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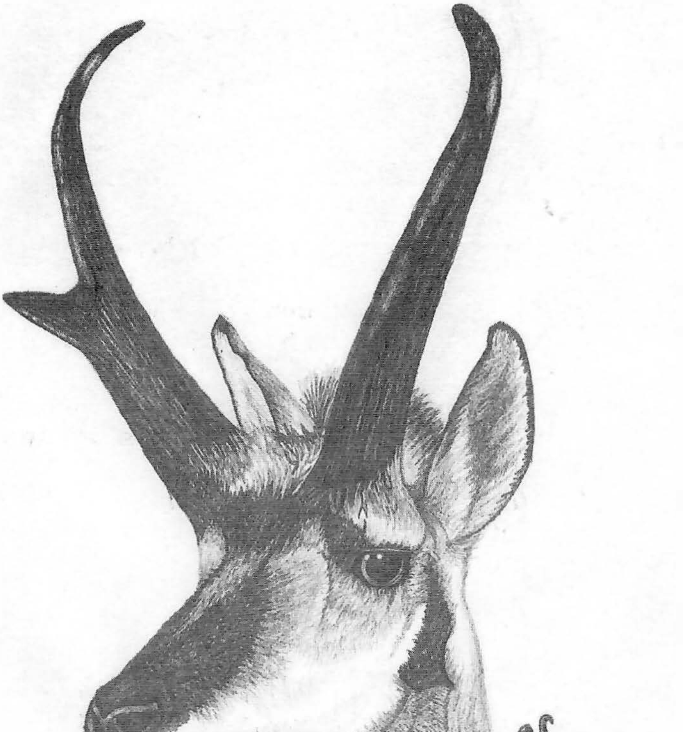

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Feeding Habitats of Spring-Migrating Blackbirds in East-central South Dakota

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ABSTRACT -- Between 27 March and 21 April 1998, we monitored blackbird (Icteridae) activity and habitat selection at a migratory staging area in east-central South Dakota. We used fixed-area observation points located within 201-km^2 circular plots centered on four wetland basins that were used as night roosts. Each roost was surveyed four times, with the surveys spread evenly throughout the blackbird migration. We recorded the number of blackbird flocks, flock size and composition, habitat used, and behavior (e.g., loafing and feeding). Fifty percent (n = 242) of the 482 flocks recorded in the quadrats was observed loafing in trees of woodlots and shelterbelts. Feeding flocks preferred habitats classified as Corn (e.g., disked, plowed, and stubble corn fields) over two other foraging habitat categories (Cultivated and Grassland). A comparison of proportional availability of Cultivated habitat (soybean [*Lathyrus odoratus*] and wheat [*Triticum aestivum*] stubble, inclusive) against proportional use by feeding flocks indicated that this habitat was avoided. Grassland habitat (hayfields, CRP, and pasture) was used according to its availability. Intensity of Grassland use depended on time of survey (AM and PM), with use greater during the PM survey. A two-factor model (habitat, time, and the interaction term) provided the best parsimonious fit of 15 *a priori* models tested with Akaike's information criterion (AIC_c). Selection of foraging habitats by blackbirds might reflect comparable strategies used by other early migrating granivores. This knowledge could help wildlife managers maximize the placement of corn field food plots for optimum benefit to wildlife species.

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Key words: agriculture, blackbirds, corn fields, feeding sites, habitat selection, shelter belt, South Dakota, spring migration.

East-central South Dakota is used by many species of birds as a migratory stopover area (Linz et al. 1995, Linz et al. 2002, Linz et al. 2004). Birds on migration will pause here for several days and acquire additional energy reserves needed to continue northward (Schaub and Jenni 2001). Several species of granivorous passerines migrate through South Dakota, either singly or in small groups, and thus are difficult to observe; however, blackbirds (Icteridae) are highly visible during migration and among the earliest of the passerines to move into east-central South Dakota (Linz et al. 2003, Homan et al. 2004). Early migration at northern latitudes can be hazardous because of low or sporadic food availability and periods of severe weather (Whitmore et al. 1977). The foraging strategies employed by blackbirds while staging here might have implications that extend beyond this specific group of birds because similar foraging strategies might be used by more cryptic granivores, some of which are species in decline in the northern Great Plains.

In a small, preliminary study conducted during early spring in east-central South Dakota, route surveys indicated that use of harvested fields of corn (*Zea mays*), soybean (*Lathyrus odoratus*), and small grains was similar among the three field types for 20 species of birds (excluding blackbirds), including upland gamebirds, waterfowl, and nongame birds (Linz et al. 1995); however, for blackbird species, use of corn fields occurred at greater frequencies than expected (Linz et al. 1995). More detailed research was conducted in stubble soybean and corn to assess rates of use by blackbirds (Linz et al. 2003) and other granivorous bird species (Linz et al. 2004). Blackbirds used corn fields at much greater rates than soybean fields; whereas, other granivorous bird species used corn and soybean fields at statistically equal rates (Linz et al. 2004). Although results from these three studies were comparable, none of them accounted for habitat availabilities across the study area. We reported in our paper on habitat selection by blackbirds (primarily, red-winged blackbirds [*Agelaius phoeniceus*]) in respect to habitat availabilities occurring over much larger areas than were considered in the other studies. The incorporation of a larger geographical area into the analysis of habitat selection might provide more realistic perspectives on the selection process used by blackbirds during spring migration in east-central South Dakota.

Spring migration is a critical time, when migrating bird populations are at their lowest levels of the year and populations might be limited by food conditions at the staging area (Hutto 1998, Petit 2000, Schaub and Jenni 2001, Smith and Moore 2005). Our objectives were to (1) document the daytime activities of migrating blackbirds and (2) describe the selection of foraging habitats within a common radius of daily travel from the spring roosts.

STUDY AREA

The study was conducted in the Prairie Coteau ecoregion of east-central South Dakota. As a result of Pleistocene glaciation, most of the area lacks a well-developed drainage network and contains high densities of wetlands (Johnson and Higgins 1997). The vegetation in this region is classified as Northern Mixed-Grass Prairie (Johnson and Larson 1999). However, most of the prairie grasses had been replaced by agriculture; 70% of the lands in the study area (15,700 km^2) was devoted to agriculture. Soybean and corn were the dominate uses of agricultural land (40 and 33%, respectively), with pasture and hay land (15%) and wheat (9%) comprising the remaining bulk of agricultural use (National Agricultural Statistics Service 2006). Average daily temperature (6°C) and total precipitation (4 cm) during the March to April study period were similar to 30-yr averages (South Dakota Climate and Weather Statistics 2006). Spring planting did not begin until May and the cultivated lands were in either a stubble or disked condition.

METHODS

We identified four major roosts with maximum populations ranging from 66,000 to 217,000 birds. The Arlington (44.3°N, 97.0°W), DeSmet (44.4°N, 97.5°W), and Ramona (44.0°N, 97.3°W) roosts were located during previous studies (Linz et al. 1995, Linz et al. 2004). The Colman (43.9°N, 99.9°W) roost was located in March 1998. The roosts were in large wetland basins (120 to 300 ha) dominated by cattail (*Typha* spp.) or common reedgrass (*Phragmites australis*). Each roost was surveyed approximately once per week between 27 March and 21 April 1998. The surveys were spread evenly across this period, which covered the major part of the early blackbird migration (Knittle et al. 1987, Linz et al. 2003, Homan et al. 2004). The study plot boundaries were based on 8-km radii (201 km^2) extending from the center of the wetland basins. One roost was done per day, with the surveys divided into two 3-hr time periods. The morning survey (AM) was 1 to 4 hr after local sunrise and the afternoon survey (PM) was 4 to 1 hr before local sunset. Observation points were located at intersections of Public Land Survey System (PLSS) section lines. All flocks greater than or equal to 50 birds within a fixed-area quadrat (0.8 km x 0.8 km) centered on the PLSS intersection were tabulated. A team of two observers was used, with an observer monitoring either the northern or southern half of the quadrat. It took about 90 seconds to complete a point. If PLSS intersections were not reachable by four-wheel drive vehicle, they were not used. The number of survey points per plot ranged from 76 to 78. Flocks observed moving from an adjacent, previously surveyed point were not tabulated. We recorded the following data: flock size, species composition, flock activity (e.g., feeding and loafing), and habitat in which the activity was occurring. We used the following five habitat categories: 1) Grassland, which included hayfields, pastures, and Conservation Reserve Program (CRP) lands; 2) Corn, which included disked, plowed, and stubble fields; 3) Cultivated, which consisted of disked and stubble fields of soybean (two-thirds of the category) and small grains (wheat, one-third of the category); 4) Trees, which included shelterbelts, woodlots, and riparian forests; and 5) Miscellaneous, which was dominated by wetlands, but also included farmsteads, roadways, developed areas, lakes, ponds, rivers, standing water, and other unidentified areas. Of the five habitat categories, only three (Grassland, Corn, and Cultivated) were considered foraging habitats. We did not conduct observations during periods of measurable precipitation or when visibilities were less than 1 km.

Each flock was considered an independent observation of a habitat-use decision. Flocks of less than 50 birds were not recorded to avoid potential bias associated with not detecting smaller flocks equally in different habitats (Thomas and Taylor 1990). For several reasons, encountering a large number of migrating birds was unlikely more than once at the observation points. The surveys were conducted about a week apart, during which time, turnover at the roost (i.e., change in the composition of individuals) would be considerable; Otis et al. (1986) estimated that the daily turnover rate for spring blackbird roosts in east-central South Dakota was approximately 10%. Moreover, the probability for encountering a flock at an observation point during the survey was small. We made nearly 2,500 counts at the observations points over the study period and recorded less than 500 flocks.

Log-linear models were constructed to describe the observed counts of feeding flocks in relation to habitat type (H), roost (R), time of day (D), and week of migration (W). A saturated model, including all terms and interactions, would describe the data perfectly (Agresti 1996), but probably would be unnecessarily complex and difficult to interpret. Instead, we considered 15 *a priori* models and used a modified Akaike's information criterion (AICc) for making inferences. Relative AICc values and Akaike weights were used to rank the models and determine the strength of evidence for each model. Model averaging techniques were used to incorporate model selection uncertainty and calculate estimates of the proportion of blackbird flocks in each foraging habitat (Burnham and Anderson 1998, Anderson et al. 2000).

The habitat term (H) was included in all of the *a priori* models because our primary interest was in assessing levels of use among different foraging habitats (Linz et al. 1995). The roost term (R) might be needed in the models if habitat selection differed from roost to roost. This seemed possible, but not certain, since the habitats surrounding the roosts were similar in configuration. Therefore, we considered a number of models with and without the R term.

Time of day (D) might be incorporated if habitat selection differed between morning and evening surveys. Thus, we tested models with and without D. Finally, flock species composition could change as the migration season progressed (Barras 1996, Homan et al. 2004), and this might result in temporal differences in habitat selection patterns. Therefore, models with and without the W term were considered. We tried to limit this effect by timing our study period to the peak period of red-winged blackbird migration, before the influx of other late-migrating blackbird species, such as the yellow-headed blackbird (*Xanthocephalus xanthocephalus*). In addition to main effect models, we considered a number of models with two-way interactions. Three-way interactions seemed less likely, and their difficult interpretation prompted us to exclude them from the analyses (Table 1).

Habitat availabilities in each of the four study plots surrounding the roosts were calculated by using a nonmapping technique (Marcum and Loftsgaarden 1980). At each observation point in the study plot, we randomly selected 16 squares from a 100 by 100 square grid placed over high resolution images (National Aerial Photography Program) of the 0.8 km by 0.8 km quadrats (approximately 1200 random samples of habitat per study plot). A habitat category was assigned to each square. The classification of the squares was verified during the 1998 field season. The proportional availabilities of the five habitat categories in the study plots were estimated from habitat proportions generated from the randomly selected squares.

RESULTS

The red-winged blackbird was the most numerous species making up 78% (144,784) of the total 186,350 flock members tallied. The common grackle (*Quiscalus quiscula*) was the second most abundant with 21% (38,374). The largest number of common grackle occurred during 4 to 9 April, the second of the four survey periods. The small remainder of blackbird species included the brown-headed cowbird (*Molothrus ater*), rusty blackbird (*Euphagus carolinus*), yellow-headed blackbird, and Brewer's blackbird (*Euphagus cyanocephalus*). Within the habitats, the flocks were generally mixed-species flocks. Although some flocks were of extraordinary size (maximum of 10,000 birds), the vast majority of the 482 flocks we counted ranged between 300 and 450 birds.

Of the 482 flocks, 242 (50%) were perched in shelterbelts and woodlands. Only one flock was observed feeding in trees. The Miscellaneous category had 59 flocks; no feeding activity was recorded for flocks observed in this habitat category. The remaining 181 flocks were observed actively feeding in Corn, Grassland, and Cultivated habitats. We used these three categories for subsequent analyses of foraging habitat selection.

Table 1. Fifteen potential *a priori* log-linear models describing the observed counts of feeding blackbird flocks around spring roosts in east-central South Dakota.

Possible Effects	*a Priori* Models	
Main Effects	Main Effect Models	
Habitat (H)[a]	H	HDR
Roost (R)[b]	HR	HWD
Week (W)[c]	HW	HWR
Time of Day (D)[d]	HD	HWDR
Two-way Interactions	Two-way Interaction Models	
H x R	H|R	H|W|D
H x W	H|W	H|W|R
H x D	H|D	H|D|R
	H|W|D|R	

[a] 1) Harvested corn fields, 2) stubble and disked soybean and wheat, and 3) CRP, pasture, and hayfields.

[b] 4 roosts: Arlington, Coleman, DeSmet, and Ramona.

[c] 4 1-week periods from 27 March - 21 April.

[d] 2 3-hr survey periods: 1 to 4 hr after sunrise and 4 to 1 hr before sunset.

A goodness of fit test indicated that the data fit well (G = 57.17, d.f. = 57, P = 0.47) with the most parameterized model (H|W|D|R) for interpreting the observations of feeding flocks. Additionally, there was no indication that the data were overdispersed ($\hat{c}$ = 1.003). A parsimonious model that adequately described the data included habitat category, time of day (AM or PM), and the interaction between these two factors (Model H|D, Table 2). Model H|D earned 67% of the support (Akaike weight, w_i = 0.67), while models HWD and HD earned 14% and 10% of the support, respectively (Table 2). Other models received considerably less support (w_i = 0.03 - 0.00). Because model H|D had almost five times as much support as the next closest model and dominated the unconditional parameter estimates, we used its structure for our interpretation.

Approximately equal amounts of the three foraging habitats were available to the birds (Table 3). Feeding flocks were observed in Corn more often than expected based on availability, with 56% of the flocks observed in this habitat. Grassland habitat was used according to its availability. Grassland habitat was used more often in the evening than the morning. Cultivated habitat, which included soybean and wheat fields, was used less than expected based on availability (Table 3).

Table 2. Summary of the evidence supporting 15 *a priori* log-linear models considered to describe the observed counts of feeding blackbird flocks around spring roosts in east-central South Dakota.

Model[a]	LogLikelihood	AICc	Delta AICc (Δ_i)	Akaike Weight (w_i)
H|D	1663.24	1674.79	0.00	0.67
HWD	1664.54	1677.95	3.15	0.14
HD	1670.87	1678.66	3.87	0.10
HWDR	1662.49	1681.32	6.53	0.03
HW	1670.33	1681.89	7.09	0.02
HDR	1668.82	1682.23	7.43	0.02
H	1676.67	1682.54	7.75	0.01
H|W|D	1651.92	1684.30	9.50	0.01
H|R|D	1651.33	1683.71	8.91	0.01
HR	1674.61	1686.17	11.37	0.00
HWR	1668.28	1685.33	10.53	0.00
H|W	1668.67	1691.02	16.22	0.00
H|R	1669.75	1692.10	17.31	0.00
H|W|R	1644.57	1694.73	19.93	0.00
H|W|R|D	1623.45	1684.94	10.15	0.00

[a] Refer to Table 1 for model descriptions and naming conventions.

Table 3. Proportion of spring-migrating blackbird flocks (n = 181) feeding in three habitats during morning and afternoon observations in east-central South Dakota.

Foraging Habitat	Proportion Available (%)	Proportion Used (%)	
		AM	PM
Grassland	35.6[a] (34.4, 36.8)[b]	8.7 (4.8, 12.6)	19.9 (14.0, 25.8)
Corn	29.8 (28.7, 31.0)	25.5 (18.9, 32.1)	30.6 (23.2, 37.9)
Cultivated	34.6 (33.4, 35.9)	7.1 (3.6, 10.6)	8.2 (4.3, 12.2)

[a] Mean

[b] 95% C.I.

DISCUSSION

East-central South Dakota has been used as a major stopover site consistently for decades by millions of blackbirds on their annual spring migration. Thus, substantial quantities of food must be available to support the energetic demands placed on the environment by this sizable migratory population. Although studies on the food habits of spring-migrating populations of granivores are rare in the literature (Hutto 1998), two studies have reported on foods eaten by the red-winged blackbird during early spring at northern latitudes, McNicol et al. (1982) in Ontario, Canada, and Mott et al. (1972) in Brown County, South Dakota. The authors found that waste grains, including corn, small grains (e.g., wheat, oats, and millet), and weed seeds (primarily, foxtail [*Setaria* spp.] and smartweed [*Polygonum* spp.]) comprised the main portion of the diet in March and early April. McNicol et al. (1982) found that 71% of the diet was waste corn in areas of intense cultivation; whereas, in non-agricultural areas, weed seeds (mainly, foxtail) formed the greater part of the diet. Mott et al. (1972), in their intensely cultivated study area in South Dakota (70% cultivated, with corn the major crop at greater than 20% of land area), found that foxtail predominated in the diet, although waste corn and wheat were also present.

Not surprisingly, waste grains and weed seeds are major diet items in early spring for blackbirds (and probably other granivores as well). For example, seed production of foxtail species common to the northern Great Plains (e.g., *S. viridis*, and *S. glauca*) is prolific. For *S. viridis* growing in corn and soybean and not treated with post-emergent herbicide, seed production was approximately 4,000 seeds/m^2 (Forcella et al. 2000). Seed density declined to approximately 400/m^2 when post-emergent herbicide was applied early in the growing season. Foxtail seeds are extremely valuable to a diverse set of granivorous species encompassing a broad range of body sizes. In some cases, foxtail will account for greater than 50% of the diet of upland game, (e.g., gray partridge [*Perdix perdix*]) waterfowl (e.g., blue-winged teal [*Anas discors*]), and ground-feeding songbirds (e.g., American tree sparrow [*Spizella arborea*]) (West 1967, Sedivec and Barker 1998). One of the other major dietary staples in early spring, waste corn, also is abundantly available in most harvested corn fields. In fields sampled in Kansas in February, average kernel density was 70 kernels/m^2 (Salter et al. 2005). This value was comparable to an estimate made by Frederick and Klass (1984) for waste corn in recently harvested fields in Nebraska (88 kernels/m^2). Dolbeer et al. (1978) measured waste corn at 69 kernels/m^2 in corn stubble during November near a winter blackbird roost in western Tennessee; however, by February, it had dropped to less than 3 kernels/m^2, presumably due to a wintering population of 5 to 10 million blackbirds feeding in the fields. Waste corn in eastern South Dakota unlikely received the kind of feeding pressure under which Dolbeer et al. (1978) recorded the severe decline of waste corn. Indeed, blackbirds in our study area apparently spent a very large portion of their time loafing in trees and wetlands, perhaps indicating that the amount of time spent foraging was relatively minor.

Heavy and consistent use of this rather confined geographic region in east-central South Dakota by large populations of blackbirds might indicate that the area attracted and supported other granivorous passerines in March and April. We have identified 20 different granivorous bird species (excluding blackbirds) in our field plots since our research began in this region (Linz et al. 1995, Smith 1999, Linz et al. 2002, Linz et al. 2004). East-central South Dakota could be a major stopover area for these granivorous species and others, but to our knowledge no estimate of migrating population sizes, besides blackbirds, is known in this region. Many of the bird species residing in the northern Great Plains have been in population decline for several years, and many of these species are granivores (Brennan and Kuvlesky 2005).

We did not sample the fields for densities of weed seeds and waste corn, instead using flock activity as our indicator of presence of food. Obviously, leftover cereal grains and weeds seeds are major food sources for granivorous birds on migration, and we recommend that more research be conducted to assess the amounts of foods available in the three foraging habitats we defined. Moreover, additional field studies aimed at documenting the optimal size, placement, configuration, and density of food patches for granivorous birds also should be considered in light of the recent population declines of several prairie grassland bird species. Managers interested in providing food plots for migrating wildlife should consider planting corn or other row crops, such as sunflower (*Helianthus* spp.), near wetlands and shelterbelts to enhance the quality and safety of critical stopover habitat (Johnson and Beck 1988). Harvested fields of row crops will be used by residents, winter migrants, and spring migrants when the ground is free of snow (Galle et al. 2004). Leaving some standing crop will provide another source of cover and food during periods of snow cover. The strategic placement of food plots at critical stopover sites should help enhance the body condition and survivability of birds at reproductive sites in the northern Great Plains (Smith and Moore 2005).

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Brood Break-up and Juvenile Dispersal of Lesser Prairie-chicken in Kansas

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ABSTRACT -- Natal dispersal is critical for genetic interchange between subpopulations of birds and little is known about the timing and extent of lesser prairie-chicken (*Tympanuchus pallidicinctus*) dispersal movements. We monitored movements of 51 transmitter-equipped female lesser prairie-chicken known to have hatched a nest. Average minimum daily brood movements differed ($t = -2.94$, $df = 829$, $P < 0.01$) between the early (273 m; 0 to 14 days post-hatch) and late (312 m; 15 to 60 days post-hatch) brood rearing periods. We captured 71 juvenile lesser prairie-chicken from 10 broods at 3 to 11 days post-hatch and marked them with passive integrated transponder (PIT) tags. We subsequently captured 41 chicks from 20 different broods and fitted them with necklace-style transmitters. Transmitter-equipped brood hens and individual chicks were monitored daily and the average date of brood break-up was 13 September (85 to 128 days post-hatch). Both males and females exhibited bimodal dispersal movements in the fall and spring. Autumn dispersal movements peaked between late October and early November for both sexes. Spring dispersal movement of males peaked during late February. Female dispersal movements in the spring peaked in late March and

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were much more extensive than fall dispersal movements. Natal dispersal distance for all marked males averaged 1.4 km (SE = 0.2, n = 9). The approximate dispersal distances of three transmitter-equipped females ranged from 1.5 to 26.3 km. Because of greater dispersal distances, females will contribute more to genetic exchanges between fragmented subpopulations. To ensure genetic connectivity, we recommend that a distance of less than 10 km be maintained between lesser prairie-chicken subpopulations through protection or establishment of suitable habitat.

Key words: brood break-up, dispersal, Kansas, lesser prairie-chicken, *Tympanuchus pallidicinctus*.

Lesser prairie-chicken (*Tympanuchus pallidicinctus*) occupies xeric grasslands in Kansas, Oklahoma, Texas, New Mexico, and Colorado (Hagen 2005). Its numbers have declined range-wide since the 1800's (Braun et al. 1994) and its occupied range has decreased by an estimated 92% (Taylor and Guthery 1980). Most of the population decline has been attributed to habitat deterioration and conversion of grasslands to intensive row crop agriculture. In Kansas, the lesser prairie-chicken still occupies habitat in 31 of 39 counties of its historical distribution (Jensen et al. 2000), but most of the original habitat is heavily fragmented by agriculture and development.

Movement of birds between subpopulations is critical to the persistence of the metapopulation and maintaining genetic variability (Greenwood 1980, Hanski and Gilpin 1997). Most genetic interchange between subpopulations likely comes from natal dispersal. Natal dispersal is the movement of an animal from its point of origin to the place where it reproduces or likely would have reproduced had it survived and found a mate (Howard 1960, Greenwood 1980). Natal dispersal is even more critical to genetic interchange for lek mating species such as the lesser prairie-chicken because adult males have extremely high fidelity to display sites and few males typically do most of the breeding (Bouzat and Johnson 2004). In addition to maintaining genetic variability, dispersal movements likely buffer mortality within small or sink-like subpopulations (Pulliam 1988). Thus, knowledge of natal dispersal distances can aid in identification of critical habitat fragments that ensure gene flow between subpopulations. However, only Copelin (1963) has reported approximate dispersal distances (fall capture site to lek site) for juvenile lesser prairie-chicken. Copelin's (1963) estimates might not provide a good estimate of natal dispersal due to movements prior to initial capture and lower search effort at long distances from the initial capture sites. Thus, little information is available on juvenile dispersal of lesser prairie-chicken and no estimates of sex-specific natal dispersal distances have been reported. This information is useful in understanding how genetic exchanges occur between fragmented subpopulations.

Our objectives were to 1) identify the timing of brood break-up, 2) identify the timing of natal dispersal, and 3) estimate natal dispersal distances for male and female lesser prairie-chicken.

METHODS

Phase I (1997-1999) of our research was initiated on a 5,700-ha sand sagebrush prairie fragment (study site I) in southwestern Kansas just south of the Arkansas River in Finney County. During Phase II (2000-2002), an adjacent study site (study site II) of approximately the same size was added and work continued on both sites through spring 2003. At the nearest point, the two sites were 3.2 km apart and both were surrounded almost entirely by center-pivot irrigated cropland. Both sites were owned privately and used primarily for livestock grazing and mineral exploration/production.

We captured female lesser prairie-chicken on leks in the spring by using walk-in funnel traps (Haukos et al. 1990, Schroeder and Braun 1991). Females were marked with an individually numbered aluminum leg band (size 12) and an 11-g necklace-style transmitter (RI-2B; Holohil Systems Ltd., Carp, Ontario, Canada) with a 1 year expected battery life. All birds were released on-site immediately following transmitter attachment. We located nests by approaching females when telemetry locations remained unchanged for greater than three consecutive days. We estimated the fate of each nest upon reinspection of the site immediately following female departure or death.

During Phase I, females that successfully hatched a nest were approached at night with spotlights at 3 to 11 days post-hatch. If chicks were present, they were captured with a long-handled net and individually marked with a passive integrated transponder (PIT) tag (Jamison 2000). When females were captured with the brood, a soft release was attempted by using an opaque-bisected release pen (Jamison 2000). If the female was not captured with the brood, the chicks were released near the capture location.

During Phase II, the same procedures were used to capture chicks but captures were not attempted until 30 to 40 days post-hatch. All captured chicks were marked with individually numbered aluminum leg bands (size 12) and birds exceeding 150 g were equipped with a 2-g necklace-style transmitter (BD-2C; Holohil Systems Ltd., Carp, Ontario, Canada) with a 60 day expected battery life. Chicks were released at their capture location immediately following handling. Beginning at approximately 55 days post-hatch, the same procedures were used to capture additional birds and all previously transmitter-equipped chicks. At this time, all captured chicks were fitted with an 11-g necklace-style transmitter and beginning midway through the 2000-field-season, blood samples were collected from each bird. Blood samples were submitted to a genetics lab (Zoogen

Incorporated, Davis, California) where chromosome analysis of blood cells was used to identify each bird's sex (Van Tuinen and Valentine 1983). Captures of previously marked chicks on lek sites during subsequent years also were used to verify the sex of birds that were not classified by chromosome analysis. The age of chicks not associated with a transmitter-equipped female was estimated from body measurements (Pitman et al. 2005).

We used a truck-mounted null-peak telemetry system to monitor transmitter-equipped females with broods and individual chicks (Phase II) daily, until death of the bird, dispersal outside of the study sites, or transmitter failure. We triangulated the location of birds by using azimuth bearings recorded from known tracking stations. We searched all suitable habitats within a 120-km radius of our study sites for dispersing transmitter-equipped chicks from a Cessna 150 aircraft by using aerial telemetry equipment. In the final year of our project (2002-2003), we located transmitter-equipped birds daily through mid-August. From mid-August to the following March, we monitored birds at approximately monthly intervals from a Cessna 150 aircraft.

We used distances between daily locations of females with chicks as an estimate of brood movements. We used a t-test for unequal variance (Ott 1993) to compare minimum daily brood movements between the early (0 to 14 days post-hatch) and late (15 to 60 days post-hatch) brood rearing periods. The timing of brood break-up was estimated by monitoring broods containing transmitter-equipped females and chicks, and estimated for each radio-marked chick. We defined the time of brood break-up as the first of three consecutive days when the distance between a female and her chick exceeded 200 m. We chose this distance because it approximated the amount of error associated with locations collected from the null-peak telemetry system used during our study. We compared the mean date and age when transmitter-equipped male and female chicks separated from their broods by using a t-test for unequal variance (Ott 1993).

We identified the timing of sex-specific natal dispersal for transmitter-equipped lesser prairie-chicken chicks by using a dispersal index (Small and Rusch 1989). This index equals the linear distance between the first and fifth location in a set of five consecutive daily locations. For each chick, we calculated a dispersal index for each consecutive five-day interval beginning on 1 August. The index was assigned to the date corresponding to the mid-point of each set. The mean index values on these dates were plotted to identify the approximate periods of dispersal for males and females, respectively. The dispersal index was calculated for transmitter-equipped females through early May. We were unable to record five consecutive daily locations for any juvenile male following mid-March. Thus, we were not able to calculate the dispersal index for juvenile males beyond that time.

Natal dispersal distances were calculated separately for juvenile male and female lesser prairie-chicken. Birds captured at lek sites were scanned with a PIT-tag reader to determine if they had been marked as chicks. For males PIT-tagged in Phase I, natal dispersal was the distance from hatch to the lek of capture the following spring. For males equipped with transmitters in Phase II, dispersal distance was the distance from hatch to the spring lek site where the bird was observed most frequently. We compared dispersal distances of PIT-tagged and transmitter-equipped males by using a t-test for unequal variance (Ott 1993). Female natal dispersal distances were only observed for transmitter-equipped birds in Phase II of our project because no PIT-tagged females were ever recaptured. Female natal dispersal distance was the distance from hatch to the first observed nest site. Because the hatch location was unknown for some chicks, an approximate dispersal distance also was estimated. Using this method, dispersal was the distance between the chicks location at approximately 60 days post-hatch and the lek most attended or the first observed nest site for males and females, respectively.

RESULTS

We captured and equipped 226 females with transmitters during our six-year study. We located 209 nests from these transmitter-equipped birds and determined fate for 196 nests. Fifty-one of these nests (26.0 %) were known to have produced at least one chick. During Phase I, we captured 71 chicks from 10 broods and implanted each chick with a PIT-tag. Five chicks died during capture and marking or as result of these procedures shortly after release. The remaining 66 chicks showed no adverse effects from marking at the time of release. During Phase II, we captured 34 chicks from 16 broods with transmitter-equipped brood hens and seven chicks from four broods with unmarked hens. We used chromosome analysis of blood cells or subsequent captures at lek sites to identify the sex of 31 of these chicks (19 male and 12 female).

Average minimum daily brood movements differed (t_{829} = -2.94, $P < 0.01$) between the early ($\bar{x}$ = 273 m, SE = 10.5, n = 393) and late ($\bar{x}$ = 312 m, SE = 7.9, n = 773) brood rearing periods with longer movements more frequently occurring during the late brood rearing period (Fig. 1). Brood break-up was determined for nine chicks (three male and six female) in six broods in which the brood hen also was equipped with a transmitter. The date these nine chicks separated from the brood hen averaged 13 September (range = 21 August to 6 October) and did not differ between juvenile male and female birds (t_4 = 1.27, P = 0.27). Juvenile age at the time of brood break-up averaged 101 days (range = 85 to 128 days) and was also similar between male and female birds (t_4 = 0.94, P = 0.40). An additional unmarked brood containing a transmitter-equipped juvenile male had not dissolved prior to 2 October when the chick was depredated at 113 days post-hatch. Three of the monitored broods contained two transmitter-equipped chicks each and both

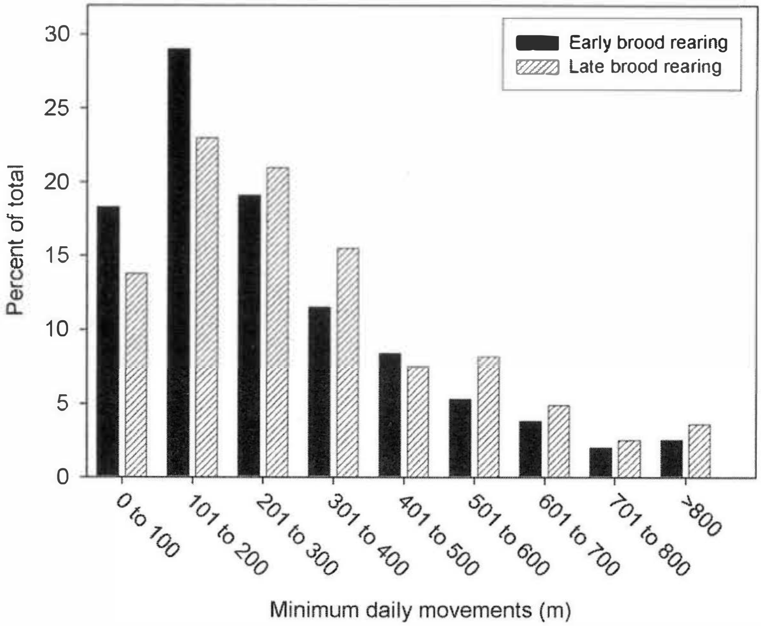

Figure 1. Percentage of minimum daily brood movements observed in each distance category for lesser prairie-chicken during early (0 to 14 days post-hatch; n = 393) and late (15 to 60 days post-hatch; n = 773) brood rearing periods in southwestern Kansas, 1997 to 2002.

chicks left the brood simultaneously in only one instance. The two chicks in each of the other two broods broke away from the brood hen at intervals of 20 and 25 days. We documented brood mixing for 2 of 41 (4.9%) transmitter-equipped chicks from two different broods at 36 and 37 days post-hatch. These chicks remained with their unmarked broods through brood break-up.

Dispersal indices revealed a bimodal dispersal pattern between August and May for both juvenile males (n = 12) and females (n = 10) (Fig. 2). The timing of autumn dispersal movements peaked between late October and early November for both sexes. However, distinct sexual differences were apparent during the spring dispersal period with peak movements occurring during late February for males and late March for females (Fig. 2). The dispersal index was similar during fall and spring for juvenile males, but the female index was much greater during the spring dispersal period.

We calculated dispersal distances of juvenile lesser prairie-chicken for 4 of 67 birds PIT-tagged during Phase I (all four were males) and 14 of 41 (11 males and 3 females) transmitter-equipped birds during Phase II. None of the other PIT-tagged

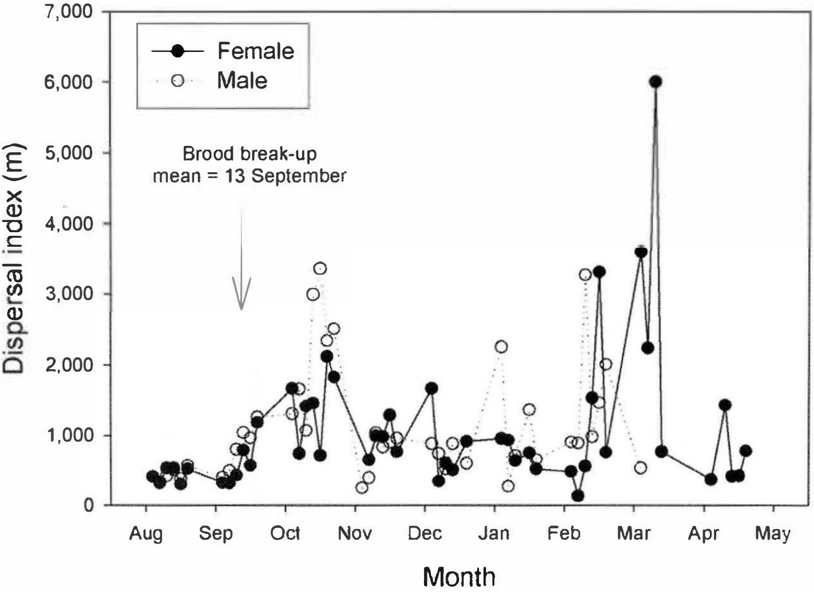

Figure 2. Sex-specific dispersal indices, indicating the approximate timing of autumn and spring transience [distance (m) between the first and fifth location in a set of five consecutive locations] for juvenile lesser prairie-chicken. Indices were derived from transmitter-equipped males (n = 12) and females (n = 10) in southwestern Kansas, 2000 to 2002.

birds was captured and 25 of the remaining 27 transmitter-equipped birds did not survive until the spring breeding season. The other two transmitter-equipped birds were last detected on 11 September and 9 January due to either dispersal beyond our range of detection or transmitter failure. The mean natal dispersal distance for all marked males was 1.4 km (SE = 0.2) and did not differ (t_7 = 0.74, P = 0.48) between PIT-tagged (1.5 km, SE = 0.3) and transmitter-equipped birds (1.2 km, SE = 0.3; Table 1). Five of seven transmitter-equipped males monitored during their first spring breeding season were recorded on multiple leks. We calculated dispersal distances for three female lesser prairie-chickens during Phase II. No female birds PIT-tagged during Phase I were ever recaptured. Two transmitter-equipped females dispersed 25.4 and 2.1 km to establish nests. The carcass of a third female was recovered on 10 April at a distance of 3.7 km from her location at 60 days post-hatch. An additional five chicks (two female and three male) equipped with transmitters during the 2002-brood-period were last located from the air on 14 March 2003. The two females were approximately 1.7 km and 18.1 km from their hatch location and the three males were all within three km of their hatch locations ($\bar{x}$ = 2,238 m ± 586).

Table 1. Mean dispersal distances (km) of PIT-tagged (PIT) and transmitter-equipped (TE) juvenile male and female lesser prairie-chicken in southwestern Kansas, 1997 to 2002.

	Natal dispersal[a]			Approximate dispersal[b]		
Gender	n	$\bar{x} \pm$ SE	Range	n	$\bar{x} \pm$ SE	Range
Male						
PIT	4	1.5 ± 0.3	0.9 to 2.3	—	—	—
TE	5	1.2 ± 0.3	0.6 to 2.1	—	—	—
Total	9	1.4 ± 0.2	0.6 to 2.3	11	1.2 ± 0.2	0.3 to 2.0
Female	2	NR[c]	2.1 to 25.4	3[d]	10.49 ± 7.94	1.5 to 26.3

[a] Distance between the hatch location and the most visited spring lek site (male) or first nest location (female).

[b] Distance between chick location at approximately 60 days post-hatch and most visited spring lek site (male) or nest location (female).

[c] NR = not reported.

[d] For one female the distance was calculated from the 60 day post-hatch location to the 10 April location where the bird's carcass was recovered.

DISCUSSION

Brood break-up and dispersal signify the time at which chicks become independent from the brood hen. For fall-dispersing prairie grouse species, the autumn dispersal period is critical because it provides juvenile males time to prospect for advertising sites prior to winter (Bergerud and Gratson 1988). Previous grouse researchers have concluded that brood break-up and dispersal occur at distinctly different times (Godfrey and Marshall 1969, Bowman and Robel 1977). Similarly, the break-up of lesser prairie-chicken broods in Kansas and the onset of autumn dispersal were not simultaneous events. Break-up of broods occurred in mid-September and the timing was similar to the dates reported for other fall-dispersing grouse species (Godfrey and Marshall 1969, Rusch and Keith 1971, Bowman and Robel 1977, Schroeder 1986). Following brood break-up, the peak of autumn dispersal for juvenile lesser prairie-chickens was preceded by three to six weeks of more localized movements.

The sex of spruce grouse (*Falcipennis canadensis*) chicks has been shown to influence the date of brood break-up with females leaving the brood later than males (Schroeder 1986). We failed to find such a relationship for lesser prairie-chicken in Kansas, but our sample sizes were small. Our results also suggested that chick age was not the primary factor associated with brood-break up of lesser prairie-chicken because age varied substantially (85 to 128 days post-hatch) at the time of brood break-up. Bowman and Robel (1977) also failed to find evidence of age-specific brood break-up for greater prairie-chicken (*Tympanuchus cupido*) in Kansas. The age of chicks in their study ranged from 70 to greater than 84 days post-hatch (n = 11 chicks in four broods) at the time of brood break-up and they suggested that break-up of broods was under photoperiodic control. Godfrey and Marshall (1969) reported photoperiodic control or meteorological changes to be involved in the breakdown of ruffed grouse (*Bonasa umbellus*) broods. We have no evidence to suggest either of these environmental conditions were driving the timing of lesser prairie-chicken brood break-up.

The timing of autumn dispersal movements and sex-specific dispersal distances have been reported for several grouse species (Godfrey and Marshall 1969, Bowman and Robel 1977, Schroeder 1986, Small and Rusch 1989, Whitcomb et al. 1996). Bowman and Robel (1977) hypothesized that dispersal of juvenile greater prairie-chicken was not complete following brief initial dispersal in the fall. The occurrence of bimodal dispersal (autumn and spring) in several grouse species supported this hypothesis (Small and Rusch 1989, Small et al. 1993, Smith 1997, Caizergues and Ellison 2002, Warren and Baines 2002). Dispersal of juvenile lesser prairie-chicken in Kansas mimicked this bimodal pattern. Thus, autumn dispersal distances probably do not approximate true natal dispersal for lesser prairie-chicken. Similarly, dispersal of juvenile greater prairie-chicken in Wisconsin is bimodal and spring dispersal movements are more extensive than more subtle autumn movements (Halfmann 2002). Final dispersal of juvenile greater prairie-chicken occurs during February-March for males and March-early April for females (Halfmann 2002). Likewise, individuals of juvenile lesser prairie-chicken exhibit sex-specific periods of dispersal and complete their natal dispersal during the same time periods as greater prairie-chicken in Wisconsin.

Juvenile lesser prairie-chicken monitored in our study exhibited sex-specific natal dispersal distances with females dispersing farther than males. Eighteen studies of 10 grouse species have quantified sex-specific natal dispersal (Table 2). Five of these studies have solely used band recoveries at spring display sites to estimate natal dispersal distances. Dispersal distances might be underestimated in these studies because search efforts usually decline with distance from the original capture site (Lambrechts et al. 1999). However, the natal dispersal distance of male lesser prairie-chicken derived from PIT-tagged birds did not differ from that of transmitter-equipped birds during our study. Thus, our data suggested that recoveries of marked birds (banded or PIT-tagged) at spring display sites could be used to reasonably approximate natal dispersal distance of male lesser prairie-chicken. Natal dispersal distance of male lesser prairie-chicken in Kansas (1.4 km) was similar to estimates derived from band recoveries in Oklahoma (less than 1.0 km; Copelin 1963). Natal dispersal distance of male lesser prairie-chicken also was

Table 2. Estimates of mean and maximum (max) sex-specific juvenile dispersal distances (km) for 10 grouse species, by using either band recoveries (BR) or transmitter-equipped (TE) birds.

		Female			Male			
Species	Method	n	Mean	Max	n	Mean	Max	Reference
Tympanuchus pallidicinctus[a]	TE	2	NR[b]	21.0	10	1.4	2.3	Our study
Tympanuchus pallidicinctus[c]	BR	5	< 3.0[d]	< 6.0	27	< 1.0[d]	< 4.0	Copelin 1963
Tympanuchus cupido	TE	88	6.9	70.0	71	2.3	17.2	Halfmann 2002
Lagopus lagopus[a]	TE	NR[b]	11.4	NR	NR	2.6	NR	Smith 1997
Lagopus lagopus	TE	14	2.0[d]	10.0	21	< 0.5[d]	< 1.0	Hudson 1992
Lagopus leucurus	BR	40	4.0[d]	28.0	126	1.3[d]	6.0	Giesen and Braun 1993
Centrocercus urophasianus	BR	12	8.8[d]	NR	12	7.4[d]	NR	Dunn and Braun 1985
Tetrao tetrix	TE	8	9.3	19.0	11	< 1.0	< 1.0	Warren and Baines 2002
Tetrao tetrix	TE	16	8.0[d]	29.0	11	1.5[d]	8.2	Caizergues and Ellison 2002
Dendragapus obscurus	TE	42	1.4[d]	11.0	24	0.9[d]	2.6	Hines 1986
Dendragapus obscurus	BR	50	2.0[d]	10.0	49	1.1[d]	9.1	Jamieson and Zwickel 1983
Falcipennis canadensis	BR	14	3.2	NR	16	2.3	NR	Robinson 1980
Falcipennis canadensis	TE	NR	5.0	NR	NR	0.7	NR	Schroeder 1986, Boag and Schroeder 1992
Bonasa umbellus	TE	2	NR	3.4	2	NR	0.8	Small and Rusch 1989
Bonasa bonasia[c]	TE	4	2.0	5.6	14	4.0	24.9	Montadert and Leonard 2005
Bonasa bonasia[a]	TE	4	4.2	6.8	3	2.7	5.7	Swenson 1991, Kämpfer-Lauenstein 1995, Fang and Yue-Hua 1997

[a] Natal dispersal is from the location of hatch to spring breeding site; all others calculated as the distance from initial summer capture site to spring breeding site.

[b] NR= not reported.

[c] Dispersal distances calculated from fall and winter capture sites to spring breeding site; might not provide an accurate estimate of natal dispersal due to movements prior to initial capture.

[d] Distances are medians; all others are means.

similar to seven of the nine grouse species for which an estimate has been reported (Table 2). Only juvenile dispersal distances of male greater sage-grouse (7.4 km; *Centrocercus urophasianus*; Dunn and Braun 1985) and hazel grouse (4.0 km; *Bonasa bonasia*; Montadert and Leonard 2005) were substantially greater than those observed for lesser prairie-chicken in Kansas.

The sex-specific natal dispersal distances observed in our study suggested that males contributed less than females to genetic exchanges between isolated populations because they generally remained within 2 km of their natal area. In a New Mexico lesser prairie-chicken population, most genetic variance was explained by differences within (96.4%), rather than among leks (3.6%) (Bouzat and Johnson 2004). These results along with observations of high lek fidelity (95%) by males within and across years led Bouzat and Johnson (2004) to conclude that female dispersal among lesser prairie-chicken leks might prevent local lek genetic differentiation at the mtDNA control level. We concurred with Bouzat and Johnson (2004) and suggested that mean natal dispersal distance of female lesser prairie-chicken could be used to identify the minimum acceptable distance between habitat fragments occupied by lesser prairie-chicken. In southwestern Kansas, natal dispersal averaged less than 10 km for female lesser prairie-chicken. When the distance between occupied habitat fragments exceeded this distance there was an increased risk of fitness effects due to genetic isolation. However, we only observed natal dispersal distances for two female lesser prairie-chicken and further research should focus on providing a more reliable estimate.

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Population Biology of Pumpkinseed in Enemy Swim Lake, South Dakota

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ABSTRACT -- Little information is available regarding the biology and population characteristics of pumpkinseed (*Lepomis gibbosus*), especially in South Dakota, a state at the western edge of the species native range. South Dakota Department of Game, Fish and Parks summer trap net survey data, collected 1998 to 2003, suggests the Enemy Swim Lake population has low abundance (0.4-2.9 per trap net night) and moderately high size structure (proportional stock density [PSD] ranges between 71 and 91). To further examine the biological characteristics of the Enemy Swim Lake population, pumpkinseed was collected from Indian Bay with trap nets during May 2003. Total length (TL), weight, and sex were recorded for 88 fish. In addition, gonads, livers, and viscera weights were recorded for calculating organosomatic indices, and sagittal otoliths were removed for aging. Relative abundance, PSD, and relative weights (Wr) were similar to other regional populations. The sex ratio (F:M) of sampled fish was 1.5. Fish age ranged from 2 to 5 years; mean pumpkinseed age was 3. The annual survival rate for age 3 to 5 was estimated at 0.25. Ultimate length for the population was estimated to be 223 mm ($K = 0.38$, $t_0 = -0.67$) and mean TL increments were 27, 16, and 14 mm for ages 2 to 3, 3 to 4, and 4 to 5, respectively. There was no difference for total length ($P = 0.57$), weight ($P = 0.37$), or Wr ($P = 0.88$) between sexes, but visceral somatic (VSI; $P < 0.0001$) and hepatosomatic (HSI; $P < 0.0001$) indices for females were greater than males. Relative weight and fish TL were correlated positively ($P<0.0001$), and Wr was correlated positively with female and male VSI ($P = 0.0031$ and 0.0144), female HSI ($P = 0.0008$), and female gonadosomatic index (GSI; $P = 0.0039$). Because these biological characteristics are seldom reported, we anticipated

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this information might be useful for population comparisons throughout the range of pumpkinseed.

Key words: GSI, *Lepomis gibbosus*, organosomatic indices, pumpkinseed.

The pumpkinseed (*Lepomis gibbosus*) is native throughout the eastern United States and southern Canada (Scott and Crossman 1973, Trautman 1981). Despite fairly broad distribution, the species' population biology is not as well-described as that of other sunfishes (*Lepomis* spp.). Scott and Crossman (1973) and Trautman (1981) provide overviews of the distribution, biology, and ecology of pumpkinseed in Canadian and Ohio populations. Carlander (1977) reported length, weight, growth, age, condition, and fecundity data from multiple pumpkinseed populations. Beckman (1946) summarized pumpkinseed growth and sex ratios in Michigan lakes, while several Ontario populations have been examined for life history variations and patterns in growth and density (Fox 1994, Fox et al. 1997). Harrington et al. (2001) described pumpkinseed abundance and size structure in Nebraska.

Pumpkinseed is present in small, scattered populations in South Dakota, at the western edge of its native range. Some pumpkinseed are collected during standardized surveys of various waters conducted by the South Dakota Department of Game, Fish and Parks (SDGFP), and general population characteristics are included in its annual reports. Summer SDGFP trap surveys from 1998 to 2003 of Enemy Swim Lake, South Dakota, have identified the population as having a stable, low density number of moderately high size structure (Table 1). The intent of our study was to further describe the biological and population characteristics of Enemy Swim Lake pumpkinseed, and compare the population to others reported in the literature.

METHODS

Pumpkinseed was collected from Enemy Swim Lake, South Dakota, which has a surface area of 870 ha, a mean depth of 5 m, and a maximum depth of 8.5 m. Sampling was conducted from 21 to 23 May 2003 by using six 19-mm (bar measure) mesh trap nets per night for a total effort of 18 net nights. Netting occurred exclusively in Indian Bay, a 63 ha embayment on the southwestern side of Enemy Swim Lake that contains large amounts of submerged aquatic macrophytes (Weimer 2004), an essential component of pumpkinseed habitat (Scott and Crossman 1973, Carlander 1977, Harrington et al. 2001). Indian Bay is considered a critical sunfish spawning area, and we expected pre-spawn pumpkinseed to be active in the nearshore. Total length (TL, mm) was recorded for all collected

Table 1. Pumpkinseed sunfish population catch and size structure characteristics for Enemy Swim Lake, South Dakota, from 1998 to 2003. Data collected with 13- and 19-mm bar measure trap nets by the South Dakota Department of Game, Fish and Parks (SDGFP). CPUE = catch per unit effort; SE = standard error; PSD = proportional stock density; RSD-P = relative stock density of preferred length (≥200 mm) fish.

Year	Net Nights	CPUE (SE)	PSD	RSD-P
1998	21	0.4 (0.18)	88	0
1999	18	0.8 (0.53)	91	0
2000	21	1.7 (0.47)	91	0
2001	24	1.7 (0.53)	75	0
2002	24	2.9 (0.77)	71	0
2003	24	1.4 (0.51)	73	9

individuals, and ten fish per 5 mm length class were transported to the laboratory where they were weighed (g), given an identification number, and frozen pending processing.

Catch per unit effort (CPUE; Hubert 1996), the number of fish greater than or equal to stock TL (80 mm) caught per net night, was used to index pumpkinseed population density. Size structure of Enemy Swim Lake pumpkinseed was indexed by using proportional stock density (PSD; proportion of stock-length fish that exceeded quality length [150 mm]) and relative stock density of preferred-length fish (RSD-P; proportion of stock-length fish that exceeded preferred length (200 mm); Gabelhouse 1984, Anderson and Neumann 1996). Length-frequency distribution of sexes was compared with the Komolgorov-Smirnov test. Fish condition was quantified by using relative weight (Wr; fish weight/standard weight of fish of that specific length x 100; Anderson and Neumann 1996).

Some dessication and shrinkage might occur during freezer storage (Blackwell et al. 2003), thus TL and weight were remeasured following thawing for calculation of indices. Liver and viscera (less stomach and intestinal contents) weights were used to calculate organosomatic indices (hepatosomatic index, HSI; liver weight/ body weight x 100) (visceral somatic index, VSI; viscera weight/body weight x 100) (Strange 1996). Statistical comparisons of TL, Wr, and organosomatic indices between sexes were done by using analysis of variance. Sex was determined during dissection. If female, the ovaries were removed and weighed for use in calculating gonadosomatic indices (GSI; ovary weight/body weight x 100; Strange 1996).

Sagittal otoliths were removed for growth analysis. A finite (annual) survival rate was determined from the descending limb of the catch curve (Robson and Chapman 1961). Analysis of covariance was used to test for differences in mean length at age between sexes. The von Bertalanffy growth model was applied to mean length-at-age to estimate ultimate total length ($L\infty$) for the population (Ricker 1975).

RESULTS and DISCUSSION

We collected 92 pre-spawn individuals of pumpkinseed between 120 and 210 mm in 18 total net nights, of which 88 were transported to the lab for processing. Pumpkinseed CPUE was 5.1 (SE = 1.43) fish per net night, greater than those reported by the SDGFP (Table 1). However, differences in survey timing and extent (whole lake vs. Indian Bay) made this comparison tenuous. The 175 to 179 mm and 180 to 184 mm size classes were the only groups containing ten or more individuals collected (n = 10 and 14, respectively; Fig. 1), which suggested that smaller individuals were not fully vulnerable to the nets. Only two preferred-length fish were collected. Sampled fish had a PSD and RSD-P of 75 and 2, respectively, similar to SDGFP surveys (Table 1).

Processed fish had a mean TL of 166 mm (SE = 2.2) and a mean weight of 112 g (SE = 4.9) (Table 2). Mean Wr for all fish was 104 (SE = 0.8) (Table 2), and was correlated positively with fish TL ($r = 0.46$, $P < 0.0001$, Fig. 2). Female pumpkinseed (n = 53) mean TL was 167 mm (SE = 3.1), mean weight was 116 g (SE = 6.9), and Wr was 104 (SE = 1.1). Male (n = 35) mean TL was 164 mm (SE = 3.1), mean weight was 107 g (SE = 6.5), and Wr was 104 (SE = 1.2) (Table 2). No statistical differences were observed between males and females for TL ($F = 0.33$, df = 1, $P = 0.57$), weight ($F = 0.82$, df = 1, $P = 0.37$), or Wr ($F = 0.02$; df = 1; $P = 0.88$). The sex ratio (F:M) of the Enemy Swim Lake pumpkinseed population was 1.5, a lower proportion of males (40%) than that previously reported by Beckman (1946) in Michigan waters (52%).

Table 2. Mean total length (TL, mm), weight (g), and indices determined for pumpkinseed in Enemy Swim Lake, South Dakota. VSI = visceral somatic index; HSI = hepatosomatic index; Wr = relative weight; SE = standard error.

	TL (SE)	Weight (SE)	VSI (SE)	HSI (SE)	Wr (SE)
Total	166 (2.2)	112 (4.9)	6.7 (0.16)	1.0 (0.03)	104 (0.8)
Females	167 (3.1)	116 (6.9)	7.4 (0.19)	1.2 (0.04)	104 (1.1)
Males	164 (3.1)	107 (6.5)	5.6 (0.13)	0.8 (0.03)	104 (1.2)

Male pumpkinseed might spawn with multiple females during the same season (Scott and Crossman 1973, Carlander 1977), a possible explanation for the lower percentage of males in the population. Possibly, pre-spawn females are more susceptible to netting than males. However, Schmittou (1967) reported the percentage of male bluegill (*L. macrochirus*), a closely related centrarchid, ranged from 20 to 38%, and Beckman (1946) found the mean percentage of males for 153 Michigan populations was 45%. This suggests our results were not unreasonable.

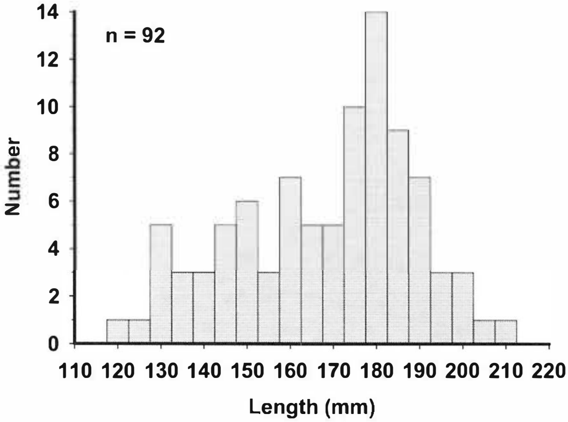

Figure 1. Histogram depicting the length-frequency distribution of pumpkinseed collected in Enemy Swim Lake, South Dakota, May 2003.

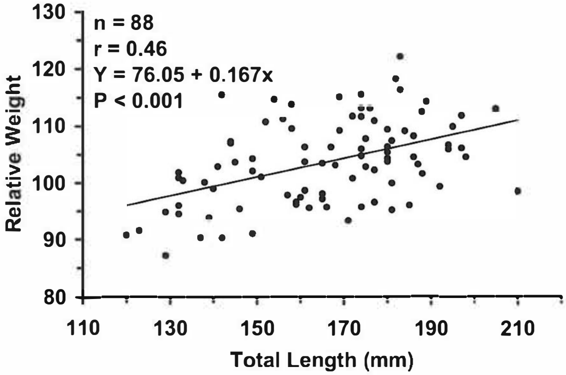

Figure 2. Relationship and simple correlation of pumpkinseed relative weight (Wr) to total length for pumpkinseed collected during May 2003 in Enemy Swim Lake, South Dakota.

Mean VSI for female and male pumpkinseed was 7.4 (SE = 0.19) and 5.6 (SE = 0.13), respectively (Table 2), and was statistically different between sexes (F = 52.71, df = 1, P < 0.01). The VSI was moderately correlated to Wr for female (r = 0.399, P = 0.0031) and male (r = 0.41, P = 0.014) pumpkinseeds (Fig. 3). Mean HSI differed significantly (F = 32.88, df = 1, P < 0.01) between females (1.2, SE = 0.04) and males (0.8, SE = 0.03; Table 2). Hepatosomatic index (Fig. 4) was correlated positively to Wr for females (r = 0.45, P < 0.01) but not for males (r = 0.04, P = 0.82). Female mean GSI was 1.9 (SE = 0.1), less than in 29 Ontario, Canada, populations (3.0-9.1; Fox 1994, Fox et al. 1997). Female GSI in Enemy Swim Lake was correlated positively with Wr (r = 0.39, P = 0.004, Fig. 5).

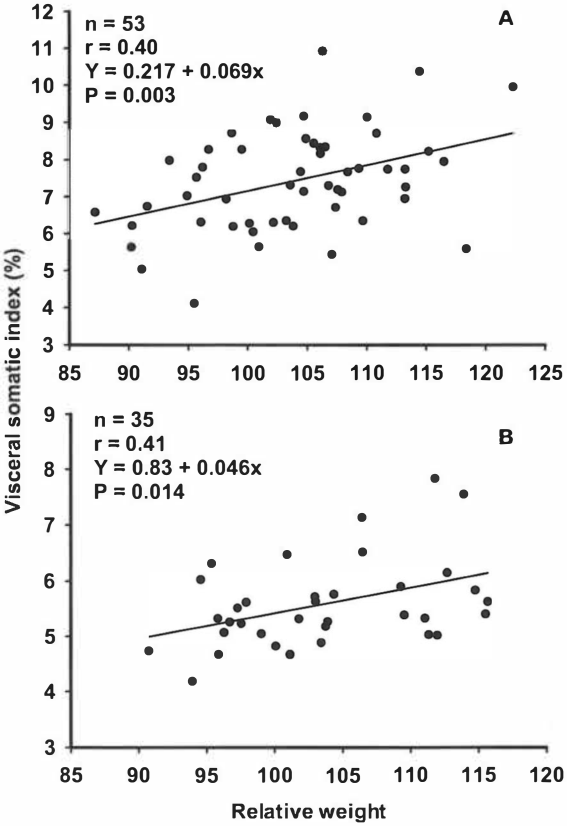

Figure 3. Female (A) and male (B) pumpkinseed visceral somatic index relationship to relative weight for pumpkinseed collected during May 2003 in Enemy Swim Lake, South Dakota.

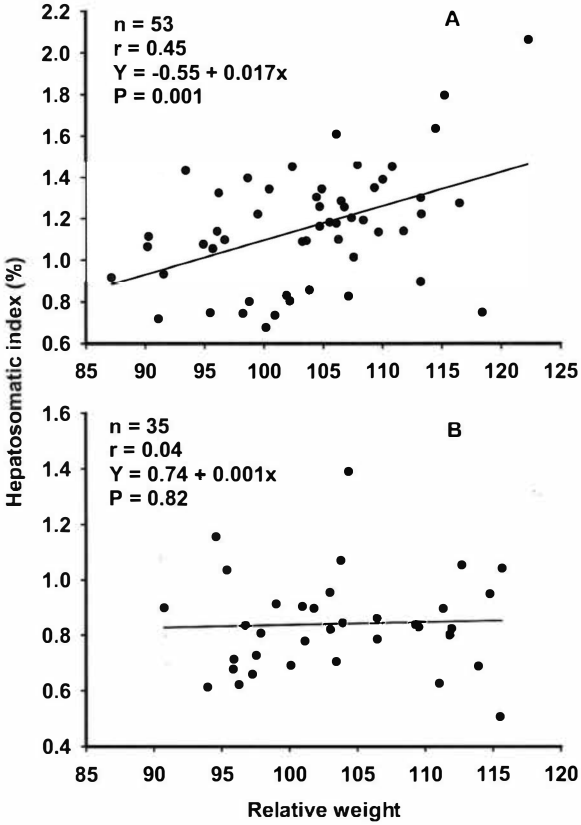

Figure 4. Female (A) and male (B) pumpkinseed hepatosomatic index relationship to relative weight for pumpkinseed collected during May 2003 in Enemy Swim Lake, South Dakota.

Age frequency peaked at age 3 (Table 3). Total length-at-age was compared between sexes by using analysis of covariance; no slope or intercept differences ($P > 0.5$) were detected, thus age/TL data for males and females were combined. Enemy Swim Lake pumpkinseed reached a mean TL of about 169 (SE = 2.2) and 184 (SE = 3.4) mm by ages 3 and 4, respectively (Table 3).

The upper range of mean TL for pumpkinseed populations from 13 states and one Canadian province was 100 to 223 mm (mean = 140) for age 3 and 117 to 286 mm (mean = 155) for age 4 (Carlander 1977). Although most of the studies summarized by Carlander (1977) used scales for age determination, it is reasonable to assume

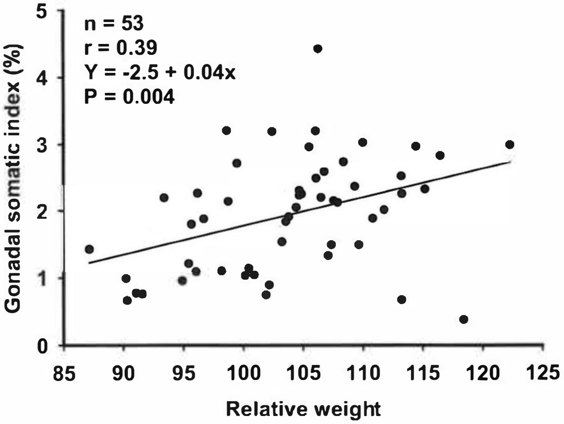

Figure 5. Relationship of female pumpkinseed gonadal somatic index to relative weight for pumpkinseed collected during May 2003 in Enemy Swim Lake, South Dakota.

Table 3. Mean total length (TL, mm) at ages 2-5 for Enemy Swim Lake pumpkinseed (n = 88) by using sagittal otoliths as an aging source. Mean of means (unweighted) and central 50% (C50) quartile range from Carlander (1977) were provided for comparative purposes.

Source	Age 2	Age 3	Age 4	Age 5
n	21	50	14	3
Mean TL	141.6	168.9	184.4	198.0
Mean of means	103	124	137	160
C50	91 - 112	109 - 136	116 - 155	145 - 175

that the Enemy Swim Lake population is near the upper bounds of reported growth rates for the species. Age information summarized in Carlander (1977) indicated that the species might live up to 8 years; however, one study reports an individual living 12 years in captivity (Flower 1935). No individuals exceeded 5 years of age in our sample.

A von Bertalanffy growth model using mean TL at ages 2, 3, and 4 produced an estimated $L\infty$ of 223 mm ($K = 0.38$, $t_0 = -0.67$, $r^2 = 0.997$). The two largest individuals (both age 5) in our sample were 205 and 210 mm TL, thus the estimate appeared to be realistic. A nonlinear model was constructed by using mean TL at ages 2, 3, 4, and 5 (otolith age) to derive a general growth function for the adult population. The resulting model was

$$TL = 100.8 + 60.5 * \ln \text{age} \ (r^2 = 0.992)$$

This model predicts that L_∞ could be attained between ages 7 and 8, similar to that reported in Carlander (1977).

Catch curve data for ages 3 through 5 were used to provide an estimate of the annual survival rate. Age 2 data were omitted from our analysis because of an inadequate sample (ascending limb of the catch curve) for that age class. The resulting survival rates for ages 3 to 4 and 4 to 5 were 0.28 and 0.21, respectively, with a combined estimate of 0.25 (catch-curve slope = -1.39). Thus, given the linearity ($r^2 = 0.997$) of the catch frequency/age relationship, average annual adult survival approached 25%.

Proportional stock density of pumpkinseed in Enemy Swim Lake was similar to populations in several Nebraska Sandhills lakes (Harrington et al. 2001), as were Wr and relative abundance. Harrington et al. (2001) reported that pumpkinseed CPUE in Nebraska Sandhills lakes was related positively to maximum lake depth and percent submergent vegetation. Enemy Swim Lake had a maximum depth (8.5 m) greater than any lakes included in the Nebraska study, with less submergent vegetation coverage. Trap-net effort in our study was limited to Indian Bay, an area that has a maximum depth of approximately 4 m and contains greater submerged vegetation coverage than the rest of Enemy Swim Lake (Weimer 2004). Indian Bay habitat and vegetation heterogeneity was similar to the Nebraska Sandhills lakes, which might account for the similarities between these populations.

In conclusion, the Enemy Swim Lake pumpkinseed population was low density and fast growing, with a moderately high size structure (fish > 200 mm TL present, but not abundant). Condition of individuals was relatively high, as indicated by Wr and other indices used in our study. The information provided in our study should be useful to biologists evaluating the status of other pumpkinseed populations.

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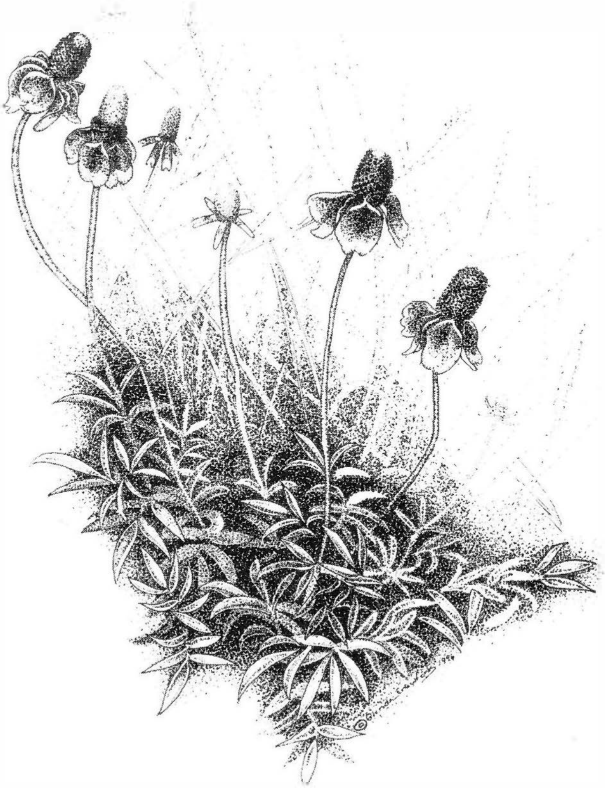

Reproductive Development in the Sicklefin Chub in the Missouri and Lower Yellowstone Rivers

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ABSTRACT -- We describe aspects of sicklefin chub (*Macrhybopsis meeki*) reproductive development from three study areas encompassing greater than 2,700 km of the Missouri and Lower Yellowstone rivers. The sicklefin chub was collected between late July and early October in 1996 and 1997. A total of 193 sicklefin chub was collected and examined for reproductive characteristics. Twenty-nine sicklefin chub were found to be reproductively mature females. Some sicklefin chub matured at age 2, but most matured at age 3 and all matured by age 4. Females first became mature at 70 to 79 mm total length (TL) in the Upper Missouri River reach in central Montana, 80 to 89 mm TL in the Missouri and Lower Yellowstone rivers in eastern Montana-western North Dakota, and 90 to 99 mm TL in the lower Missouri River in Nebraska, Iowa, Kansas, and Missouri. Gonad mass of gravid females averaged 6.9% of total body mass and ranged from 1.7 to 13.5%. Total number of oocytes per female, ranged from 7 to 1,561. Reproductive development

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of the sicklefin chub appeared to be group synchronous or asynchronous indicating multiple spawnings during a spawning season. This variability in spawning mode required cautious interpretation of gonadosomatic index values and oocyte counts as estimates of total fecundity, because some females might have released a cohort of oocytes prior to their capture.

Key words: age at maturity, fecundity, *Macrhybopsis meeki*, Missouri River, reproduction, sicklefin chub, size at maturity, Yellowstone River.

The sicklefin chub (*Macrhybopsis meeki*) is a small minnow of large, turbid rivers in the central United States. It historically inhabited the entire mainstem Missouri River and Mississippi River downstream from the Missouri River's confluence (Pflieger 1997). Sicklefin chub declined in the Missouri River following construction of reservoirs along the middle one-third of the river (Werdon 1993, Hesse 1994, Galat et al. 2005). These reservoirs reduced turbidity, altered natural thermal and hydrologic regimes, and fragmented fish populations (Morris et al. 1968, Keenlyne et al. 1994, Galat and Lipkin 2000). In 1994, the United States Fish and Wildlife Service (USFWS) identified the sicklefin chub as a Federal Category 1 candidate species for listing under the Endangered Species Act of 1973 because of its reduced range. Range reduction likely was due to destruction and modification of habitat, such as altered thermal regimes, which might have impacted temperature dependent spawning cues, predation, and competition from non-native fishes (USFWS 1995). By 2000, the sicklefin chub was thought to occupy only 54% of its former range within the Missouri River system in three reproductively isolated populations (USFWS 2001). Although a petition for Federal listing of the sicklefin chub as endangered was denied (USFWS 2001), it currently is listed as critically imperiled or imperiled in six of the seven mainstem Missouri River states (NatureServe 2005).

Fundamental life history information can aid in the recovery of declining species. Currently, the life history of the sicklefin chub is poorly known. Baltz (1990) considered reproduction to be an essential life history aspect requiring study. Specifically, he listed four areas of primary concern: (1) age and size at maturity; (2) fecundity estimates; (3) spawning season, including environmental cues such as stream discharge and water temperature; and (4) spawning habitat.

Grisak (1996) studied the sicklefin chub in the Missouri River in central Montana and reported on some aspects of its reproduction. He collected gravid females and ripe males in 1994 and 1995 and reported sexual maturity at ages 2 to 4. Five gravid females and one ripe male were collected between 5 and 17 August 1994, when water temperatures averaged 21.7°C (range 19.7 to 22.7°C). Eleven gravid females were collected between 18 and 31 July 1995, when water temperatures averaged 21.3°C (range 20.5 to 22.5°C). Twenty-two ripe males were collected between 19 July and 16 August 1995, when water temperatures averaged 22.3°C (range 18 to 28°C).

These results suggest that the sicklefin chub might have a protracted spawning season in the Missouri River. A protracted spawning season could result from each female spawning multiple times (i.e., multiple or repeated spawner) or the population might exhibit asynchrony in gonadal development (de Vlaming 1983). For example, different aged fish might spawn at different times (Mills 1987) or different populations spawn at different times at different latitudes (Leggett and Carscadden 1978). Patterns of oocyte development can be discerned by plotting the frequency of oocytes in an ovarian sample as a function of oocyte diameter. Wallace and Selman (1981) found that three basic patterns of oocyte development can be revealed by examination of oocyte size distributions. Development is termed "synchronous" if all oocytes, once formed, grow in unison, and thus oocyte size-frequency distribution consists of a single mode. This mode of development is characteristic of semelparous fishes like anadromous salmon (*Oncorhynchus* spp.) and eels (*Anguilla* spp.).

"Group-synchronous" oocyte development occurs when at least two size classes of oocytes (i.e., bi-or multi-modal size distributions) can be distinguished in the ovary of a single female at some time during the spawning season. Each mode of similar-sized eggs is spawned at one time but several cycles of egg development and spawning can occur. An entire year might be required for one cycle to be completed in annual spawning fishes or it might only take a few weeks for fishes that spawn at multiple discrete times within one spawning season. This is the most common ovarian development type among teleost fishes (de Vlaming 1983).

Lastly, "asynchronous" oocyte development occurs when oocytes of all stages of development might be present (Murua and Saborido-Rey 2003). The oocyte size-frequency distribution is continuous except in ripe ovaries, where there might be a clear separation between ripe and yolked oocytes. Asynchronous spawning fishes continually develop and release oocytes. In some species, individuals might spawn a few eggs every day throughout a spawning season.

Asynchronous spawners presumably undergo multiple spawnings over a protracted spawning season, whereas group synchronous spawners might or might not spawn multiple times during the spawning season. However, the actual number of spawnings and the number of eggs released during each act cannot be assessed from oocyte size-frequency distributions alone, but must be determined from direct observations of spawning females (West 1990).

Although some information on sicklefin chub reproduction has been reported, information is lacking on its type of ovarian development and fecundity by size class. Also, size and age at maturity in the Missouri River at locations outside of Montana are lacking. The purpose of our study was to present preliminary information on the reproductive development of the sicklefin chub based on specimens collected as part of a study examining habitat use and population structure of benthic fishes in the Missouri and Lower Yellowstone rivers (Pierce et al. 2003, Berry et al. 2005). Our objectives were to determine: (1) age and size at maturity, (2) total number of oocytes and gonadosomatic indices (GSI), and (3) type of ovarian development for sicklefin chubs.

STUDY AREA

The Missouri River originates at the confluence of the Jefferson, Gallatin, and Madison rivers in western Montana and flows 3,768 km to its confluence with the Mississippi River near St. Louis, Missouri. The drainage basin encompasses 1,327,000 km^2 in portions of 10 states and four physiographic provinces; the Rocky Mountains, Great Plains, Central Lowlands, and Interior Highlands (Robinson 1986). The freeze-free season ranges from about 40 days in the extreme upper basin to greater than 120 days in the lower basin (Hesse et al. 1989).

Individuals of the sicklefin chub were collected from three river reaches separated by mainstem impoundments. The Upper Missouri River reach (UMR) was the Missouri River upstream from Fort Peck Dam, Montana, between river kilometer (rkm) 3,141.0 and 3,029.0. The Upper Inter-Reservoir reach (UIR) encompassed portions of the Missouri River between Fort Peck Dam and the headwaters of Lake Sakakawea, North Dakota (rkm 2,736.9 to 2,497.2) and the lower 114 rkm of the Yellowstone River, Montana. The third reach, Lower Missouri River (LMR), included the most downstream 958 rkm of the mainstem Missouri River below Gavins Point Dam, South Dakota, flowing through Iowa, Nebraska, Kansas, and Missouri. The UMR and UIR reaches were characterized by wide channels with islands, sand bars, and side channels. Tributary inputs and absence of an upstream impoundment on the Yellowstone River permit a semblance of the historical flow regime with high spring flows and low stable summer flows (Galat and Lipkin 2000). The LMR reach flowes through a single, often rock-lined channel confined by navigation structures and levees and has flows regulated to maintain navigation, reduce flood peaks, and provide hydroelectric energy production (Hesse et al. 1989).

METHODS

Individuals of the sicklefin chub were collected between late July and early October in 1996 and 1997 following standardized collection procedures (Sappington et al. 1996, 1997). Shallow water habitats, less than 1.2 m deep, were sampled with a 10.7 m long by 1.8 m high seine with 5 mm mesh and a 1.8 by 1.8 by 1.8 m center bag. Deep-water habitats, greater than 1.2 m, were sampled with a 2 m wide by 0.5 m high benthic trawl with a 3.2 mm inner mesh net. Water temperature

(°C) was measured at the surface at each collection site with a YSI Model 30 conductivity/water temperature meter. All specimens were fixed in 10% neutral buffered formalin and then transferred to 80% ethanol. Total length (TL) in millimeters and total body mass to the nearest 0.1 g were measured on preserved specimens in the lab. Scales were removed from these fish for aging and aged by following methods described in Braaten and Guy (2002). Scales were removed from an area between the lateral-line and dorsal fin insertion and mounted between glass slides. Scales were viewed at 50X magnification under transmitted light and two readers independently aged all fish. If readers did not agree on an age after two independent examinations, the fish was omitted. Annuli were determined most often by crowded circuli, indicative of slowing growth, or less frequently, by the presence of cut-over incomplete circuli. Although assigned ages were verified with our use of two independent readers, ages were not validated with formal methods such as recapture of previously marked, known-age individuals. We examined the following aspects of sicklefin chub reproductive development: age and size at sexual maturity; total number of oocytes present, GSI values, and oocyte size-frequency distributions for gravid females.

Gonads were classified as immature or mature based on gross examination of preserved tissues under a dissecting microscope following descriptions in Bagenal and Braum (1968), Lehtinen and Layzer (1988), and Crim and Glebe (1990) and by histological examination based on descriptions in Crim and Glebe (1990) and Takashima and Hibiya (1995), if gross examination was uncertain. Gonads for histological examination were prepared following standard histological methods and were stained with Mayer's hematoxylin and eosin (H&E) (Humanson 1967, Hinton 1990). Gonads were classified as immature if they were (1) visually transparent, very small, not visible to the naked eye and often difficult to identify under the dissecting microscope or (2) were larger, usually visible to the naked eye, and opaque but contained no mature cells. The extremely small size of the former precluded their histological preparation and sexual determination, whereas, histological examination of the latter, revealed only immature egg or sperm cells (e.g., primary oocytes or spermatocytes). Mature gonads were large and visible to the naked eye. Mature testes were white colored. Gravid ovaries were orange colored with numerous fully developed eggs present that were easily seen with the naked eye. Eggs were round and typically white-yellow colored. Ovaries subsequently were placed in Gilson's fluid following weighing to facilitate egg separation. Mature ovaries, based on histological examination, contained primary and tertiary yolk granule oocytes and often empty follicles indicating that some oocytes had been ovulated (Crim and Glebe 1990). Flaccid ovaries, either empty or nearly empty with little internal tissue present were considered spent. A few ova were present in some spent ovaries. All individuals classified as mature or spent were considered sexually mature adults.

The GSI was calculated as the ratio of ovarian mass to total body mass (Crim and Glebe 1990). Gonad mass was measured to the nearest 0.01 g after they had been blotted dry with a paper towel. Number of oocytes present was determined by using a dissecting microscope to make direct counts of oocytes from gravid females. The type of ovarian development was evaluated by examining size-frequency histograms of oocyte diameters of a random subsample of about 400 ova from each gravid female.

RESULTS

We collected and examined 193 individuals of the sicklefin chub. Fifty-one individuals were collected from the UMR reach, 85 from the UIR reach, and 57 from the LMR reach (Tables 1 and 2). Total lengths of all specimens ranged from 16 to 118 mm and ages were between 0 and 4 years old. The ratio of males to females was 0.85:1 for all specimens whose sex was determined (Tables 1 and 2). Only 29 specimens were reproductively mature females. Sixteen of these 29 females were gravid with large numbers (228 to 1,561) of eggs present, whereas three other females had only a small number (7, 27, and 189) of mature oocytes present (Table 3). These three females were classified as gravid also because their oocytes were large in size and easily seen. The remaining 10 mature females were considered

Table 1. Percent of mature fish at ages for sicklefin chub (*Macrhybopsis meeki*) collected from three reaches of the Missouri and lower Yellowstone rivers, July to October, 1996 and 1997. Numbers in parentheses are number of fish examined for each reach, age group, and sex. The UMR reach is the Missouri River upstream from Fort Peck Reservoir, Montana. The UIR reach includes the Missouri River between Fort Peck Dam and Lake Sakakawea and the lower Yellowstone River in eastern Montana and western North Dakota. The LMR reach is the lower Missouri River in Iowa, Nebraska, Kansas, and Missouri.

	UMR reach		UIR reach		LMR reach	
Age group	Female	Male	Female	Male	Female	Male
0	0%(9)*		(0)	(0)	0%(32)*	
1	0% (1)	0% (2)	(0)	0% (2)	0%(3)	0%(8)
2	5%(21)	23%(13)	25%(24)	17%(30)	17%(6)	67%(6)
3	100% (2)	(0)	92%(13)	100%(10)	100%(1)	100%(1)
4	100% (1)	(0)	100% (5)	100% (1)	(0)	(0)

*sex not determined.

spent. Eighteen of 19 gravid females were collected between the last week of July and mid-August when water temperatures averaged 21.6°C (Table 3). However, water temperatures were quite variable during sampling, ranging from 16.7 to 25.4°C (Table 3).

Sexual maturation

All collected individuals of sicklefin chub less than 2 years old were immature, whereas all 3 year old and older individuals, except one, were classified as mature (Table 1). Less than 50% of females in all three populations and of males in the UMR and UIR reaches were sexually mature at age 2. No age 4 and only two age 3 individuals were collected in the channelized LMR reach. Females first became sexually mature at 70 to 79 mm TL in the UMR, 80 to 89 mm TL in the UIR reach and at 90 to 99 mm TL in the channelized LMR reach (Table 2).

Table 2. Percent of mature sicklefin chub (*Macrhybopsis meeki*) for 10 mm length groups for three reaches of the Missouri and lower Yellowstone rivers, July to October, 1996 and 1997. Numbers in parentheses are total number of fish examined for each reach, length group, and sex. The UMR reach is the Missouri River upstream from Fort Peck Reservoir, Montana. The UIR reach includes the Missouri River between Fort Peck Dam and Lake Sakakawea and the lower Yellowstone River in eastern Montana and western North Dakota. The LMR reach is the lower Missouri River in Iowa, Nebraska, Kansas, and Missouri.

	UMR reach		UIR reach		LMR reach	
Length group TL (mm)	Female	Male	Female	Male	Female	Male
< 30	(0)	(0)	(0)	(0)	0%(18)*	
30-39	0% (2)	(0)	(0)	(0)	(0)	(0)
40-49	0% (7)	(0)	(0)	(0)	0%(3)	0%(4)
50-59	(0)	0% (2)	(0)	(0)	0%(1)	0%(1)
60-69	0% (5)	0% (3)	0% (2)	0% (2)	(0)	0%(4)
70-79	8%(12)	33% (9)	0%(10)	0%(10)	0%(1)	(0)
80-89	14% (7)	0% (2)	46%(13)	33%(18)	0%(3)	100%(1)
90-99	(0)	(0)	86% (7)	100% (5)	50%(2)	80%(5)
≥ 100	100% (2)	(0)	100%(11)	100% (5)	100%(1)	(0)

*sex not determined.

Table 3. Fish identification (ID) number, collection reach, date, water temperature at time of capture, age, total length (TL), gonadosomatic index value (GSI), total number of oocytes, and number of egg diameters measured for 19 gravid females of the sicklefin chub (*Macrhybopsis meeki*) collected in the Missouri and lower Yellowstone rivers, July to October 1996 and 1997. The UMR reach is the Missouri River upstream from Fort Peck Reservoir, Montana. The UIR reach includes the Missouri River between Fort Peck Dam and Lake Sakakawea and the lower Yellowstone River in eastern Montana and western North Dakota. The LMR reach is the lower Missouri River in Iowa, Nebraska, Kansas, and Missouri.

Fish ID number	Collection reach	Collection date	Water temperature (°C)	Age	TL (mm)	GSI	# oocytes	# of eggs measured
29	UMR	7/27/96	22.9	3	106	10.3	1,115	416
185	UMR	8/11/97	24.5	3	90	10.0	1,055	390
184	UMR	8/11/97	24.5	4	117	11.0	1,561	512
5	UIR	8/7/96	17.2	3	86	13.5	1,473	302
4	UIR	8/13/96	24.0	3	104	2.2	487	375
11	UIR	9/11/96	14.3	3	93		641	410
148	UIR	8/7/97	25.2	3	93	5.3	228	228
145	UIR	8/7/97	25.2	4	102	1.9	7	7
146	UIR	8/7/97	25.2	4	105	1.7	27	27
144	UIR	8/7/97	25.2	4	105	2.9	189	189
160	UIR	8/7/97	24.9	4	107	5.2	495	389
169	UIR	8/13/97	17.1	2	88	9.0	444	403
173	UIR	8/13/97	16.7	2	90	5.5	388	388
170	UIR	8/13/97	17.4	3	107	7.2	421	421

Table 3, continued.

Fish ID number	Collection reach	Collection date	Water temperature (°C)	Age	TL (mm)	GSI	# oocytes	# of eggs measured
179	UIR	8/14/97	17.6	2	90	5.3	411	411
180	UIR	8/14/97	17.6	2	99	4.6	419	419
168	UIR	8/15/97	16.8	3	104	7.6	617	413
71	LMR	8/13/96	25.4	3	112	8.1	1,104	406
200	LMR	7/31/97		2	92	12.5	702	469

Number of oocytes, gonadosomatic index, and ovarian development

Gonad mass of gravid females averaged 6.9% (SD = 3.6%) of total body mass and ranged from 1.7 to 13.5% (Table 3). However, fish identification numbers 145, 146, and possibly 144 might have been spent due to their nearly empty and flaccid ovaries. Excluding these fish, total number of oocytes present ranged from 228 to 1,561 (Table 3). Several specimens between 86 and 112 mm TL were collected in mid-August from different reaches and all had greater than 1,000 ova (fish 5, 71, 185), whereas other specimens of similar lengths contained fewer than 500 ova (fish 4, 173, 179) and had possibly released one or more clutches before capture. Consequently, number of oocytes per female was correlated only weakly with total length (r = 0.26, P = 0.28, n = 16). Egg diameter size-frequency histograms were generally unimodal, (Fig. 1). However, two gravid females showed a bimodal distribution in egg diameters (fish 184 and 11, Fig. 1).

DISCUSSION

Roff (1981) recommended using the lowest age or size at which one-half of a cohort reproduces as the definition of age or size at maturity for a population. Based on these criteria, reproductive maturity of sicklefin chub in the Missouri River tentatively occurs at age 3 and for fish exceeding 90 mm TL.

No spent female sicklefin chubs were collected in the LMR reach. Few gravid females (21% of total females collected) and low numbers of spent females in our collections might indicate post-spawn mortality. Trautman (1981) noted large numbers of dead, recently spawned individuals of the related silver chub (*M. storeriana*) washed up on the shores of Lake Erie during the spawning season in June and July in Ohio. If confirmed, the larger size at maturity for females of the sicklefin chub in the LMR reach coupled with a potential for post-spawn mortality could represent a population bottleneck in the lower river. Females of the sicklefin chub would need to grow and survive until they reach 90 mm TL to spawn in the lower river, but if substantial numbers of females die following spawning, most females of the sicklefin chub might only live to spawn once in the LMR reach. Alternatively, in upstream reaches, more females might be able to release eggs because smaller-sized females can spawn there. Some of these females might die from post-spawn mortality but some either survive to larger sizes or else similar-sized conspecifics do not reproduce, but instead, survive to spawn the following year. This would explain the wider size range of mature females in the UMR and UIR reaches compared with the LMR reach (Table 2).

Uneven sex ratios can reduce the genetically effective size (N_e) of small populations (Nelson and Soulé 1987, Meffe and Carroll 1997). We found females of the sicklefin chub (54%) to be more common than males (46%), a pattern common

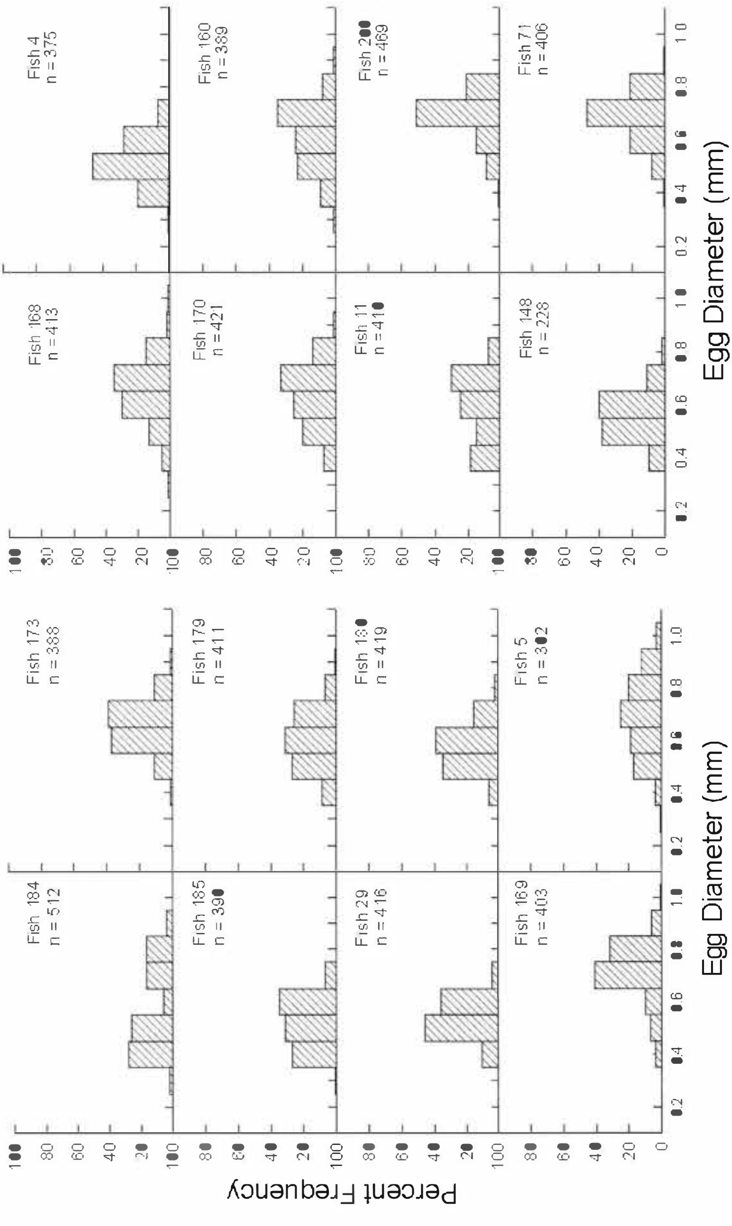

Figure 1. Size-frequency distributions of egg diameters (mm) for gravid females of the sicklefin chub (*Macrhybopsis meeki*) collected from the Missouri and Lower Yellowstone rivers, July to October, 1996 and 1997. Fish identification number and number (n) of eggs listed in each panel.

among many freshwater fishes (Bennett 1970). For example, Gould (1985) reported 51% of flathead chub (*Platygobio gracilis*) collected in selected Montana streams to be female, whereas 49% were male. A genetically adequate sex ratio for a population likely varies by species, but Meffe and Carroll (1997) provide a simple formula for calculating N_e based on the numbers of breeding males and females in a population. We do not know of any published estimates of sex ratios for sicklefin chub and therefore recommend using our ratio as a baseline for future studies. However, we acknowledge that some factors can affect these estimates, such as collecting fish in disproportion to their sex ratio. For example, if our largest numbers were collected in a particular habitat and most males where in some other habitat not well sampled, we might not have collected them in true proportion to their abundance in the entire river. Alternatively, sex can be miss-classified if gonads from immature fish or early seasonal development are used, although we tried to alleviate this by omitting immature fish from our sex ratio determination. Spawning sicklefin chub under controlled conditions and rearing the young might be necessary to help resolve estimates of true sex ratios.

Our results on ovarian development in conjunction with other information supported classifying the sicklefin chub as a group-synchronous or possibly an asynchronous spawner. Two individuals appeared to show group-synchronous ovarian development as indicated by a somewhat bimodal oocyte size-frequency distribution, whereas all other females exhibited a unimodal oocyte size-frequency distribution that would imply synchronous development. However, the wide range of number of oocytes per female for individuals of similar length (e.g., fish identification numbers 185, 173, and 179; Table 3) suggested some individuals might have released one or more clutches before capture. The first appearance of larval sicklefin/sturgeon chub (i.e., it is not presently possible to distinguish these two species at larval stages) in mid June in the LMR (Tibbs and Galat 1997) is consistent with our finding that some or all of the females collected in August already might have released one or more batches of eggs (i.e., multiple spawners), or that different fractions of the population spawn at different times. Others have reported collecting sicklefin/sturgeon chub larvae from mid-June through mid-September in various years in the LMR (Galat et al. 2004, Reeves 2005), which would indicate multiple spawning periods also. Finally, our observations of large diameter oocytes in sicklefin chub ranging from two to four years old indicated that individuals likely spawn more than once in their lifetime, which suggests that the species is iteroparous as are most cyprinids (Helfman et al. 1997). The bimodal oocyte size-frequency distribution in two fish, seasonal lateness of our collections, variable number of oocytes present per female, and large oocyte diameters in many females (Fig. 1, Table 3), coupled with a 3-month period when larval sicklefin/sturgeon chub have been collected by others argues against the species having synchronous ovarian development and for sicklefin chub exhibiting group-synchronous or asynchronous ovarian development. If so, the maximum number of oocytes we recorded (1,561) would be an underestimate of fecundity if individual sicklefin chub are multiple spawners and this female had released eggs previously. This is why we reported numbers of oocytes recorded per female, rather than referring to it as fecundity. Fecundity of the closely related sturgeon chub (*Macrhybopsis gelida*) was reported to range from 2,000 to approximately 5,300 immature and mature oocytes, but was based on only eight fish (Stewart 1981, Werdon 1992).

Group-synchronous or asynchronous ovarian development indicates that the species can spawn over a protracted spawning period, which is consistent with other fishes inhabiting highly variable environments, such as the Missouri River. Fishes with a limited spawning season, based on a narrow range of environmental cues, might risk loss of an entire year class if those proximate spawning cues are not realized in a given year. Even if a species successfully spawns, subsequent harsh environmental conditions, such as flooding, might kill all newly spawned eggs or larvae (Harvey 1987). Thus, in highly variable environments the most successful species might be those exhibiting protracted spawning seasons to ensure some individuals are able to survive sporadic harsh conditions (Matthews 1998). Numerous short-lived fishes inhabiting the variable streams and rivers of the Great Plains Region exhibit protracted spawning seasons (Starrett 1950, Fausch and Bestgen 1997, Dodds et al. 2004). Therefore, not surprisingly the sicklefin chub appears to have a similar reproductive strategy.

In summary, our results for sicklefin chub collected throughout most of the length of the Missouri River indicated that at least some individuals mature at age 2, but most mature at age 3. Females can produce over 1,000 oocytes that might compose more than 10% of their total body mass. Large differences in numbers of oocytes among similar sized individuals, the presence of bimodal egg size frequency peaks in some individuals, and the long period when larvae have been reported in the lower Missouri River lead us to hypothesize that the species is a protracted spawner and perhaps some individuals might be multiple spawners. These results are preliminary and should therefore not be over interpreted. They need to be more rigorously evaluated by collecting larger sample sizes of females of the sicklefin chub earlier and later in the year and conducting more detailed histological analyses of ovarian development. Laboratory studies, where spawning is induced (e.g., Platania and Altenbach 1998), can help determine their spawning mode, reproductive behavior, and egg type (e.g., demersal vs. pelagic). Such fundamental information on reproductive development and strategies is required for successful management of this and other imperiled small-bodied, big river fishes.

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Christmas Bird Counts for North Dakota 2005

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Weather conditions in North Dakota during the 2005 Christmas Bird Count period typically were varied. After a relatively mild fall season the first weekend of the count period was very cold. It was followed with average to above average conditions for the remainder of the period. Temperatures ranged from a low of -14°F to a high of 44°F. Snow cover was light with only two areas reporting significant drifts and wind was generally from the west or northwest and was mostly light but with two areas reporting velocity as high as 25 mph.

Twenty areas were included in the North Dakota Christmas Bird Counts. These are shown in Fig. 1. One area that had been included during the previous four years was cancelled due to extreme icy conditions and could not be rescheduled.

There were 216 observers in the field and 41 additional participants counting the birds, which visited their feeders. The field observers were out for about 522.25 hours, 109.75 on foot and 412.5 in cars. Feeder watchers added 97.5 hours to the total. The field observers covered 121.2 miles on foot and 5648.7 miles in vehicles. Some additional effort was spent in six of the areas where 14.5 hours and 123 miles were devoted to "owling".

There were 99 species and one additional race of birds found on the 20 counts. Of this total the downy woodpecker was the only species seen in each of the 20 areas and there were 21 species represented by only one individual.

The count at Mayville-Portland set a new high number for its count total and both Minot and Bismarck-Mandan tied their previous high counts. One new species was added to the North Dakota Christmas Bird Count list when a red-shouldered hawk was found during the Upper Souris NWR count. This brings the North Dakota state total to 166 species.

New species also were added to several local area lists. In addition to the red-shouldered hawk, the Upper Souris counters added the American crow and the Eurasian collared-dove. The Eurasian collared-dove also was added to the list at Hazen and at Lake Ilo NWR. Grand Forks added the hermit thrush and golden

NORTH DAKOTA CHRISTMAS BIRD COUNTS 2005

Species	Medora 12/17/05	North Unit T.R.N.P. 12/22/05	Dickinson 01/02/06	Lake Ilo NWR 12/19/05	Des Lacs NWR 01/04/06	Upper Souris NWR 12/23/05	Hazen 12/22/05	Garrison Dam 12/16/05	Minot 12/18/05	Bismarck-Mandan 12/18/05	J. Clark Salyer NWR 12/22/05	Long Lake NWR 12/15/05	Arrowood NWR 12/14/05	Jamestown 12/16/05	Valley City 12/19/05	Icelandic State Park 12/20/05	Tewaukon NWR 12/20/05	Mayville Portland 12/17/05	Grand Forks E Grand Fks 12/18/05	Fargo Moorhead 12/17/05	Number of areas seen	Number of Individuals
Snow Goose										1											1	1
Cackling Goose								5		401										2	3	408
Canada Goose								11280	450	6420			CW		2					870	5	19022
Wood Duck																			1		1	1
Gadwall									1												1	1
American Wigeon														1							1	1
Mallard								2600	78	322				10	182		12		8	325	8	3537
Northern Pintail										1											1	1
Redhead								1												1	1	2
Ring-necked Duck																				3	1	3
Greater Scaup								2													1	2
Long-tailed Duck								1													1	1
Bufflehead								6													1	6
Common Goldeneye								39	1	20	1									1	5	62
Hooded Merganser								2							4						2	6
Common Merganser								111													1	111
Gray Partridge			4			17	12	14	26			28		26	9				21	11	10	168
Ring-necked Pheasant	8	65	199	44	31	14	178	623	2	246	41	479	102	24	149	1	277		15		18	2497
Sharp-tailed Grouse	35	46			37	113	36	82	97	4	85	340	333	109	37	39		7	22		16	1424
Greater Prairie Chicken																			13		1	13
Wild Turkey	110	13	20		42	256	40	1	172	95			26	38	4	139		38	6	27	16	1027
Great Blue Heron														CW			1				2	1
Bald Eagle	2a, 1i			1a		1a		29		7a, 2i	4			2a	2a, 2i	1a	1a	9a, 2i	5	1	13	72
Northern Harrier																	1				1	1
Sharp-shinned Hawk			CW				CW		1	1		1		1	1			1	5		13	11
Cooper's Hawk										CW				1	CW					2	4	3
Northern Goshawk			1					6	1	2				1		1					6	12
Red-shouldered Hawk						1															1	1
Red-tailed Hawk	7	1							1	4			1						1	1	7	16
Rough-legged Hawk	4	1	5			CW		9		1	2	1	5	2			3	1	CW		13	34
Golden Eagle	9			1a	2								1						CW		5	14
Accipiter sp.							2														1	2
American Kestrel								1		2									CW	1	4	4
Merlin			1						1	CW		1					1		2	2	7	8
Gyrfalcon			1					2													2	3
Prairie Falcon			1		1			1						1							4	4
Herring Gull								118													1	118
Thayer's Gull								1													1	1
Glaucous Gull								4													1	1
Rock Pigeon		29	9	45	64	101	68	55	517	100	15	24	21	107	336	284	46	142	1031	794	19	3788
Eurasian Collared-Dove			2	1		3			1					4				3			6	14
Mourning Dove			2				1		1	1				2	CW			1	3	1	9	12
Eastern Screech-Owl								2	1	2				CW					3		5	8
Great Horned Owl	1		2	1		7	1	6	3	2	3	11	1	4	4	1	2	1	4	5	18	59
Snowy Owl		1			1	1		1				1	1		1				1		8	8
Short-eared Owl									1		2	1									3	4
Northern Saw-whet Owl						1															1	1
Belted Kingfisher								1		1											2	2
Red-headed Woodpecker																1					1	1
Red-bellied Woodpecker							1											1		2	3	4
Downy Woodpecker	2	5	5	1	3	11	5	12	25	31	3	4	2	23	8	12	3	17	37	19	20	228

NORTH DAKOTA CHRISTMAS BIRD COUNTS 2005

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Hairy Woodpecker	3	3	3		3	8	3	11	14	16	2		1	5	5	13	1	8	19	23	18	140
Northern Flicker (y-s)	1	1	4				1	1	7	21		1							1		9	42
Pileated Woodpecker															1	3		2	2	12	5	20
Northern Shrike	1	2	2		2	9	2	4	5	2	2	3	1	2		1	1	1	1		17	41
Blue Jay			11	14	1	13	15	14	**47**	22	1	11	7	62	19	50	2	41	21	21	18	372
Black-billed Magpie	12	3			24	13	8	9	6	6	4	5				21		8	8		13	127
American Crow	5		26		9	**7**			4	58		3	3	337	46	16		61	179	386	14	1140
Common Raven					1											6					2	7
Horned Lark			596	1	28	275	101	286	300	59		920	1	329	1		51	7	55	1	16	3011
Black-capped Chickadee	50	20	19		41	40	17	34	171	116	44	1	6	54	34	152	6	35	121	162	19	1123
Red-breasted Nuthatch			6			2	2		9	13					3	3		5	6	1	10	50
White-breasted Nuthatch	9	1	8		4	6	8	4	47	13	2			6	8	59		21	36	84	16	316
Brown Creeper									1	1							1		1	5	5	9
Golden-crowned Kinglet									17											4	2	21
Eastern Bluebird										4											1	4
Townsend's Solitaire	5	7						1		7		2									5	22
Hermit Thrush																			**1**		1	1
American Robin	200	338	5			CW	2		CW	**918**	4	4		1				1	29	8	11	1510
Varied Thrush											1										1	1
Northern Mockingbird										1											1	1
Brown Thrasher									**1**					CW							2	1
European Starling			**72**		6	37	36	11	61	424		49		280	176	22	28	244	90	4714	15	6295
Bohemian Waxwing	23	40			20	80		90			95					**86**		**100**	14	41	10	569
Cedar Waxwing	16		4		31		40	56	19	77	5	32		239	12			108	53	9	14	700
American Tree Sparrow	37			CW	1	27		35		3	8	17		34			6	1	8	2	13	170
Chipping Sparrow														CW		**1**					2	1
Fox Sparrow										**1**											1	1
Song Sparrow												3	1								1	4
sparrow, sp.												1									1	1
White-throated Sparrow									1										10	1	3	12
Harris's Sparrow	1		1			2		2		3				1						2	7	12
Dark-eyed (Oregon) Junco										7									2		2	9
Dark-eyed (Sl-col) Junco							10	15		92	20					12	22		136		8	315
Dark-eyed Junco (form?)	10		**52**		20	21			**158**			6	4	55	16			191		140	11	673
Lapland Longspur			19		1	8		1834	1360	55		321		296				307	220	27	11	4248
Snow Bunting	4					1	CW	19	60	4		17	101	335	273	100	47	**1877**	1066	377	15	4281
Northern Cardinal															1				**5**	1	3	7
Red-winged Blackbird										7				13			12		1	1	5	34
Western Meadowlark																	1		CW		2	1
Yellow-headed Blackbird											**1**										1	1
Rusty Blackbird										2		1		54							3	57
Brewer's Blackbird												8									1	8
Common Grackle			1				CW			4				17			5	2	1		7	30
Purple Finch			1				CW		4	3	2			CW	1	1		2	1		10	22
House Finch			18		17		35	20	252	96				608				19	248	74	10	1387
Red Crossbill										2											1	2
White-winged Crossbill														2							1	2
Common Redpoll	1							9							10	6			16		5	42
Pine Siskin			1	CW	50	20	8	50	152	8				30		49		2	16	6	13	396
American Goldfinch	104		7	4	239	37	23	**472**	54	114	23	118	CW	178	14	189	15	154	86	24	19	1855
Evening Grosbeak																2					1	2
House Sparrow	1		95	54	340	274	141	320	222	480	9	187	199	948	678	306	184	376	1247	1044	19	7090

NORTH DAKOTA CHRISTMAS BIRD COUNTS 2005

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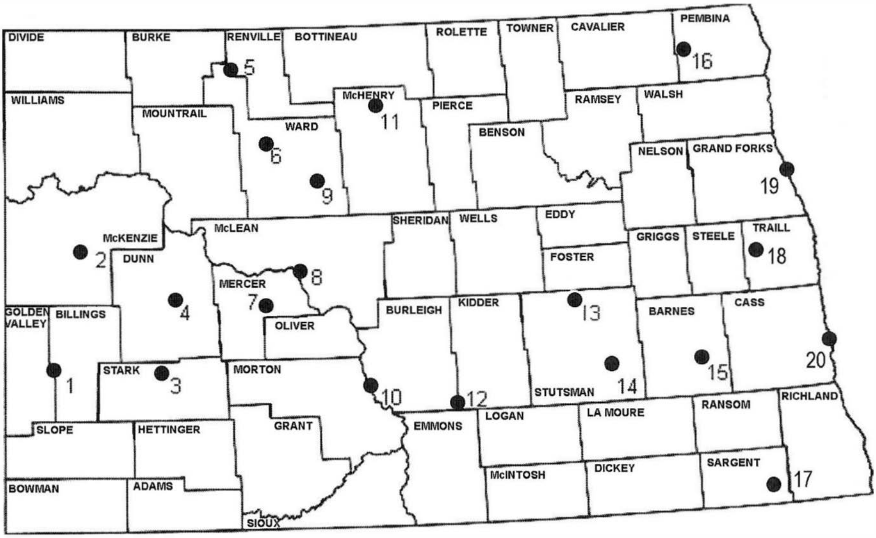
Total Species	27	17	34	11	27	31	30	51	43	53+1	25	31	20	40	30	30	25	35	48	44	99+1
Total Individuals	658	596	1201	167	1021	1403	841	18286	4354	10307	381	2398	821	4240	2039	1536	729	3795	4885	9238	68918
+ CW	0	0	1	2	0	2	4	0	1	2	0	0	2	4	2	0	0	0	4	0	
Observers, field	9	3	3	10	4	16	10	8	7	11	6	13	32	15	13	8	6	6	24	12	216
Hours afoot	5	8.5	1.25	0.5	4	5.25	4	9	4.5	9.5	4	10	0	6.75	1	2	0.5	1.75	9.75	22.5	109.75
Hours by car	21.25	11	11	10	16	19.5	10.5	26	18	28	13	24	17.75	40.25	20	23	1.5	23.75	49	29	412.5
Total hours	26.25	19.5	12.25	10.5	20	24.75	14.5	35	22.5	37.5	17	34	17.75	47	21	25	2	25.5	58.75	51.5	522.25
Miles afoot	9	8	1.25	1	4	5	6.25	11.5	5	9	2.7	19.5	0	11	3.25	2	1	1.5	7.75	12.5	121.2
Miles by car	255	181	180	142.2	235	302	131	433	280	428	167	320	312	461.5	238	215	130	325	757	156	5648.7
Total miles	264	189	181.25	143.2	239	307	137.25	444.5	285	437	169.7	339.5	312	472.5	241.25	217	131	326.5	764.75	168.5	5769.9
Owling, hours	0	0	0	0	0	5	0	0.5	2.25	2.5	0	0	0	0	0	0	0	0	4.25	1	14.5
Owling, miles	0	0	0	0	0	1	0	9	25	25	0	0	0	0	0	0	0	0	63	1	123
Feeder watchers, no.	2	0	8	3	0	1	12	0	12	5	0	0	0	0	5	12	0	10	9	1	41
Feeder watchers, hours	6	0	3.5	1.5	0	0.25	14	0	23.75	10	0	0	0	0	8.5	11	0	4	14	1	97.5
Weather:																					
Wind	W 10-15	SW 5-10	SE 5-10	NW 0-15	C	NW 5-20	NW 0-10	NW 15-25	W 5-10	W 6-8	C - W10	NW18	SW11-16	NW10-25	SW2-8	NW0-10	W3-7	NW10-15	W4-12	C - N20	
Temp. Low - Hi	-9° - 2°	13° - 42°	26° - 29°	3° - 19°	15° - 27°	35° - 44°	32° - 36°	6° - 10°	-11° - 11°	-8° - 8°	22° - 37°	16° - 20°	21° - 29°	9° - 12°	7° - 18°	14° - 26°	19° - 24°	4° - 7°	-14° - 0°	5° - 14°	-14° - 44°
Snow depth	3"-5"	1"	2-4"	2-3"	1"	0-2"	1-3"	0-1"	0-4"	2-24"	2"	0-2"	0	5"-3'	1-4"	8-15"	5-36"	3"	4"	12"-3'	0 - 3'

Note: **Bold** face indicates new species or unusually high numbers



1. Medora
2. North Unit, Theodore Roosevelt N. P.
3. Dickinson
4. Lake Ilo NWR
5. Des Lacs NWR
6. Upper Souris NWR
7. Hazen
8. Garrison Dam
9. Minot
10. Bismarck-Mandan
11. J. Clark Salyer NWR
12. Long Lake NWR
13. Arrowwood NWR
14. Jamestown
15. Valley City
16. Icelandic State Park
17. Tewaukon NWR
18. Mayville-Portland
19. Grand Forks-East Grand Forks
20. Fargo-Moorhead

Figure 1. Location of count areas

eagle and Bismarck-Mandan added the belted kingfisher. Minot added the gadwall and Jamestown added the American wigeon, while Tewaukon NWR added the merlin and a great blue heron, which was seen during count week. Counters at Mayville-Portland added the sharp-tailed grouse and red-bellied woodpecker, and those at Arrowwood NWR found a song sparrow. Fargo-Moorhead added the ring-necked duck and J. Clark Salyer NWR added a varied thrush.

While the total number of birds was about average for the North Dakota Christmas Bird Counts, many specific areas had unusually high counts of certain species. There were 918 individuals of the American robin found on the Bismarck-Mandan count. This was more than three times as many as were ever seen there before. These, along with high counts of American robin at Medora and the North Unit of Theodore Roosevelt National Park gave a total about 30% higher than ever before on all North Dakota Christmas Bird Counts. Grand Forks had five individuals of the Northern cardinal, which is the most ever reported from any specific North Dakota Christmas Bird Count. They also had 10 individuals of the white-throated sparrow, which was the most ever reported from a single area. At Fargo-Moorhead the high count of 4,714 individuals of the European starling made up about three quarters of the state total count of the European starling.

The American goldfinch was found in new high numbers at both Garrison Dam and Mayville-Portland and the North Dakota total was the highest since 1982, the year the highest count on record was made. The Bohemian waxwing was found in high numbers at Icelandic State Park and Mayville-Portland, and the North Dakota total was the highest since 1992. Eight individuals of the Brewer's blackbird at Long Lake NWR were the most seen on any counts since 1997.

The Eurasian collared-dove, which first appeared on a North Dakota Christmas Bird Count in 1999 when one bird was seen in each of two areas, has extended its range and abundance gradually. In 2005 it was found in six areas with a total of 14 birds. Mayville-Portland had a high count of 1,877 individuals of snow bunting. This species frequently appears in large numbers in the Red River Valley, but this was the highest count for any specific area this year.

The gyrfalcon is a seldom seen visitor from the north and two were seen on the count at Garrison Dam. Some other sightings of special interest were a fox sparrow, four individuals of the eastern bluebird, and a northern mockingbird at Bismarck-Mandan. Grand Forks had wood duck and wild turkey for the second time. Minot had a red-tailed hawk at the same spot for the third year in a row, and a brown thrasher.

The number of downy woodpecker was the lowest since 1996, but it was still the only species reported from all 20 count locations. Black-capped chickadee has often been seen in all reporting areas, but this year they were found in only 19 and the total number was the lowest since 1979, a year when counts were made in only 14 areas. American crow was found in 14 areas, but its total numbers were the lowest since 1997. Common redpoll followed its usual cycle and this year it was found in only five areas with a total of 42 individuals. Evening grosbeak was seen again this year after being absent for two years, but only two individuals were found. The number of house sparrow was the lowest ever reported on North Dakota Christmas Bird Counts.

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NOTES

FIRST RECORD OF HAIRY WOODRUSH FROM SOUTH DAKOTA -- Hairy woodrush (*Luzula acuminata* (Juncaceae)), a native perennial graminoid, has recently been recorded for the first time from South Dakota. I first discovered hairy woodrush (var. *acuminata*) in western South Dakota, Lawrence County, during botanical surveys of the Black Hills in 2000. Hairy woodrush has been reported previously from Alberta, east to Nova Scotia and Prince Edward Island, and south and west in the United States to as far as Georgia, Arkansas, Missouri, Iowa, and Minnesota where it occurs in open woods, meadows, and hillsides, from 0 to 500 m (Flora of North America Editorial Committee 2003). This species has not been reported from South Dakota (D. Ode, South Dakota Department of Game, Fish and Parks, and G. Larson, South Dakota State University, personal communication). Neither Dorn (1977), Larson and Johnson (1999), Van Bruggen (1996), nor the Great Plains Flora Association (1986) include hairy woodrush in the flora of South Dakota or the Great Plains. Since 2000, its distribution has been further expanded to include nine distinct geographical locations, all within Lawrence County. Numbers of individuals at each location range from a dozen to several thousand. My report extended the range of hairy woodrush and represented the farthest western-known occurrence of this species in the United States.

Occurrences of hairy woodrush in Lawrence County, South Dakota, were in a 21 by 15 km area, approximately 10 km south of Deadwood, South Dakota. In the Black Hills this species usually occurs in the White Spruce (*Picea glauca*) Alluvial Black Hills Forest type and less frequently in the Paper Birch (*Betula papyrifera*)/ Hazel (*Corylus cornuta*) Forest type described in Marriott and Faber-Langendoen (2000). Occurrences were in mesic habitats of partial to closed canopies at elevations ranging from 1,353 to 1,829 m and on slopes from 0 to 50%. All occurrences were in dry or perennial drainage bottoms or on northwest to northeast-facing low slopes adjacent to drainages where moist cool conditions persist. Associated species included quaking aspen (*Populus tremuloides*), ironwood (*Ostrya virginiana*), common juniper (*Juniperus communis*), twinflower (*Linnaea borealis*), Oregon grape (*Mahonia repens*), bunchberry dogwood (*Cornus canadensis*), wild lily-of-the-valley (*Maianthemum canadense*), wild sarsaparilla (*Aralia nudicaulis*), rough-leaved ricegrass (*Oryzopsis asperifolia*), and various sedges (*Carex* spp.). Sites occurred within the Central Core of the Black Hills, which is composed of Precambrian granite and metamorphic rock (Larson and Johnson 1999). Sites often had a high cover of mosses and lichens.

Hairy woodrush has solitary flowers (early May) and a cymose inflorescence, characteristics that differ from other *Luzula* species found in the northern Black Hills, such as common woodrush (*Luzula multiflora*) and smallflowered woodrush

(*Luzula parviflora*). Leaves of hairy woodrush often turn a reddish color in the fall, which facilitates the ability to locate this plant. Additionally, the long soft cobwebby hairs along the leaf margins are a good diagnostic characteristic of the genus *Luzula*. When early spring inflorescences are lacking and without the reddish color in the fall, this plant blends in with other wide-leaved graminoids and is easily overlooked. Presumably, hairy woodrush is distributed more widely in the northern Black Hills than initially thought.

Voucher specimens were deposited in the Rocky Mountain Herbarium (which includes the National Herbarium of the United States Forest Service); University of Wyoming at Laramie, Wyoming; and the Charles A. Taylor Herbarium at South Dakota State University, Brookings, South Dakota.--*Katherine A. Zacharkevics, United States Forest Service, Black Hills National Forest, Spearfish, SD, 57783. E-mail address: kzacharkevics@fs.fed.us*

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Book Reviews

RAPTORS AT YOUR FINGERTIPS

Raptors in Your Pocket: A Guide to Great Plains Birds of Prey. Dana Gardner. 2006. University of Iowa Press. 16 pages (laminated). $9.95.

This new raptor identification resource is a valuable guide for anyone interested in birds of prey. It is easy and useful to have such a guide at your fingertips, to fold it out and concentrate on the differences and similarities of birds of prey (and vultures). The quality lamination will help to protect and preserve the 8-panel, map-folded, brochure-sized pocket publication. It features color illustrations of 26 species with a number of views of each species, perched and in flight, including 108 identification illustrations.

While this pocket guide is a great identification guide to the raptors that can be found in the Great Plains, it is not perfect. I would offer the following criticisms and suggestions to improve this useful publication:

One species that seems a bit out of order as a “Great Plains raptor” is the Swallow-tailed Kite, which is limited to a few southeastern states during the nesting season. The White-tailed Hawk would seem to be a much better choice to include in a Great Plains guide, since they are common in southern Texas.

The coverage of species that may be encountered in the Great Plains is amply expansive; however, the corresponding descriptions of the range of each species are at least troubling. It appears these descriptions are for the state of Iowa, rather than for the Great Plains as a whole. For instance, the Swainson’s Hawk is described as a “Common summer visitor,” but in reality this species is a widespread nesting species across a vast portion of the Great Plains. On the back panel, the text refers to the Great Plains as the region from northern Minnesota to northern Texas. Geez, not in my geography class. If that is indeed the area of interest, perhaps a better title for this guide would be: *Raptors of the Extreme Eastern Edge of the Great Plains*. After all, there is a lot of land between the Red River and the Rocky Mountains that is considered the true Great Plains region of North America.

Some species would have benefitted from an illustration that shows the back (dorsal) side of the bird in flight. The Ferruginous Hawk illustrations fail to show one of its best identifying characteristics—the white wing patches that can be seen on the dorsal side of an adult in flight (and below if you’re astute). Similarly, because there is no dorsal view of the Swainson’s Hawk in flight, the white rump, which can be helpful in identification of this *Buteo*, is not illustrated or pointed out by the author.

Regarding coloration, an adult Zone-tailed Hawk should have white bands on the tail rather than the gray bands illustrated in this guide, and the Ferruginous Hawk is colored considerably darker orange than almost all adults of this species. Further, the feet of the perched Osprey appear disproportionately large. There also is a design *faux paux*: the small image of the Black Vulture in flight on the front cover panel of this guide has been positioned upside down.

With these improvements, and by changing the term "phase" to "morph," *A Guide to Great Plains Birds of Prey* would serve anyone in the field or at the library, including students and birders—beginners, intermediates and advanced alike—as well as ornithologists.—*Paul M. Konrad, Wildlife Adventures, Kulm, ND 58456.*

FRIENDLY FLORA

Dakota Flora: A Seasonal Sampler. David J. Ode. 2006. South Dakota State Historical Society Press, Pierre, SD. 260 pages. $29.95 (paper).

A tribute to Great Plains plants is laid out in *Dakota Flora: a Seasonal Sampler*, marking a literary and visual bounty for readers of *The Prairie Naturalist.* Do not be misled by a whimsical title. A sampler may be interpreted as a small, piecemeal collection that one puts together for practice. By contrast, David Ode's essays and photographs provide an expansive view of plants as integral to history and outdoor experiences on the Great Plains, in which all plants have stories and terms of residency associated with them.

Each plant profile has a natural history highlight, often linked to scientific inquiry, threads of personal experience, thinly veiled affection for places, and allusion to the seasons, in vignettes that resonate across the Great Plains. The cross-references to traditional plant uses or mythology often have a contemporary connection, e.g., *Psoralea esculenta* is characterized as the key ingredient in South Dakota's best Indian fry bread, while "Tinpsila" is listed as its common name in deference to the older Lakota name, rather than the "Indian breadroot" as more widely used by biologists. This book is a feast as only one who has studied and explored Great Plains landscapes could set before the reader—with brief allusions to hunting adventures, courting season, boyhood memories, and, by inference, hopes and dreams set on the side, that beguile the reader on his or her journeys.

I stumbled over the word "Dakota" in the title as though the author wished to perpetuate the myth that the two states were indiscernible (admittedly sharing many of the same plant species). As I read, I suspected it was used as reference to vast plains that transcend state boundaries, also freeing it up from "North" and "South" prefixes to lead back to the older etymological term for "friend."

I also stumbled over the word "flora" until realizing that the book has no pretense of an exhaustive representation of each plant species occurring in the author's home state of South Dakota. However, the author has deliberately recruited a full cast of characters among the biggest and smallest, plainest and most stunning, native and exotic, pervasive and rarest of the plant species in the flora to highlight the breadth and bounty. A lichen and two mushrooms round out the line-up.

As a botanist, it is tempting to critique the critiques written by non-botanists instead of the book itself. The book jacket, for example, boasts of a book "brimming with information and anecdotes" and also "perfect for home and field." Books about plant species tend to fall into one of three categories: technical publications, non-technical identification guides, or non-technical pretty picture books. Reviewers and the book jacket author seem inordinately eager to point out that it is "not too technical" and might find a place on the coffee table or augmenting a field guide.

Admittedly, its origin is a fixed-length series of popular articles on individual plant species that were published in *Conservation Digest*, of the South Dakota Department of Game, Fish and Parks from 1987 to 2005. In spite of the brevity of each article, the value of this collection goes beyond the three narrow categories of plant books by illustrating that there are many planes of knowing and ways of appreciating plants, a message reinforced by the rich photography. It is a glimpse of botanical intrigue, looking for lessons from Charles Darwin lurking in a puccoon, or malodorous versions of pollination theory in a carrion flower. It is also noteworthy in presenting botanical study as a process, while introducing the reader to past and present figures in that process across South Dakota and beyond. Last and perhaps most important, it is engaging and enjoyable in the same style of delivery as a conversational stroll with a friend.

Essay contents and photograph formats are not standardized, and captions are mostly limited to common names. This unevenness provides elements of surprise on each page. The same low-key approach leaves it to the reader to realize that the riveting landscape photograph of yucca has the South Dakota State Capitol as its backdrop. The varied photographic style includes vivid close-up photography contributions by Jeanne Kilen Ode.

This book lends itself to public libraries and personal libraries alike, and begs to be shared among friends. It is a work of art and science, in text and photography. It is a springboard for considering native plants growing all around, and those which can be grown at home, reminiscent of a series of newspaper articles in *The Jamestown Sun* by Harold Kantrud. The last reason I would recommend buying a book would be to augment cocktail party talk, but the book offers this, too. What wild plant flavors an overseas brew called "Bison Brand Vodka"? What wild plant has been cross-bred to disinfect and deodorize hog manure? What wild plant of prairie potholes can spread from one square yard to an acre in two weeks? What wild plant anchors South Dakota's sweet position as one of the top honey-producing states? ... The answers, and far more, can be found in *Dakota Flora.—Bonnie Heidel, Wyoming Natural Diversity Database, University of Wyoming, Laramie, WY 82071.*

GRASSLANDS OF THE U. S. FOREST SERVICE

The National Grasslands. Francis Moul. 2006. University of Nebraska Press, Lincoln, NE. 153 pages. $19.95 (paper).

The 20 National Grasslands currently administered by the U.S. Forest Service cover more than 3.8 million acres from Oregon and California eastward to eastern North Dakota and northeastern Texas. This volume arose from, and appears to be developed around, a doctoral dissertation in Environmental History at the University of Nebraska. Thus, its core is a three-chapter treatise on the ecological (Dust Bowl) and political backgrounds, grassroots acquisition, and broad-brush restoration and management activities on these predominantly prairie landscapes. Chapter 3 focuses on the New Deal, which led to acquisitions beginning in 1934 as Land Utilization Projects within the newly formed Soil Conservation Service. Chapter 4 focuses on the Farm Credit Administration and Resettlement Administration of 1933 and 1935, respectively, as they purchased lands for grazing leases in Dawes and Sioux counties of Nebraska. Once the projects were transferred to the Forest Service in 1954 to be designated National Grasslands (as "Forest" Districts) in 1960, restoration activities included the Forest Service's retention of Soil Conservation Service practices of managing fragmented parcels within the contiguous, privately owned landscape. Chapter 5 reviews the failure of political attempts to transfer the national grasslands to states for privatizing, and mentions the standard environmental legislative history that mandates contemporary on-the-ground restoration and management of Forest Service lands. Chapter 5 ends with a rather curious account of how one rancher on the Crooked River National Grassland in Oregon provided leadership in developing and implementing a vision for greater grassland productivity and natural resource diversity, seemingly in the absence of a Forest Service role.

In contrast to the rather scholarly writing of the core chapters, the volume leads off with a prelude (not a preface), a popularized overview of the geologic prehistory of the Great Plains, followed by an Introduction that briefly hints at the three text "parts" coming. Part I is the core of the text as described above. Part II is far from the promised "detailed description" of each grassland. Unlike the academically referenced text in Part I, Part II is based upon documented phone conversations with personnel at all grasslands and is accompanied by a sophomoric (Rand McNally style) map of each grassland. The maps plot all-encompassing boundaries that fail to identify real property lines or the level of internal fragmentation within a grassland administrative unit. Better information on any one of the national grasslands can be obtained on the World Wide Web. Part III is offered in the Introduction as an analysis of grassland issues, conclusions, and future alternatives. However, this latter effort is actually titled "Bison instead of cattle." The author points out that there is no legislative mandate to manage the grasslands for grazing and argues for land swapping and acquisition of fragmented parcels with the vision of fenceless horizons grazed by bison not dissimilar from the "Buffalo Commons" idea proposed more than a decade ago. Following is a closing/separate statement published as an "Afterword" that acknowledges the controversial nature of prairie dog management on the Great Plains. Text statements regarding the bison and prairie dog are conversational rather than academic and fail to reference any ecological literature relative to the roles of either bison or prairie dogs vs. cattle. These seeming addenda both come across as environmentalist advocacy.

The volume includes 28 photographs by Georg Jutras. Jutras provides a personal travelogue on his photographic mission to include at least one image from each of the 20 American grasslands plus the Grasslands National Park of Canada. A few of these photographs are fine landscape images of rolling hills of grass, whereas a majority leave the reader wondering what the topic grassland looks like. (The photo of the Caddo National Grassland is of two egrets in a cottonwood tree, for Thunderbasin National Grassland we see two blurry freight trains, and in many images the reader either doesn't see grass or is drawn to the presence of trees.)

Additional inconsistencies will annoy some readers. Obviously, the California, Oregon, and Nevada grasslands do not have a Great Plains geological and ecological history, and the political foundation of the Grassland National Park of Canada (not an "American" grassland per the subtitle) is only briefly covered in its site account within Part II. Current conservation vision, fiscal support, and staffing of the grasslands are not addressed, nor does the reader find any discussion as to whether the grasslands should be removed from Forest Service administration, a question that routinely surfaces in political dialogues. Neither the robust literature on prairie ecology and conservation nor prairie-dog conservation of the last decade is referenced; likewise also, the bison/cattle foraging literature of the last two decades is ignored. The reader is given personal perspectives in Part III on grassland issues, conclusions, and future alternatives, which will be read by many as politically naive.

Native prairies (and the Forest Service's National Grasslands remnants) deserve enhanced public and political awareness and understanding. Without a preface, the envisioned audience for this volume is unclear; and inconsistencies in tightness of focus and level of rigor across topics sadly compromise the presentation. The natural resources profession and American public still await a comprehensive history and contemporary conservation vision for the national grasslands. Likewise, North American prairies still await a spectacular photo essay to enhance public appreciation for the vast, singular beauty of "endless grass-scapes" that once were the awe-inspiring western horizon in settlement history of North America.—*F. L. Knopf, U.S. Department of the Interior (Retired), 713 Boulder Circle, Fort Collins, CO 80524.*

THE COVER AND ITS ARTIST

The pronghorn (*Antilocapra americana*) is an endemic species to North America. It is the only extant species in the Family Antilocapridae. The pronghorn is widely distributed across the Great Plains in grassland habitats. Population densities are highest in Wyoming, but there are fair numbers in the western parts of North Dakota, South Dakota, Nebraska, and Kansas as well as the Rocky Mountain states. Does typically have twins and the mating system is highly variable. The pronghorn is one of the fastest land mammals in world. Some authors speculate that its speed is a reflection of a "ghost of predation past" (i.e., predation pressures from swift predators that are now extinct). The pronghorn has a horned sheath that differs from true horns of Bovidae and antlers of Cervidae. The sheath is shed annually and occurs in both sexes.

Melissa Johann is a graduate of Fort Hays State University, Hays, Kansas. She has worked with a wide variety of plants and animals in a number of biology positions in the Great Plains, and did contract work on crab-fishing boats in the Bering Sea, Alaska. Melissa hopes to someday be a full-time illustrator and work to create high-quality biology identification textbooks. More of Melissa's artwork can be seen on *The Prairie Naturalist* web site.

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