest income-tested subsidies usable in both nonprofit and commercial child care. Then, dramatic improvements in staff-child ratios combined with generous operating grants that favored a rapid expansion of commercial child care. By the turn of the last century, operating grants had been eliminated. In the early 2000s, Alberta developed a system of accreditation of child care services, along with wage grants. Langford gives us the personalities, the ideologies, the work of advocacy and lobby groups, the institutional details, and the shifts in social and political power that help explain these changes.

Alberta's experiences in child care are relevant for their own sake, of course, but also because Alberta is the spiritual and political homeland of Canada's Republican-style Conservative government. The themes that echo so strongly through political debates in this book are likely to be part of Canada's future as well as Alberta's past.

GORDON CLEVELAND
Department of Management
University of Toronto Scarborough

Storied Landscapes: Ethno-Religious Identity and the Canadian Prairies. By Frances Swyripa. Winnipeg: University of Manitoba Press, 2010. xi + 296 pp. Maps, illustrations, photographs, notes, index. C$55.00 cloth, C$26.95 paper.

Frances Swyripa's study of the ethno-religious landscape of the Canadian prairies is a delightful painting of the visual legacy of the settlement landscape and at the same time a careful analysis of the nuances that undergirded the religious sensibilities of the particular groups she examines. *Storied Landscapes* pays most attention to Mennonites, Ukrainians, Doukhobors, and Icelanders, and less to other Scandinavians, other Europeans, and Mormons. Three single location settlements in Saskatchewan are also represented: the Esterhazy-Kaposvar Hungarian settlement, the English Barr Colony near Lloydminster, and the German St. Peter's Colony at Muenster.

The book sets out to examine the settlement history of the Canadian prairies through new eyes. Swyripa aims to tease out how a "sense of identity or belonging was shaped by the complex interplay" of the land, group experience, and shared histories with other westerners. Following an introduction, the book begins at the local level and gradually expands its analysis in successive chapters to explore regional group consciousness; the role of prairie-based identities in relation to the Canadian nation; and the impact of international ties with the homeland, the diaspora, and the United States. The final three chapters redirect the reader to the legacy of the ethno-religious settlement experience from the point of view of successive generations.

One is struck by the richness of the ethno-religious influence in creating the prairie landscape, from the grotto of Mundane, Alberta, to the diverse symbolism found in obscure cemeteries. More interesting, perhaps, is the author's elaboration of the diverse ways in which successive generations hybridized and reified the meanings of both the artifacts and symbols of the early settlers. Landing sites, for example, were sometimes transformed into sacred ground, such as Willow Point on Lake Winnipeg, which for Icelandic descendants became the subject of a painting, a poem, and annual pilgrimages.

To be sure, comparing a number of ethno-religious groups over the vast expanse of the prairies over 150 years has meant some important cultural aspects of the landscape and its meanings have been left out, or mentioned only in passing. How did the cultural imprint of the landscape change when 6,000 Mennonites left southern Manitoba and Saskatchewan for Mexico in the 1920s? Does the Jewish imprint on the landscape not go beyond the story of failed agricultural settlement?

On the whole, however, *Storied Landscapes* is a welcome and novel way of looking at ethno-religious settlement on the Canadian prairies. Its comparative approach helps to lay bare the multiplicity of meanings the land came to have as religious and ethnic space.

Hans Werner
Department of History
University of Winnipeg

Winnipeg Beach: Leisure and Courtship in a Resort Town, 1900–1967. By Dale Barbour. Winnipeg: University of Manitoba Press, 2011. xiii + 211 pp. Photographs, maps, illustrations, notes, bibliography, index. C$24.95 paper.

The back cover designates this book as "history," but, like the best social history, it offers much to a broad range of other disciplines, including women's and gender studies, cultural geography, folklore, and cultural studies. Though modest in size and aims, *Winnipeg Beach* is a superb example of how a scholar fascinated with everyday life can link it with broader social movements.

Manitoba's answer to such waterside attractions as Coney Island and Blackpool, Winnipeg Beach saw tremendous social change over the nearly 70 years Dale Barbour explores. The dates correspond to "the lifespan of Winnipeg Beach as a tourist destination, from its creation by the Canadian Pacific Railway (CPR) in 1901 to the demolition of its dance hall, roller coaster, and boardwalk in 1967." Barbour traces the complexities of the town's development as a primarily heterosocial space for socializing and as a destination for families; its meaning as a paradoxical mixing of nature and culture; and its class and ethnic associations (in contrast to exclusive white, elite, British locations like Victoria Beach). He indicates the CPR's role, not only in providing a mode of transport for Winnipeggers to visit the town, but also in developing facilities for tourist use, including a hotel, dance facilities, and pier.

Barbour shows that despite its mainstream associations in terms of sexuality and ethnicity, Winnipeg Beach's early users included (for the most part closeted) gay and lesbian folks and a (geographically constrained) Jewish community, among others. Because of the profusion of tourist accommodations, women had opportunities for economic control not usually associated with urban areas at the time. Barbour notes that young people sometimes enforced the town's ethnic boundaries, but also undermined them by socializing together. After World War II, however, teenagers became associated with moral panic related to sex and liquor. Throughout, however, the boardwalk and beach were locations for social mixing. Now a Provincial Park, the locale currently betrays little of its history as an "industrial saturnalia."

Drawing extensively upon a wide range of sources—literary, archival, and periodical as well as bibliographic—Barbour also conducted interviews and consulted other oral history sources. In a welcome departure from too much history, which fails to include the actual words of those who experienced the time and place under consideration, Barbour quotes extensively from interviews as well as from sources contemporary to his discussion. But the book is more than just a congeries of quotations. Barbour also weaves in classic and current social theory, using a variety of sources from Mikhail Bakhtin and Judith Butler to Michel Foucault, Anthony Giddens, Joan W. Scott, and Gill Valentine. *Winnipeg Beach,* nevertheless, remains eminently accessible and readable. The illustrations offer more

than a diversion: they further clarify many of Barbour's points, such as the changing dimensions of the beach during low- and high-water years.

Undergraduate and graduate students and general readers alike will find *Winnipeg Beach* a useful book.

Pauline Greenhill
Women's and Gender Studies
University of Winnipeg

Two Toms: Lessons from a Shoshone Doctor. By Thomas H. Johnson and Helen S. Johnson. Salt Lake City: University of Utah Press, 2011. xi + 90 pp. Map, photographs, glossary, index. $15.95 paper.

The Shoshone Indians, originally known as the Snake Indians to European fur trappers, occupied the western Great Plains along the eastern slopes of the Rocky Mountains beginning in the early 1500s. It was not until the 1780s, after their traditional enemies, the Blackfeet, had gained firearms, that they were pushed west across the Rockies, leaving the Southern Shoshones, today known as the Comanches, stranded on the southern Great Plains. Today the Shoshones reside on fifteen reservations in Nevada, Utah, Oregon, Idaho, and Wyoming. The Wyoming Shoshones, on the Wind River Reservation, are the descendants of those who once hunted and lived east of the Rockies.

Thomas H. Johnson, one of the co-authors of *Two Toms: Lessons from a Shoshone Doctor*, was a graduate student at the University of Illinois at Urbana-Champaign when he first met Tom Wesaw in 1966 at a Sun Dance on the Wind River Reservation. Johnson returned to live with Wesaw during 1969–1970, in order to learn about Shoshone language and culture. *Two Toms* is based on his field notes from that stay.

Tom Wesaw (1886–1973) was a traditional Shoshone doctor, Sun Dance leader, and member of the Native American (Peyote) Church. He had left Wind River Reservation when only fifteen to live with relatives among the Shoshones on the Fort Hall Reservation in Idaho. Returning to Wyoming, he married Helen Hill and raised a family. When Johnson came to stay with him in 1969, Wesaw's wife had been dead for a few years, and the old man was living by himself. He welcomed Johnson, who cooked for him, drove him around, pumped water, and tended the fire at sweat lodge ceremonies, in exchange for being taught the ways of a traditional Shoshone medicine man. The name of this delightful book comes from the nickname the two of them received on the reservation, since they were always seen together.

Two Toms contains descriptions of the Sun Dance, peyote meetings of the Native American Church, sweat lodge ceremonies, and a Shoshone funeral, as well as information on Chief Washakie, the history of the Wind River Reservation, and a number of contemporary issues such as tribal enrollment and tribal royalties from oil and gas reserves located on the reservation. The most important aspect of this work, however, is the traditional Shoshone philosophy of Wesaw, which taught tolerance and inclusiveness of all people, no matter their background or ethnicity. What the authors do not reveal in this work is how Wesaw's healing gift has been passed down, first to his son, George Sr., then his grandson, George Jr., and now carried on by his great-grandson, George Wesaw III.

Christopher Loether
Department of Anthropology
Idaho State University

A White-Bearded Plainsman: The Memoirs of Archaeologist W. Raymond Wood. By W. Raymond Wood. Salt Lake City: University of Utah Press, 2011. xvii + 364 pp. Photographs, notes, bibliography, index. $49.95 cloth.

Over a period of more than 50 years, Ray Wood has published a string of major works on Great Plains culture history and other subjects. He has held important professional posts, interacted with a vast cohort, and trained a generation of midcontinent archaeologists. Beyond all that, Ray's memoir, *A White-Bearded Plainsman*, shows him to be a fine writer and terrific storyteller.

Wood presents his story in chronological order, appropriate for a culture historian, but it happens that Ray came up at a time when Plains archaeology was blooming: his story describes the growth of Plains prehistory. Born and raised on the northern edge of the Nebraska Sandhills, Wood begins by recollecting the youthful experiences that made him curious about the region, sensitive to its subtle but distinctive features, and freely disposed to rambling across its substantial breadth. After prepping at Chadron State College, Ray came to the University of Nebraska, where he found a stimulating post-WWII community that included a vibrant group of archaeologists.

At the behest of the new Department of Anthropology, the university became the base for the Smithsonian Institution's Missouri River Basin Surveys of the Inter-Agency Archeological Salvage Program, a recently conceived unit created to deal with archeological resources being destroyed by the huge reservoirs under construction across the Northern Plains. Ray had access to a "genial cadre" and a string of fieldwork and analysis opportunities. He worked closely with several of the leaders of the Basin Surveys, but was never directly employed on the program's staff. It is easy to be critical of "salvage archeology," but Wood's presentation communicates the sincere interest, industry, and scholarly and resource limitations that were part of that work. His description of the social life of the Plains archeological community is warm, and, as he relates his adventures and associations, it is clear he was always a research scholar. From the beginning of his career he had the ability to frame interesting questions and proceed to present excavation results with clarity and insight. After completing his PhD at Oregon, Ray took a teaching and research post a

Missouri, allowing him to conduct problem-oriented investigations and support a string of graduate students who entered the profession with skill and drive.

Plains scholars will read this book to understand the growth of Great Plains research and also because it presents substantive discussions of important aspects of Plains culture history. Anyone interested in the history of American archaeology should read this memoir because it records a formative phase in the development of government involvement in cultural resources. Ray's positive account of how he stayed active, interested, and engaged in significant work will be helpful to anyone interested in understanding what it takes to become and remain a productive scholar. Finally, Ray's students, associates, and friends—a substantial community—will read it with joy.

Peter Bleed
Department of Anthropology, Emeritus
University of Nebraska–Lincoln

Oral History on Trial: Recognizing Aboriginal Narratives in the Courts. By Bruce Granville Miller. Vancouver: UBC Press, 2011. 195 pp. References, index. $94.00 cloth, $32.95 paper.

Anthropologist Bruce Miller's new treatise will prove an essential resource for historians, ethnographers, and anthropologists both inside and outside the academy and for lawyers working in the areas of Aboriginal law and Indigenous rights. Demonstrating the classic "iceberg" principle, Miller's broad and deep knowledge of the contemporary theoretical underpinnings that inform approaches to Indigenous oral history in academic practice and in the courtroom are immediately apparent. He gives us the tip of that iceberg in a readable, comprehensible exegesis backed by solid research and accessible references. Addressing the complex theoretical and teleological divisions among disciplines with remarkable lucidity and plain language, Miller paints a picture of the real and perceived interdisciplinary struggles over where and how "truths" may be ascertained—or valued.

In Canadian courts, a great deal depends on how judges receive and analyze oral history evidence placed before them by Indigenous plaintiffs. The legal tests for illegal impacts on constitutionally protected Aboriginal and treaty rights are often dependent on the oral history residing with the Elders in the communities seeking court protection. The Supreme Court of Canada says that the treaty rights to hunt, trap, and fish "as formerly" must remain meaningful. This signifies that governments must take steps to ensure that the habitat and ecosystems necessary for the practice of those rights are protected. The result is that Indigenous rights law is actually the strongest law for environmental protection in Canada. The negative environmental impacts arising from unbridled mining and tar sands development, and those associated with water issues, throughout the prairies can be most successfully resisted by the assertion of First Nations treaty rights. To accomplish such protection, Indigenous groups must prove where their ancestors hunted, trapped, and fished at the time of treaty-signing; for those in the Great Plains, much of this information resides in their oral histories.

Miller does a fine job of taking apart the Canadian federal government's oral history gunslinger/expert witness, Alexander von Gernet, who has repeatedly been brought to court to denigrate and downplay oral history evidence (even though the courts themselves have found that his approach offends their own pronouncements on the importance of attending to oral history). Miller points out the inconsistencies in the sources the Crown witness uses to support his claims that oral histories are unreliable and "impure." Still, the author never fully releases the hounds on those he disagrees with, but rather cobbles together what we might call a methodology of hospitality both in his own theoretical practice and in the suggestions he has for lawyers and judges about how they might more appropriately approach, receive, review, and understand the dialogue of oral history within the current legal purview of rights determinations (indeed, the book is structured as a dialogue between academic theory, oral history practitioners, and courtroom outcomes). Ultimately, Miller is optimistic that the interdisciplinary backgrounds of today's legal professionals can support a nuanced cross-cultural dialogue leading to more just outcomes.

Considering the risks that rampant and unplanned developments are creating, both locally and globally, the opportunity to learn to listen to oral history scholars in a more nuanced way will likely prove important for all of us.

Drew Mildon
Woodward & Company
Victoria, British Columbia

Lone Star Law: A Legal History of Texas. By Michael Ariens. Foreword by Gordon Morris Bakken. Lubbock: Texas Tech University Press, 2011. xiv + 366 pp. Illustrations, maps, photographs, tables, notes, bibliography, index. $49.95 cloth.

In 1949, the federal government sued Texas in the Supreme Court for ownership of mineral rights in the seabed off the Texas coast. Texas claimed that even if other states did not own their tidelands, Texas did because the treaty of annexation by which the Republic of Texas joined the United States allowed the state to keep all its "vacant and unappropriated" lands. The suit was seen by most Texans as an unconscionable federal grab for power.

House Speaker Sam Rayburn tried to broker a compromise giving the state 60% of the mineral revenues, but state officials rejected it. The Supreme Court ruled in favor of the United States, seizing upon language in the treaty admitting Texas to the Union "on equal footing with the existing States." The Court said this language put Texas in the same position as the other states—for better and worse: since no other state owned its offshore land, neither did Texas.

The opinion was an interesting exercise in legal reasoning and had huge economic consequences. But Michael Ariens shows that those were the least of the reasons for its importance. In the eyes of many, the dispute was a proxy for the coming states' rights battle over segregation. Fighting the feds made a hero of Texas Attorney General Price Daniel, propelling him to the governor's office. One of the real parties in interest was the oil industry, which would owe the federal government three times as much in royalties as the state collected. In the 1952 presidential election, Democrat Adlai Stevenson supported the Court's decision while Republican Dwight D. Eisenhower promised to sign legislation giving the tidelands to the states. Most of the state officeholders supported Eisenhower and he carried Texas, a blow from which the Texas Democratic Party has never fully recovered.

The tidelands case is one of many examples of Ariens's success in weaving the narrative of a legal development into the state's political, economic, and social history. He meticulously analyzes scores of decisions and statutes, clearly and economically explains them, and locates them in the larger history of Texas.

Some of Texas legal history is unique because of Texas's origins as a republic and its membership in the Confederacy, but other chapters, particularly those relating to land, minerals, water, and railroads, will resonate in the other Great Plains states. Ariens wisely declines to trumpet Texas exceptionalism. The infatuation with Texas myth that has bedeviled many chroniclers of the state's past will not be found in this careful, honest work. The book is a must for anyone who seeks an authoritative source for Texas legal history and a delight for anyone who just wants to understand the Lone Star State.

David Anderson
School of Law
University of Texas at Austin

Texas Bobwhites: A Guide to Their Foods and Habitat Management. By Jon A. Larson, Timothy E. Fulbright, Leonard A. Brennan, Fidel Hernández, and Fred C. Bryant. Austin: University of Texas Press, 2010. xii + 280 pp. Photographs, tables, maps, illustrations, appendices, glossary, references, index. $40.00 cloth, $24.95 paper.

Texas Bobwhites: A Guide to Their Foods and Habitat Management is a pictorial guide to the identification of seeds commonly consumed by northern bobwhites (*Colinus virginianus*)—and the plants that produce them—in Texas. The authors "hope that interest in what constitutes good bobwhite habitat among hunters and nature enthusiasts will be enhanced by this guide to the identification of seeds eaten by quail." Targeting this lay audience leads to certain constraints regarding how the text, particularly, is presented. Regardless, because Texas includes much of the southern terminus of the Great Plains, this book is directly relevant to readers of *Great Plains Research* interested in bobwhite conservation, identifying seeds eaten by bobwhites and other wildlife, and identifying the plants that produce these seeds.

The book is organized into five chapters: an introduction; a layman's summary of bobwhite food habits, nutrition, and bioenergetics; a pictorial guide to 92 seed species commonly eaten by bobwhites in Texas and the plants producing them; a primer to bobwhite habitat restoration and management; and a presentation addressing exotic grasses in Texas, problems such grasses pose for bobwhites and other wildlife, and management techniques for controlling these plants. The text is followed by three appendices providing the common and scientific names of other plant species producing seeds eaten by bobwhites in Texas, other wild animals that consume plants discussed in the book, and the common and scientific names of the plants and animals mentioned in the text. *Texas Bobwhites* ends with a useful glossary (primarily addressing botanical terms), bibliographical references, and an index.

The plant and seed identification guide (chapter 3) is organized into five sections that include 18 species of rushes and grasses; 58 species of forbs; 2 species of woody vines; 13 species of woody plants, shrubs, and trees; and 1 succulent species. Unfortunately, these headings are not included in the table of contents. Details concerning each plant—including taxonomic classification; descriptive statistics regarding seed occurrence in bobwhite crops; plant and seed description; a map delineating some of the Texas counties where the plant occurs; color photographs of the plant (no reference to size); a magnified view of the seed next to a portion of the reverse side of a U.S. dime (same resolution in all photos); and a second magnified view of the seed where magnification varies by seed (scale in mm)—are presented on facing pages. The excellent focus, clarity, and contrast of nearly all photographs are alone more than worth the book's price. The other content chapters do an adequate job of presenting primers on their respective topics.

Since numerous graduate students, wildlife ecologists, and other natural resource professionals will purchase and use *Texas Bobwhites,* a few minor changes in future editions would benefit this audience greatly without appreciably changing the text's length or readability. For example, in "Notes on Using this Section" (pp. 14–15), a listing of the herbariums referred to (or other techniques used) would clarify why the plant distribution maps look the way they do. Similarly, if the studies of the bobwhite food habits were listed by Texas region in "Notes on Using this Section," then readers would know what publications to evaluate if they require more details regarding the occurrence of a particular seed in bobwhite crops.

Regardless of these relatively minor shortcomings, I expect hunters, nature enthusiasts, ecologists, and wildlife managers alike to find *Texas Bobwhites: A Guide to Their Foods and Habitat Management* a useful resource and a bargain at its price.

Markus J. Peterson
Department of Wildlife and Fisheries Sciences
Texas A&M University

Energy Development and Wildlife Conservation in Western North America. Edited by David E. Naugle. Foreword by Mark S. Boyce. Washington, DC: Island Press, 2011. xviii + 305 pp. Maps, graphs, tables, illustrations, photographs, reference lists, index. $80.00 cloth, $40.00 paper.

Wildlife populations across the West have been challenged with direct loss and degradation of habitats tied to cultivation, settlement, and livestock operations. Coupled with this, exponential human population growth has created an unparalleled human demand for energy. Current and pending energy developments are likely to alter nearly 100 million hectares of wildlife habitat. David Naugle has compiled the inaugural synthesis of energy development impacts on wildlife populations across western grassland, shrubland, and forested systems. Part 1 sets the stage, characterizing energy development in the West.

In part 2 ("Biological Responses"), Johnson and St-Laurent (chapter 3) propose a unifying experimental framework to monitor and assess consequences of energy development, urging proactive rather than reactionary science, conducted as experiments rather than observations, better informing both science and management. Chapters 4–6 discuss effects of energy development on wildlife populations, beginning with sage-grouse. Naugle and others primarily review their existing publications, showing negative behavioral and demographic consequences for grouse in energy fields, and broader population declines with lagged effects. Hebblewhite's literature synthesis of ungulate responses (chapter 5) is compelling. Understanding is limited by poor study designs, "aimed at merely appeasing the small-scale regulatory process," and more proactive adaptive management studies are needed to address energy-wildlife impacts.

Bayne and Dale summarize effects on songbirds within both forested and grassland systems (chapter 6), linking behavioral responses to energy developments and, in turn, population declines, reinforcing the need for coordinated studies across large spatial extents. Evangelista and others (chapter 7) link energy development to establishment and spread of invasive plants, resulting in ecosystem changes with impacts on wildlife. They echo prior calls for coordinated studies, moving beyond small spatial-scale and short-term observational studies, and emphasize prioritization and restoration of disturbed sites. While alternative or renewable energy sources such as wind, solar, and biofuels appear "green," they don't come without costs for wildlife. Johnson and Stephens (chapter 8) review consequences of alternative energy for species such as lesser prairie chicken, passerines, and bats; yet with strategic placement and planning, these sources may represent viable alternatives to conventional energy, potentially limiting wildlife impacts.

The book's final section (part 3) contains four chapters aimed at solutions to energy-wildlife conflicts. Kiesecker and others (chapter 9) review existing publications focused on avoiding impacts on important wildlife habitats before secondarily restoring habitat both on and off site. Similarly, Copeland and others (chapter 10) summarize their publications using sage-grouse distributions and spatial energy development projections to prioritize landscapes and evaluate mitigation options and tradeoff scenarios. With over 81% of federal lands already leased for oil and gas development, conservation planning will require a collaborative effort involving many stakeholders, implemented across large landscapes, to be effective. Benson (chapter 11) highlights how current legislation, such as the Mineral Leasing Act of 1920, with its requirements for managing conflicting multiple uses, limits our ability to protect wildlife and their habitats. There is a need for legislation and management to be more amenable to adaptive strategies, particularly on public lands. To facilitate this, Neudecker and others (chapter 12) argue for prioritization of conservation efforts through collaborative, community-based conservation, rooting conservation within society. They eloquently conclude that "this book is a wake-up call to those who reject prioritizing landscapes for conservation and instead continue to work in highly degraded landscapes because they deny inevitable impacts of energy development." To save our western landscapes, prioritization, conservation, and protection of key wildlife resources will be necessary, with restoration and reclamation important but secondary components. The volume outlines novel ways to accomplish these lofty but attainable goals across the West.

CAMERON L. ALDRIDGE
Department of Ecosystem Science and Sustainability
Colorado State University

The Gospel of Sustainability: Media, Market, and LOHAS. By Monica M. Emerich. Urbana: University of Illinois Press, 2011. xvii + 232 pp. Appendix, references, index. $50.00 cloth.

One could well imagine the Emperor Constantine telling the creators of the early versions of the Bible, "The texts [should] tell users that they are conscious, wise, alert, and savvy while also being progressive, modern, chic, and cutting-edge." Then again, maybe not. Many of those who are writing today's gospels of sustainability are telling consumers to be all these things as they seek to turn interests in health and the environment into economic gains. Much like the early Christians whose worlds were turned upside down when Constantine converted to their faith and began the process of moving worship ceremonies from homes into large churches where priests demanded tithes, those who have lived off the land are finding their way of life co-opted by the rich and powerful. It is no longer enough to grow your own food to be considered environmentally conscious. According to Emerich in *The Gospel of Sustainability*, being green means driving a hydrogen-powered car, patronizing businesses that sell free-trade coffee, and subscribing to the proper magazines.

Emerich provides a backstage pass (as well as front-stage views in the form of quotes from conferences and media stories) where one can view how the conflicts around sustainability

arose and are maintained as various actors try both to meld and tear apart capitalism and wanton consumerism, desiring to live lives that will translate into more resources for future generations. What may be more interesting to those studying macrostructures is the fact that even to have a movement as portrayed by Emerich—referred to as Lifestyles of Health and Sustainability (LOHAS)—there must be large amounts of capital that will bring media and big business attention to the demands being made. This is even more exciting if the demands are being made by the Walmarts and The Men's Warehouses of the world.

After trudging through the battles and compromises between capitalism and sustainability, the reader is asked the following question at the beginning of the concluding chapter: "How are we to live?" Emerich ends that same section with, "In essence, LOHAS presents a way in which to think about late capitalism as both ruination and remedy." If you are confused, you are not alone. Being confused, however, seems to be the point. In late modernity, the path to enlightenment is through consultation with experts. The LOHAS experts are those who are selling the products consumers need to understand how they are to live a better life. The good life is not necessarily gained by making your own clothes and composting, though those can help as long as you have purchased the right guidebooks telling you how to do those things, but by purchasing green products.

Finally, we cannot talk about gospels without talking about faith. According to Emerich, true change in the area of sustainability will only happen with the right forms of spiritual capital. The trick is deciding who is selling the right stuff at the right price.

Toby A. Ten Eyck
Department of Sociology and
Michigan State University Extension
Michigan State University

NEWS AND NOTES

CONFERENCES

March 28–30, 2012
The University of Nebraska's Center for Great Plains Studies presents its 38th Interdisciplinary Symposium in collaboration with Homestead National Monument of America, National Park Service. "1862–2012: The Making of the Great Plains" will be held at the University of Nebraska–Lincoln.

In 1862, Congress passed four landmark pieces of legislation: the Homestead Act, the Morrill Act, the Pacific Railroad Act, and the act to establish the U.S. Department of Agriculture; it was also the year of the fateful Dakota Conflict. These acts and events fundamentally shaped the Great Plains. This symposium will examine their consequences for the society, culture, and commerce of the Great Plains.

The public is encouraged to register for the conference. Contact the Center by e-mail: cgps@unl.edu; or web site: www.unl.edu/plains.

March 30–31, 2012
The 144th Annual Meeting of the Kansas Academy of Science will be held at Wichita State University. Web site: www.kansasacademyscience.org/. The Keynote Speaker is Dr. Andrew H. Knoll, Fisher Professor of Natural History & Professor of Earth and Planetary Sciences, Harvard University Botanical Museum.

April 20, 2012
The Annual Meeting of the Nebraska Academy of Sciences and the Nebraska Junior Academy of Sciences State Science Meeting will be held at Nebraska Wesleyan University in Lincoln, Nebraska. Web site: www.neacadsci.org.

May 9–11, 2012
The 64th Annual Meeting of the Rocky Mountain Section of the Geological Society of America will be in Albuquerque, NM. *Rio Geo Fiesta!* Web site: www.geosociety.org/Sections/rm/2012mtg/.

June 25–28, 2012
The Seventh International Conference on Interdisciplinary Social Sciences will held at Universidad Abat Oliba CEU in Barcelona, Spain. More information may be found at www.SocialSciencesConference.com.

July 26–29, 2012
The 75th Annual Meeting of the Rural Sociological Society will be held at the Palmer House Hotel in Chicago.

By this time pretty much everybody knows that 2012 is the 75th Anniversary of the founding of the Rural Sociological Society and that our meetings will be held in the same hotel where the RSS was launched in 1937. What you may not realize is that 2012 is also the 150th Anniversary of the founding of the U.S. Department of Agriculture, the federal agency that has primary responsibility for the quality of life in rural America. This confluence should encourage us to use the annual meetings as a time of reflection not only of the path traveled but the road ahead. What policies—public and otherwise—have contributed to the patchwork of uneven prosperity we find at home and abroad and how can we do better?

The theme for this meeting is "Local Solutions to Inequality." For more information, see the web site: www.ruralsociology.org.

August 5–10, 2012
The 97th Annual Meeting of the Ecological Society of America will be held in Portland, OR. This meeting's theme is "Life on Earth: Preserving, Utilizing, and Sustaining our Ecosystems." Web site: www.esa.org/portland/index.php.

November 4–7, 2012
The Annual Meeting of the Geological Society of America will be in Charlotte, NC. The theme is "Geosciences: Investing in the Future." Web site: www.geosociety.org/meetings/.

November 11–14, 2012
The 60th Annual Meeting of the Entomological Society of America will be held in Knoxville, TN. This year's theme is "A Global Society for a Global Science." Covering all aspects of the science, the section & member symposia will provide insight into many of the world's most vexing problems that affect you and the global community, and will help you with your research. Web site: www.entsoc.org/entomology2012.

November 14–18, 2012
The 111th Annual Meeting of the American Anthropological Association will be held in San Francisco, CA. The theme is "Borders and Crossings." San Francisco offers the perfect venue for thinking about border crossings across time, space, embodied differences, language and culture. If we have learned anything in the last decade with the increasing globalization of social movements, the election of the first black US president, and the legalization of gay marriage in five states, it is that borders—taboos, injunctions, stigmas and resource flows—are not fixed, but open to renegotiation. It is in that spirit that we dedicate this meeting to recognizing our discipline's borders and those borders' permeability to relevant transgressions. Web site: www.aaanet.org/meetings/.

Charles E. Bessey Award

Great Plains Research is pleased to announce the winners of the Charles E. Bessey Award for the best paper in natural sciences published during the volume year of 2011 are Alexander J. Smart, Matthew J. Nelson, Peter J. Bauman, and Gary E. Larson for their paper, "Effects of Herbicides and Grazing on Floristic Quality of Native Tallgrass Pastures in Eastern South Dakota and Southwestern Minnesota," *Great Plains Research* 21 (Fall 2011):181–89. The annual award includes a cash prize of $250.

Smart is a professor, Nelson a graduate student, and Larson a professor, all in the Department of Natural Resource Management at South Dakota State University. Bauman is with the Nature Conservancy in Clear Lake, SD.

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 2011 are Peter J. Longo and Joan M. Blauwkamp for their paper, "Workplace Religious Accommodation for Muslims and the Promise of State Constitutionalism," *Great Plains Research* 21 (Spring 2011):3–15. This annual award also includes a cash prize of $250.

Longo is professor of political science and Blauwkamp is associate professor of political science, both at the University of Nebraska at Kearney.

Atlas wins awards

The *Atlas of the Great Plains* by Stephen J. Lavin, Fred M. Shelley, and J. Clark Archer, Foreword by David J. Wishart, Introduction by John C. Hudson, published by the University of Nebraska Press in 2011, has received two awards: the 2011 *Booklist* Editor's Choice, reference category; and one of three best reference works in the Travel & Geography category by the *Library Journal Reviews* (February 28, 2012).

> With more than 300 maps and diagrams, this beautifully crafted atlas complements the earlier, award-winning *Encyclopedia of the Great Plains* (Univ. of Nebraska). As defined here, the region stretches across 15 states and three provinces from Alberta to Texas, an area of 973,500 square miles. The atlas includes both reference and thematic maps. The latter depict the areas' environment, history, employment, politics, religion, recreation, and other social indicators. Where else could you have successive maps on symphony orchestras, rodeos, and powwows? LJ 11/1/11

The Center for Great Plains Studies was one of the supporters for the publication. J. Clark Archer is a fellow of the Center and past editor of *Great Plains Research*. The late Stephen J. Lavin was also a fellow of the Center. David J. Wishart is a fellow of the Center and editor of the *Encyclopedia of the Great Plains*.

INSTRUCTIONS TO AUTHORS

SUBMISSIONS

- All manuscripts must be concise: no more than 5,000 words excluding abstract and reference sections.
- Tables and figures (including maps) must be carefully composed to achieve the author's goal of clarity of presentation.
- There is no limit for either figures or tables accompanying the manuscript. Authors must, however, be judicious in their use of figures and tables.
- All submissions must be double-spaced, and include abstract, key words, text, and references, and printed on 8.5 by 11-inch white paper with 1-inch margins. Use Times New Roman font.
- Informational footnotes are not accepted.
- Authors must prepare a separate title page with their name(s) and affiliation(s), and any acknowledgments, which will not be sent to reviewers. The title of the paper must be repeated directly above the abstract.
- Authors must submit three copies of their manuscripts and a CD-R of all figures and tables.
- If the manuscript is accepted for publication, author(s) will be asked to send the final document as an e-mail attachment or on a CD-R in Word or Rich Text Format/.rtf file.

REVIEW PROCESS. ALL MANUSCRIPTS ARE GIVEN DOUBLE-BLIND REVIEW. Authors must prepare a separate title page with their name(s) and affiliation(s), and any acknowledgments, which will not be sent to reviewers. The title of the paper must be repeated directly above the abstract. Authors should avoid self-identification in the text. When at least two external reviewers with expertise in the topic have submitted their evaluations, the manuscript is reviewed by the Editor who makes the final decision to publish.

Send your submissions to
Editor
Robert F. Diffendal, Jr.
Great Plains Research
University of Nebraska–Lincoln
P.O. Box 880246
Lincoln, NE 68588-0246

Phone: (402) 472-6970
E-mail: gpr@unl.edu

Article Style. Authors should write simply and in the first person, communicate with a broad interdisciplinary audience in jargon-free language, and avoid sexist, racist, or otherwise biased language or intent.

Title. Article titles should not exceed 10 words (or 82 characters) and should not have subtitles.

(1) **Text Headings** are left-justified, all caps, and bold: INTRODUCTION, METHODS, RESULTS, DISCUSSION, CONCLUSIONS, ACKNOWLEDGMENTS, REFERENCES. (2) **Text Subheadings** are left-justified, title caps, and bold. (3) **Text Lower Subheadings** are left-justified, title caps, bold, no tab, and lead into the paragraph.

Abstract. A short abstract of fewer than 200 words should precede the main text. The abstract should identify the problem addressed in the paper, indicate the methodology, and summarize the results. Authors should prepare an abstract that will be interesting to and understood by nonspecialists in the field. Five to eight **key words** should accompany the abstract.

Illustrations. All illustrations including maps should be referenced parenthetically by arabic numbers in the text. For example, "Rainfall increases with elevation (Fig. 1)." Captions for figures should be sent as a separate file and not included or embedded into the figure itself. All illustrations should be sized for 1-column width (3.25") or 2-column width (6.625"), be no more than 9.0" in height, and be sent as separate files as "grayscale" **tiff** or **eps** graphic files at 350 dpi, and "line" illustrations should be 1200 dpi. High quality **pdf** files are acceptable.

DO NOT send figures embedded into your article, as Word figures, or as PowerPoint® graphics. Send illustrations/figures as separate files on a CD-R. Use a sans serif font such as Arial.

Maps. A bar scale in kilometers and a north arrow must be included on all maps. Enlarged details of maps should be to scale. All geographic places mentioned in the text should be shown on a map. Use a sans serif font such as Arial.

Measurements. All measurements should be given in **SI units** (expanded metric system).

Tables. Tables should be presented on separate sheets apart from the text and printed as quality images. They should be formatted to fit the standard text area of the journal [1-column width (3.25") or 2-column width (6.625") and no more than 9.0" in height], since they <u>may</u> be treated as camera-ready illustrations at the time of publication. Send tables separately as Word files <u>with</u> article file on CD-R. Use Times New Roman font.

Reference Style. *Great Plains Research* uses *The Chicago Manual of Style*, 16th edition, as its reference guide. The journal uses author-date citations in chronological order in the text [for example: (Smith et al. 1990; Templer 1992; Jones in press)] and a complete reference section that gives author, year, title, source, and page references for journal or newspaper articles. **Include page numbers for quotations** [for example: (Templer 1992, 45)].

- For a journal article:
  Murkin, H.R. 1998. Freshwater functions and values of prairie wetlands. *Great Plains Research* 8:3–15.
- 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.

For complete guidelines, please see our web page: **www.unl.edu/plains**

inside this issue

GREAT PLAINS RESEARCH

VOLUME 22, NUMBER 1 SPRING 2012

University of Nebraska Lincoln

ISSN 1052-5165