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Amphibians and Reptiles in a Mixed-Grass Prairie in Northwestern North Dakota

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ABSTRACT -- There have been almost no surveys of herpetofauna at 109 km^2 Lostwood National Wildlife Refuge (LNWR) or surrounding counties in northwestern North Dakota, an area possibly undergoing significant environmental change from fossil fuel extraction and use. We used 30 m drift fences to survey amphibian and reptile species in prairie-wetland transition zones at LNWR during mid-May to early-July in 1985 to 1987, and again in 1999 and 2000. We captured only four amphibian and two reptilian species and noted one other reptilian species incidental to our survey. Several species expected to occur in the area were not detected.

Key words: amphibians, biological diversity, Great Plains, mixed-grass prairie, North Dakota, reptiles, wildlife refuges.

Lostwood National Wildlife Refuge (LNWR) in northwestern North Dakota is the most extensive, publicly owned tract of native prairie pothole habitat in the northern Great Plains region. Surprisingly, little is known of reptiles and amphibians in the refuge and surrounding counties and it is unclear how these faunal elements might respond to significant environmental changes in the area.

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Class I air quality must be maintained in the refuge's 2257 ha Wilderness Area (United States Fish and Wildlife Service 1998). Although air and water quality data collected at LNWR during the late 1980's and early 1990's did not indicate elevated levels of pollutants associated with the fossil fuel industry (Smith et al. 1999), unusually high levels of methylmercury were documented recently in refuge wetlands (K. Johnson, United States Fish and Wildlife Service, Bismarck, North Dakota, and D. Krabbenhoft, United States Geological Survey, Middleton, Wisconsin, unpublished data). Here we report relative abundances of amphibian and reptilian species in prairie-wetland transition areas characteristic of LNWR. Our goal was simply to help substantiate baseline refuge resources in the face of possible broad ecological changes and to improve on the limited knowledge of faunal distributions in northwestern North Dakota.

STUDY AREA and METHODS

LNWR covers 109 km^2 of rolling to hilly moraine in Burke and Mountrail counties, North Dakota (48°37' N; 102°27' W). Wetlands, covering 20% of the refuge, are numerous ($\bar{x}$ = 40 basins/km^2); they vary markedly in area, hydroperiod, and salinity. Uplands are mostly native needlegrass-wheatgrass association (*Stipa-Agropyron*; Coupland 1950), although one-fourth of uplands are composed of previously cropped fields revegetated with native and introduced species of plants. Area climate is semi-arid, with nearly one-half of the mean annual precipitation of 42 cm falling as rain in May to July. Annual precipitation was average to below average (46, 45, and 31 cm) during our 1985 to 1987 sampling period but was above average (73 and 70 cm) during 1999 to 2000 sampling (United States Fish and Wildlife Service, unpublished data).

We used drift fences (Gibbons and Semlitsch 1981, Vogt and Hine 1982) to survey reptiles and amphibians. In spring 1985, we established five drift fence sites in representative mesic prairie communities, 0.8 to 1.4 km apart across the center of LNWR and 0.1 to 3.3 km south of the refuge's Wilderness Area. Each of the five sites included two 30 m drift fences, 50 to 80 m apart. We installed each drift fence parallel to and between borders of xeric prairie and a nearby (2 to 25 m away) seasonal or semipermanent wetland. Each drift fence consisted of partly buried, 0.6 m tall aluminum flashing with a 0.3 x 0.3 x 0.8 m long, 0.6 cm mesh funnel trap in the center and a total of eight 20 l pitfall traps with funnel rims. Pitfalls were paired on either side of the fence, at both fence ends and midway between fence ends and the funnel trap (modification of Fig. 17b in Vogt and Hine [1982]). Drift fences were checked every 2 to 3 days and operated continuously from mid-May through early-July. We maintained 3 to 6 cm of water in pitfall traps to keep amphibians alive. Specimens were identified and released 2 to 3 m on the side of the fence opposite that where captured.

For each species and sampling year, we calculated relative abundance as the mean number of individuals captured/100 drift fence days, where one drift fence day represented 15 m of drift fence open for 24 hr (Vogt and Hine 1982). We broadly classified species relative abundance based on total of years of occurrence and mean captures/100 drift fence days/sampling period: (1) common - all years, mean number of individuals captured/period greater than 5.0; (2) uncommon - all years in at least one sampling period, mean number captured/period 0.2 to 5.0.

RESULTS and DISCUSSION

We recorded only four amphibian species and two reptilian species (Table 1). Variable annual occurrence and abundance of western chorus frog (*Pseudacris triseriata*) and tiger salamander (*Ambystoma tigrinum*) in drift fences appeared related mainly to water conditions in local wetlands; relatively minor variation in weather and precipitation strongly influence the population ecology of herpetofauna (e.g., Semlitsch 1985). Northern leopard frog (*Rana pipiens*) was uncommon during the first sampling period but was not detected despite greater precipitation levels during the second sampling period. Western chorus frog was the most abundant amphibian, due in part to a high number of captures (n = 639) during 3 days in late June 1999, which likely represented the emergence of recently metamorphosed juveniles. Tiger salamander was caught each year and was particularly common in 1987. The initial appearance of the wood frog (*R. sylvatica*) in 1999 and 2000 probably reflected local distributional change. The first record of wood frog in western North Dakota occurred about 17 km northeast of LNWR in 1984, followed by records on the northeastern boundary of LNWR in 1986, then about 3 km further south and west of the refuge in 1987 (Murphy 1987). By the mid-1990's, the species could be heard calling from seasonal and semi-permanent wetlands over the entire refuge on warm April evenings (Robert K. Murphy, personal observation).

Plains garter snake (*Thamnophis radix*) was uncommon throughout the study, whereas smooth greensnake (*Opheodrys vernalis*) was rare, captured only in 1986. Perhaps smooth greensnake was represented poorly because some individuals might have escaped through the relatively large, 0.6 x 0.6 cm diameter mesh of our funnel traps. The species is observed infrequently in the area (Robert K. Murphy, personal observation). Painted turtle (*Chrysemys picta*) was not detected in drift fences but a specimen was recorded incidental to our study near the center of LNWR in 1987 (Robert K. Murphy and United States Fish and Wildlife Service, Kenmare, North Dakota, unpublished data).

Several reptilian and amphibian species were expected on the basis of distributional range maps but were not detected. We did not detect red-sided garter snake (*T. sirtalis*; nearest records 25 km east, and 25 km southwest of LNWR),

Table 1. Relative abundances of amphibian and reptilian species in areas of transition between upland mixed-grass prairie and seasonal or semi-permanent wetland at Lostwood National Wildlife Refuge, northwestern North Dakota, based on the mean capture rate among five drift fence sampling sites during mid-May to early-July. Total numbers of individuals captured are in parentheses.

	Mean ± SE no. individuals captured/100 drift fence days[a]						
Species	1985	1986	1987	$\bar{x}$	1999	2000	$\bar{x}$
Tiger salamander (*Ambystoma tigrinum*)	0.5 ± 0.4 (5)	0.9 ± 0.4 (9)	5.2 ± 2.3 (52)	2.2	0.8 ± 0.4 (7)	0.8 ± 0.3 (7)	0.8
Western chorus frog (*Pseudacris triseriata*)	1.0 ± 0.4 (10)	3.9 ± 0.8 (39)	7.7 ± 3.4 (77)	4.2	79.0 ± 43.7 (711)	2.4 ± 0.9 (21)	40.7
Northern leopard frog (*Rana pipens*)	8.0 ± 6.0 (80)	0.9 ± 0.4 (9)	0.3 ± 0.2 (3)	3.1	0	0	0
Wood frog (*R. sylvatica*)	0	0	0	0	0.3 ± 0.1 (3)	0.2 ± 0.1 (2)	0.3
Plains gartersnake (*Thamnophis radix*)	0.3 ± 0.2 (3)	1.4 ± 0.7 (14)	1.5 ± 0.2 (15)	1.1	0.2 ± 0.1 (2)	2.1 ± 0.4 (18)	1.2
Smooth greensnake (*Opheodrys vernalis*)	0	0.3 ± 0.2 (3)	0	0.1	0	0	0
n sampling days	50	50	50		45	43	
n 15 m drift fence days	1000	1000	1000		900	860	

[a]Abundance for each species was calculated at each drift fence site annually as the total number of individuals captured/100 drift fence days. One drift fence day = 15 m of drift fence open for 24 hr (Vogt and Hine 1982). Thus, two 30 m drift fences at each of the five sites yielded four 15 m drift fence days every 24 hr.

western hog-nosed snake (*Heterodon nasicus*; nearest record 100 km southeast of LNWR), or any of three *Bufo* spp. (nearest records 100 km southeast of LNWR; Wheeler and Wheeler 1966). There have been no incidental observations of any of these five species at LNWR despite multiple biological investigations in the 1980's and 1990's. We are unsure why, except that sandy soils needed by the western hog-nosed snake and Great Plains toad (*Bufo cognatus*) are unavailable at LNWR, and red-sided garter snake tends to be associated with woodland more than prairie at northern latitudes (Russell and Bauer 1993).

Our baseline data suggest a relatively limited diversity of reptilian and amphibian species occurred in mixed-grass prairie characteristic of LNWR during a 3 year sampling period (1985 to 1987) that overlapped years of acceptable Class I air quality standards at the refuge. We failed to detect one of these species, the northern leopard frog, during a subsequent sampling period (1999 to 2000). This change was not readily explained by differences in precipitation levels between sampling periods.

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Morphometrics of Six Turtle Species from South Dakota

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ABSTRACT -- During 2002 and 2003, morphometric measurements were recorded for 755 turtles representing six species in South Dakota. Turtles were captured in a wide variety of wetland habitats across the entire state. With few exceptions, morphometric measurements for South Dakota were near or within the range of measurements reported for all six species from studies in nearby states or provinces. We recommend that morphometric measurements be taken on turtles in future turtle studies and particularly for the less common and rare species.

Key words: body condition, morphometrics, South Dakota, turtles.

Relatively little information has been published on South Dakota turtles compared to neighboring Midwestern states (Minnesota: Oldfield and Moriarty 1994; Wyoming: Baxter and Stone 1985; North Dakota: Wheeler and Wheeler 1966, Hoberg and Gause 1992; Iowa: Christiansen and Bailey 1997). The only extensive research on turtles in South Dakota was done by R. L. Timken (1968a) for his dissertation at the University of South Dakota in Vermillion. Species distribution maps were updated by Ballinger et al. (2000), based solely on museum specimen data. Both of these studies indicate that seven species of turtles might occur in South Dakota including the false map turtle (*Graptemys pseudogeographica*), smooth softshell turtle (*Apalone mutica*), spiny softshell turtle (*Apalone spinifera*), western painted turtle (*Chrysemys picta bellii*), snapping turtle (*Chelydra serpentina*), ornate box turtle (*Terrapene ornata ornata*), and

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Blanding's turtle (*Emydoidea blandingii*). The population status of these turtles is monitored by the South Dakota Natural Heritage Program (Ashton and Dowd 1991, Dowd Stukel and Backlund 1997). Except for Timken (1968a), morphometric data for South Dakota turtles were published rarely (Over 1924, 1943; Hammer 1968, 1969; Timken 1968b, Peterson 1974), so our study updated the current knowledge of turtles in South Dakota and the Midwestern United States.

Morphometric data are commonly used to aid in identification of sex as well as age characteristics of turtles. The purpose of our study was to record the standard morphological metrics to determine sex and age characteristics of six turtle species common to South Dakota.

STUDY SITE

We collected turtles from riverine (rivers), palustrine (wetlands), and lacustrine (lakes) habitats in all counties of South Dakota from 2002 to 2003. Riverine sites (n = 286) included channelized sections and backwater areas of streams and rivers, most of which maintained intermittent or perennial flows. Palustrine sites (n = 35) included forested and emergent wetlands that ranged from temporary to semi-permanently flooded water regimes (Cowardin et al. 1979). Lacustrine sites (n = 83) included deepwater habitats characteristic of natural glacial lakes of eastern South Dakota (Stukel 2003) or small impoundments of western South Dakota (Wilson 2002).

MATERIALS and METHODS

Turtles were captured from 20 May to 21 August in 2002 and 12 May to 12 August in 2003 with hoop nets baited with cut pieces of common carp (*Cyprinus carpio*). Each site was trapped for two consecutive nights with one baited hoop net per site. Sites were sampled only once unless the bait was removed by a turtle or a common muskrat (*Ondatra zibethicus*) after which the net was re-baited and re-set for up to two consecutive trap nights.

The protocols used in our study for recording standard morphological metrics followed the standard guidelines for turtle measurements. Measurements were taken of carapace length, plastron length, shell height, carapace width, and mass on all captured specimens. Following the methods of previous South Dakota studies (Hammer 1968), the carapace length was measured as a curved length, whereas all other measurements were straight line measurements.

Carapace length, plastron length, shell height, and carapace width were all measured to the nearest 0.1 cm with a metric steel tape measure. Body wet mass was determined to the nearest 0.1 g by using an Ohaus compact scale that has a 2 kg capacity or a Pesola spring scale with a 5 kg or 20 kg capacity. The accuracy of scales can be reduced due to the effects of wind, extreme temperatures and movements of the turtle (Jennings 1989), so turtles were weighed inside the truck or under bridges to avoid the effects of wind and temperature.

Turtles were sexed by standard methods (Ernst et al. 1994). Juveniles were not separated by sex because turtles are not sexually dimorphic prior to sexual maturity.

RESULTS

Male western painted, spiny softshell, smooth softshell, and false map turtles averaged smaller across all measurements than females of the respective species (Tables 1-4). In contrast, female snapping turtles averaged smaller than males across all measurements (Table 5). Metrics for only one male ornate box turtle were obtained. This prevented any sex or age comparisons for this species (Table 6). For curved carapace length morphometrics data, see Appendices A, B, and C.

DISCUSSION

Western painted, snapping, smooth softshell, spiny softshell, and false map turtles were, on average, similar in size and mass to those previously captured in South Dakota (Hammer 1968, Timken 1968a), Minnesota (Oldfield and Moriarty 1994), Missouri (Johnson 2000), Wyoming (Baxter and Stone 1985), North Dakota (Wheeler and Wheeler 1966, Hoberg and Gause 1992), Iowa (Christiansen and Bailey 1997), and the United States as a whole (Ernst et al. 1994). As in all populations of snapping turtle across the United States, males were, on average, larger than females for all measurements. Similarly, western painted, false map, smooth softshell, and spiny softshell females were, on average, larger than males of the respective species. Substantial size differences can occur between the sexes of false map, spiny softshell, and smooth softshell turtles (Dowd Stukel 1993). Adult female false map turtles can be up to 10 cm longer than adult males. Adult female smooth softshells and spiny softshells are usually 5 to 20 cm longer than adult males (Oldfield and Moriarty 1994).

The average mass for individuals of the snapping turtle was not provided in most turtle reference books or in Timken's (1968a) study. The mass range (4.5-16 kg) of individuals of the snapping turtle captured in South Dakota in 2002 to 2003 was similar to those reported in other states (Minnesota: Oldfield and Moriarty 1994; Missouri: Johnson 2000; Wyoming: Baxter and Stone 1985; North Dakota: Wheeler and Wheeler 1966, Hoberg and Gause 1992; Iowa: Christiansen and Bailey 1997; and United States: Ernst et al. 1994) although our largest specimen, a female,

Table 1. Mean, standard deviation (SD) and minimum-maximum range of straight line measurements of carapace width (cm), plastron length (cm), shell height (cm), and mass (g) for 606 individuals of the western painted turtle captured in South Dakota during 2002 and 2003.

	Age/Sex			
	Adult Male	Adult Female	Juvenile*	Overall
n	322	263	21	606
Carapace Width	13.1	14.7	7.6	13.6
(SD)	(1.8)	(3.0)	(1.5)	(2.8)
Min.-Max.	9.1-17.7	7.0-21.2	2.6-10.0	2.6-21.2
Plastron Length	13.7	15.1	7.3	14.1
(SD)	(2.1)	(3.0)	(1.5)	(2.9)
Min.-Max.	9.0-22.0	8.0-21.1	2.6-9.4	2.6-22.0
Shell Height	4.6	5.3	3.1	4.9
(SD)	(0.8)	(1.4)	(0.5)	(1.2)
Min.-Max.	1.0-6.6	1.5-13.1	2.0-4.0	1.0-13.1
Mass	393.9	558.5	80.8	453.7
(SD)	(161.5)	(285.7)	(24.9)	(245.4)
Min.-Max.	128.0-978.0	82.0-1,405.0	3.2-141.0	3.2-1,405.0

*Individuals not sexually dimorphic.

Table 2. Mean, standard deviation (SD) and minimum-maximum range of straight line measurements of carapace width (cm), plastron length (cm), shell height (cm), and mass (g) for 30 individuals of the spiny softshell turtle captured in South Dakota during 2002 and 2003.

	Age/Sex			
	Adult Male	Adult Female	Juvenile*	Overall
n	12	17	1	30
Carapace Width	23.1	27.2	7.4	24.9
(SD)	(5.5)	(4.6)		(6.2)
Min.-Max.	14.6-29.0	17.4-33.0		7.4-33.0
Plastron Length	19.1	22.6	5.4	21.2
(SD)	(7.0)	(4.5)		(5.8)
Min.-Max.	5.3-27.5	14.5-28.0		5.3-28.0
Shell Height	4.9	5.5	2.0	5.1
(SD)	(1.1)	(1.5)		(1.4)
Min.-Max.	3.5-7.0	3.0-8.5		2.0-8.5
Mass	2,132.3	3,022.9	43.0	2,549.7
(SD)	(1,312.0)	(1,302.6)		(1,421.4)
Min.-Max.	399.0-4,050.0	700.0-4,500.0		43.0-4,500.0

*Individuals not sexually dimorphic.

Table 3. Mean, standard deviation (SD) and minimum-maximum range of straight line measurements of carapace width (cm), plastron length (cm), shell height (cm), and mass (g) for 12 individuals of the smooth softshell turtle captured in South Dakota during 2002 and 2003.

	Age/Sex			
	Adult Male	Adult Female	Juvenile*	Overall
n	9	3	0	12
Carapace Width	22.6	23.0		22.7
(SD)	(1.6)	(0.6)	—	(1.1)
Min.-Max.	21.0-25.1	22.4-23.5		21.0-25.1
Plastron Length	17.6	18.0		17.7
(SD)	(1.1)	(0.5)	—	(1.0)
Min.-Max.	15.7-18.8	17.5-18.5		15.7-18.8
Shell Height	4.6	4.7		4.6
(SD)	(0.5)	(0.6)	—	(0.5)
Min.-Max.	4.0-5.5	4.0-5.0		4.0-5.5
Mass	1,270.4	1,310.3		1,280.4
(SD)	(177.6)	(85.2)	—	(156.8)
Min.-Max.	967.0-1,542.0	1,212.0-1,362.0		967.0-1,542.0

*Individuals not sexually dimorphic.

Table 4. Mean, standard deviation (SD) and minimum-maximum range of straight line measurements of carapace width (cm), plastron length (cm), shell height (cm), and mass (g) for five individuals of the false map turtle captured in South Dakota during 2002 and 2003.

	Age/Sex			
	Adult Male	Adult Female	Juvenile*	Overall
n	3	2	0	5
Carapace Width	11.6	21.0		15.4
(SD)	(1.4)	(2.6)	—	(5.4)
Min.-Max.	10.1-12.9	19.2-22.8		10.1-22.8
Plastron Length	11.5	21.1		15.3
(SD)	(1.7)	(0.8)	—	(5.3)
Min.-Max.	10.0-12.4	20.5-21.6		10.0-21.6
Shell Height	4.3	8.5		6.0
(SD)	(0.5)	(0.7)	—	(2.3)
Min.-Max.	3.8-4.7	8.0-9.0		3.8-9.0
Mass	214.7	1,200.0		608.8
(SD)	(73.9)	(212.1)	—	(552.5)
Min.-Max.	135.0-281.0	1,050.0-1,350.0		135.0-1,350.0

*Individuals not sexually dimorphic.

Table 5. Mean, standard deviation (SD) and minimum-maximum range of straight line measurements of carapace width (cm), plastron length (cm), shell height (cm), and mass (g) for 108 individuals of the snapping turtle captured in South Dakota during 2002 and 2003.

	Age/Sex			
	Adult Male	Adult Female	Juvenile*	Overall
n	39	61	8	108
Carapace Width	33.6	30.3	10.5	30.2
(SD)	(6.4)	(6.2)	(9.0)	(8.4)
Min.-Max.	19.0-43.0	17.0-44.0	3.0-22.5	3.0-44.0
Plastron Length	22.6	20.9	7.2	20.6
(SD)	(4.4)	(4.2)	(6.1)	(5.7)
Min.-Max.	13.0-38.0	12.0-30.0	1.7-14.6	1.7-38.0
Shell Height	12.2	10.9	4.1	10.9
(SD)	(3.9)	(3.3)	(3.7)	(4.0)
Min.-Max.	7.0-28.0	3.5-25.0	0.5-9.0	0.5-28.0
Mass	8,022.1	5,807.2	759.8	6,232.3
(SD)	(3,599.8)	(3,387.2)	(835.6)	(3,832.9)
Min.-Max.	1,739.0-13,200.0	1,060.0-20,000.0	7.0-2,000.0	7.0-20,000.0

*Individuals not sexually dimorphic.

Table 6. Straight line measurements of carapace width (cm), plastron length (cm), shell height (cm) and mass (g) for one ornate box turtle captured in South Dakota during 2002 and 2003.

	Age/Sex			
	Adult Male	Adult Female	Juvenile*	Overall
n	1	0	0	1
Carapace Width	14.7	—	—	14.7
Plastron Length	12.1	—	—	12.1
Shell Height	5.0	—	—	5.0
Mass	320.0	—	—	320.0

*Individuals not sexually dimorphic.

with a mass of just over 20 kg was larger than those reported for all states except Minnesota (29.6 kg) (Oldfield and Moriarty 1994). The only ornate box turtle specimen we captured in South Dakota had measurements similar to those measurements reported for Wyoming (Baxter and Stone 1985) and Iowa (Christiansen and Bailey 1997).

Due to an information gap of 35 years in morphometrics of South Dakota turtles and the relative paucity of current information on the status of turtle species in the Midwestern United States, we suggest that our information can provide a baseline for comparison for future studies. Our morphometric information is also critical in determining the status and health of turtle species in the Northern Great Plains.

There have been no aging studies done on the turtles of South Dakota except for a preliminary study by Hammer (1968). Research that would determine the age of turtles compared to our carapace length to mass regressions would be beneficial in providing time saving information for future researchers (see appendices A, B, and C). Fewer measurements might be needed to produce the same amount of information. Such a study would require the collecting of numerous individual turtles, which some populations might not be able to withstand. Future turtle studies should include morphometric measurements so that temporal changes and trends in turtle populations could be compared to earlier baseline data sets.

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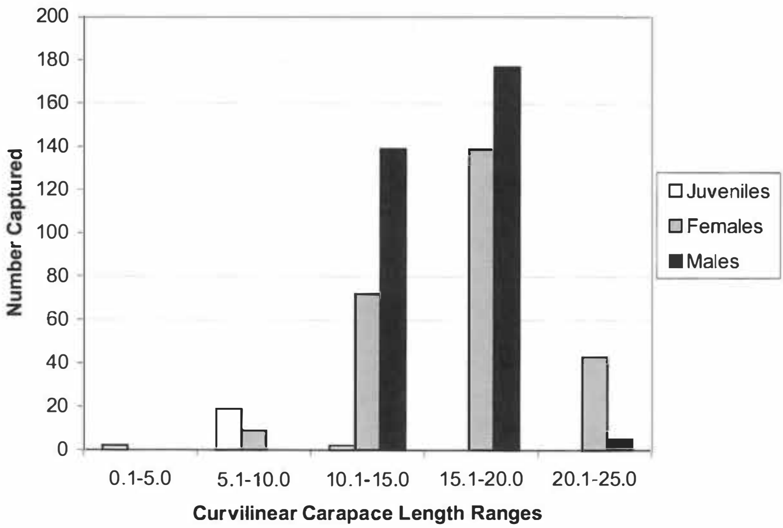
Editor's note: Because curved carapace lengths presently are not standard measurements for turtles, they are listed in the appendices for reference only.

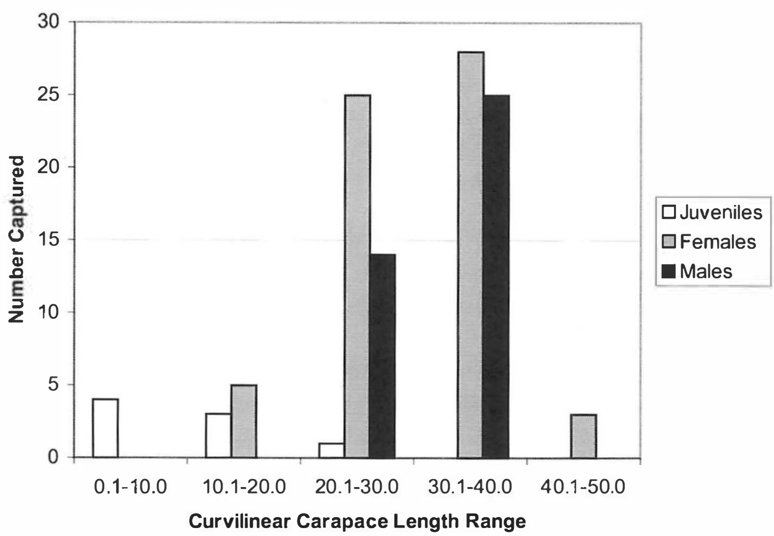
Appendix A. Sample size (n), mean ± S.D., and minimum-maximum range curvilinear measurements of carapace length (cm) for turtle species captured in South Dakota during 2002 and 2003.

Age/Sex	Ornate Box Turtle	Snapping Turtle	Western Painted Turtle	Spiny Softshell Turtle	Smooth Softshell Turtle	False Map Turtle
Adult Male						
n	1	39	322	12	9	3
$\bar{x}$ ± SD	13.1	32.8 ± 5.6	15.5 ± 2.5	26.3 ± 8.9	25.8 ± 1.8	13.1 ± 1.8
Min.-Max.		21.5-40.0	9.0-22.4	10.2-36.5	22.1-27.7	11.1-14.5
Adult Female						
n		61	263	17	3	2
$\bar{x}$ ± SD	---	16.8 ± 3.4	16.8 ± 3.4	33.3 ± 5.4	27.4 ± 0.1	24.2 ± 1.1
Min.-Max.		8.6-23.3	8.6-23.3	20.7-40.5	27.2-27.4	23.5-25.0
Juvenile*						
n		8	21	1		
$\bar{x}$ ± SD	---	8.3 ± 1.7	8.3 ± 1.7	8.1	---	---
Min.-Max.		2.7-21.2	2.7-11.0			
Overall						
n	1	108	606	30	12	5
$\bar{x}$ ± SD	13.1	29.2 ± 8.1	15.8 ± 3.3	29.3 ±8.7	26.2 ± 1.7	17.6 ± 6.2
Min.-Max.		2.7-44.0	2.7-23.3	8.1-40.5	22.1-27.7	11.1-25.0

*Individuals not sexually dimorphic.



Appendix B. Size classes of male, female, and juvenile western painted turtle captured in South Dakota during 2002 and 2003.



Appendix C. Size classes of male, female, and juvenile snapping turtle captured in South Dakota during 2002 and 2003.

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Evaluation of Habitat Enhancement Structure Use by Spotted Bass

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ABSTRACT -- Habitat enhancement is a common and effective method used to positively influence fish populations. However, there is a paucity of species-specific evaluations of stream habitat enhancement structures for warmwater fishes. We evaluated use of half-log, rootwad enhancement structure, and simulated undercut bank (LUNKERS) by adult and juvenile spotted bass (*Micropterus punctulatus*) in natural and experimental streams. Enhancement structures were installed in Otter Creek, Kansas. Adult spotted bass use of natural and enhancement structure was documented weekly during summer and fall of 2001 and 2002 with radiotelemetry. Mean total length (TL) of adult fish was 292 mm (SE = 13 mm). Half-logs were selected positively by adult spotted bass even though availability was low. Habitat use by juvenile spotted bass was evaluated in an experimental stream. Mean TL of juvenile fish was 92 mm (SE = 3 mm). Rootwad enhancement structures were selected negatively and half-logs were selected positively by juvenile spotted bass. Half-logs were used by adult and juvenile spotted bass, not influenced by sedimentation in Otter Creek, and the least expensive to install (US\$212/m^2). Thus, we recommend half-logs for lotic spotted bass habitat enhancement projects.

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Key words: cover structure, habitat enhancement, habitat use, Kansas, *Micropterus punctulatus*, spotted bass.

Spotted bass (*Micropterus punctulatus*) is a major sport fish and predator native to southeastern Kansas streams (Cross and Collins 1995); however, its densities are relatively low and populations are vulnerable to overharvest (Tillma et al. 1998, Horton et al. 2000). Therefore, increasing spotted bass populations is a long-term goal of the Kansas Department of Wildlife and Parks. Research by Tillma et al. (1998) and Horton and Guy (2002) shows that spotted bass population characteristics and habitat use are strongly associated with large woody debris (LWD), natural rootwads, and undercut banks. Horton and Guy (2002) found natural cover structure use was non-random and spotted bass used LWD, natural rootwads, and undercut banks significantly more than open water and overhanging vegetation. Habitat improvement is a common method used to enhance fish populations and usually is accomplished by installing habitat enhancement structures (hereafter called enhancement structures) that alter habitat characteristics such as stream velocity, overhead cover, depth, and substrate. Research on instream habitat enhancement and restoration techniques used to enhance fish populations historically has concentrated on salmonids (Riley and Fausch 1995, Huusko and Yrjänä 1997, Giannico 2000, Roni and Quinn 2001, Roni et al. 2001).

Habitat use studies on *Micropterus* spp. that include information on more than one life stage are rare. Futhermore, information concerning enhancement structure use by *Micropterus* spp. on low gradient or warmwater streams is limited (Edwards et al. 1984, Carline and Klosiewski 1985). Documenting habitat use of adult fishes in lotic environments commonly is conducted by visual observation or biotelemetry (Rankin 1986, Todd and Rabeni 1989, Horton and Guy 2002). Contrastingly, small body size decreases the visibility of fish and increases the relative size of implanted transmitters, which increases the likelihood of abnormal effects on behavior and growth (Mellas and Haynes 1985, Adams et al. 1998). The turbid nature of many low-gradient streams adds to the difficulty of visually documenting habitat use. Thus, little information exists on evaluation of appropriate instream enhancement structures for adult and juvenile spotted bass.

We concentrated our study on cover structure and compared spotted bass use of both natural and enhancement structures. The objective of our study was to evaluate use of three types of enhancement structures by adult and juvenile spotted bass to determine the most appropriate structures for lotic enhancement projects. Adult habitat use was documented in a Kansas stream by using biotelemetry. Juvenile habitat use was documented visually in an experimental stream to avoid difficulties with observations of small fish in a natural stream. We predicted that juvenile and adult spotted bass positively would select enhancement structures because of the rheotactic behavior of most centrarchids.

METHODS

Natural Stream

Instream cover structure evaluation for adult spotted bass was conducted in Otter Creek, within the Flint Hills region of Kansas. Otter Creek is a fourth order tributary (Strahler 1964) located in the Fall River Wildlife Management Area, Greenwood County, Kansas. The mean annual discharge is 2.3 m^3/s and has varied from 0.016 m^3/s to 6.5 m^3/s during the past 54 years (United States Geological Survey 2003). Sand and gravel dominate the substrate of Otter Creek. The study reach was approximately 1.5 km long and 9.6 km upstream from the confluence with the Fall River.

Three types of enhancement structures were installed in pool habitat in Otter Creek: rootwad enhancement structures, LUNKERS (i.e., a wooden structure providing bank cover for fish as described by the Federal Interagency Stream Restoration Working Group [1998]), and half-logs (Fig. 1). Rootwad enhancement structures and LUNKERS were installed in spring 2001 and half-logs were installed in spring 2002. Twelve LUNKERS (Fig. 1a) were constructed from untreated oak (*Quercus* spp.) and installed end-to-end in three groups of four structures as described by Vetrano (1988) and Proboszcz (2003). Five rootwad enhancement structures (Fig. 1b) were constructed from either American elm (*Ulmus americana*) or green ash (*Fraxinus pennsylvanica*) and installed in groups of one or two at least 2 m from each LUNKERS grouping. Site characteristics and access determined the number of rootwad enhancement structures installed near each LUNKERS grouping. Twelve modified Hunt (1993) design half-logs (Fig. 1c) were constructed of oak and installed at approximately 100 m intervals throughout the study reach.

Area of all cover structure (both natural and enhancement) was measured and mapped (Binns and Eiserman 1979). A cover structure was considered an object capable of concealing a fish greater than or equal to 200 mm total length (TL) from overhead view (modified from Riley and Fausch 1995). All mapped structures were underwater and at least 0.2 m long and 0.2 m wide (Simonson et al. 1994, Riley and Fausch 1995). Distance to nearest bank was measured from the structure center to the bank and distance to nearest structure was measured between the closest edges of both structures. Natural structure consisted of: natural rootwad, LWD, and undercut bank. Enhancement structure consisted of: rootwad enhancement structure, half-log, and LUNKERS. Depth was measured at each structure to the nearest 0.01 m (Simonson et al. 1994) and point velocity was measured to the nearest 0.01 m/s. New natural structure was mapped after water level changed greater than 1 m or when new structure became available. Morphometric maps depicting site dimensions and structure locations were produced and used to record fish locations (White and Garrot 1990).

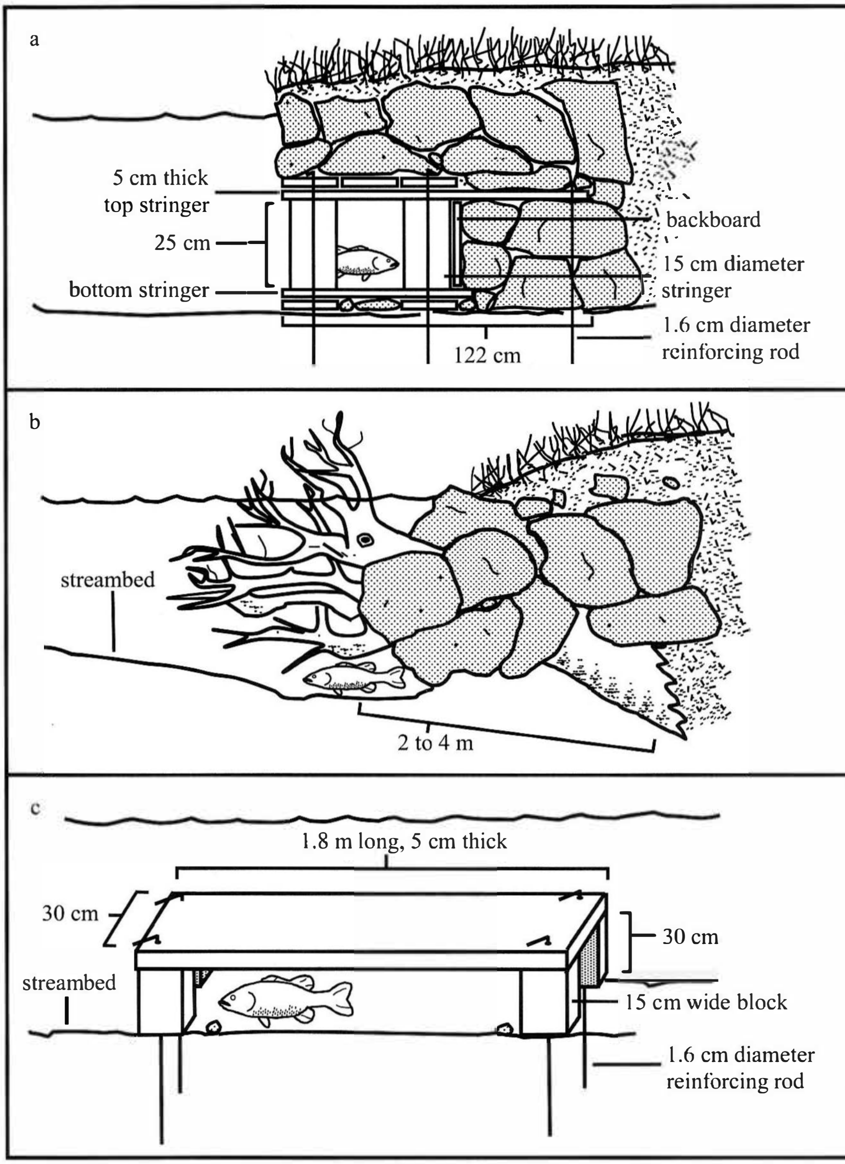

Figure 1. Lateral view of an installed LUNKERS (a) and rootwad enhancement structure (b). Side view of a modified Hunt half-log (c).

Spotted bass adults were sampled in the study reach by using Coffelt VVP 15 boat-mounted DC electrofishing gear. Instream live wells were used to hold fish for 2 hr to alleviate stress caused by electrofishing. According to methods from Horton and Guy (2002), we implanted fish with radio transmitters. Transmitters were 24 mm long, 13 mm wide, and 7 mm deep, weighed 3.6 g and had a 140 d life-span. Twenty six adults were implanted with transmitters.

Accuracy and precision of locations was estimated by concealing a transmitter downstream of the study reach while the tracker was not present. The distance between the location identified by the tracker and the true location was considered location error. This exercise was repeated five times by two trackers.

Tracking commenced one week following implantation as recommended by Gallepp and Magnuson (1972). Individuals were tracked from June 13 to September 2 in 2001 and from June 11 to November 14 in 2002. Tracking was conducted once a week over a 24 hr period, in which eight, 2 hr tracking periods were selected. Two periods always encompassed the crepuscular times of day. The beginning of the other six tracking periods were selected randomly from the remaining 2 hr periods available in the 24 hr period. Each fish was located from the bank during each 2 hr period. Structure use and time were recorded at each location.

Only individuals that were located greater than or equal to 20 times and had enhancement structure available in their home range were used in the analyses. Home range was defined as the area of stream reach remaining after eliminating 2.5% of the most upstream and downstream locations (Matheney and Rabeni 1995). Availability and use of natural and enhancement structure in a home range were determined for each fish from morphometric maps. Available structure (LWD, half-logs, undercut banks, LUNKERS, natural rootwads, and rootwad enhancement structures) was defined as its proportion of stream surface area in each home range. Use was defined as the proportion of locations recorded in a structure.

Analyses of the natural stream study followed methods of White and Garrot (1990) and Neu et al. (1974). Selection analysis was confined to natural and enhancement structure located in pool habitat. A chi-square goodness of fit test was used to determine if individual fish used structure in equal proportion to availability. For all fish that demonstrated unequal proportionate use of structure in comparison to availability, a method developed by Neu et al. (1974) was used to determine selection type (positive or negative) for each structure type. Ninety percent Bonferroni confidence intervals were constructed for the proportion of use of each structure type by individual fish and was compared to the proportion of availability. Structure use confidence intervals overlapping the proportion of availability indicate neutral selection (i.e., use in equal proportion to availability) for that structure. Structure use confidence intervals greater than the proportion of availability indicate positive selection for that structure. Conversely, confidence intervals less than the proportion of availability indicate negative selection for that structure. Analysis of variance and least-squares means with a Bonferroni adjustment were used to determine if structure types were different in velocity, area, depth, distance to nearest bank, and distance to nearest structure.

Experimental Stream

During September and October 2001, ten juvenile spotted bass were collected with seines from Deep Creek in the Flint Hills physiographic region, Kansas. Mean TL of juvenile fish was 92 mm (SE = 3 mm). Individuals were transported to the laboratory and held separately in 38 l aquaria. They were held for at least 2 d before being placed in the experimental stream. Individuals were fed live invertebrates and red shiners (*Cyprinella lutrensis*) daily.

Enhancement structure evaluation for juvenile spotted bass was conducted in a Frigid Units® oval experimental stream. The experimental stream was 410 cm in length and had a channel width of 41 cm, and two basins (i.e., pools) with a diameter of 124 cm. The pools were located at opposite ends of the oval. Water depth was kept at 35 cm in the channels and 60 cm in the basins. Water temperature varied from 21.9° C to 25.5° C and dissolved oxygen varied from 3.2 mg/l to 6.3 mg/l. Velocity was maintained by two submersible pumps and varied from 0 m/s to 1.45 m/s in the stream. A grid was marked on the walls and floor of the stream to facilitate precise fish location. The grid was marked at 15.2 cm intervals along the length of the channel (X axis), 7.6 cm intervals across (Y axis), and 5.1 cm depth intervals (Z axis). Timed incandescent lights were used to produce a photoperiod of 14 hr light and 10 hr dark. All enhancement structures were constructed of wood, were similar in design to structures installed in Otter Creek, and had an overhead area of 0.08 m^2. An empty space (hereafter called open water area) of the same area as each enhancement structure was included in the study to determine the relative selection of open water in the experimental stream. Half-log, rootwad enhancement structure, LUNKERS, and open water area were arranged randomly among four positions (two positions in each basin) for each fish. Ten trials were conducted, each testing one fish individually in the experimental stream. Each fish was released at a randomly selected position in the stream and allowed to acclimate for 36 hr, after which 2 d of observation followed. Observations were made from behind a black curtain with viewing slits to prevent disturbing the fish. Observations were made six times daily, once during each of the following time periods: 0700-0900 hr, 1000-1200 hr, 1300-1500 hr, 1500-1700 hr, 1700-1900 hr, and 1900-2100 hr. During each time period, spotted bass were assigned a location and habitat type every 30 s for 15 min. Temperature and dissolved oxygen were measured once during each time period. Light intensity and current velocity were measured in structure and open water habitats after all fish were observed.

Selection analysis for the experimental stream study was conducted as in the natural stream study. Analysis of variance and least-squares means with a Bonferroni adjustment were used to determine if there was a difference between mean light intensity and velocity among half-log, rootwad enhancement structure, LUNKERS, and open water area. Two-tailed t-tests were used to determine if there were differences in velocity between experimental and natural stream enhancement structure types. All statistical analyses were conducted by using SAS (SAS Institute Inc. 2000). An alpha level of 0.05 was chosen to determine statistical significance in the natural and experimental stream studies.

RESULTS

Natural Stream

Installed rootwad enhancement structures and LUNKERS remained in place and available after a discharge event of 50 m^3/s on June 14, 2001. However, 90% of LUNKERS and rootwad enhancement structures were either filled with sediment or dislodged by a discharge event of 220 m^3/s on June 20, 2001. The structures were then excavated and made available for the remainder of the 2001 tracking period. One hundred percent of LUNKERS and 80% of rootwad enhancement structures were filled with sediment for the entire duration of tracking in 2002 following a discharge event of 450 m^3/s on September 18, 2001. Nine half-logs (75%) were available throughout 2002. Two of the three remaining half-logs were dislodged during a discharge event of 150 m^3/s on June 21, 2002 and the other half-log was dislodged at an unknown time. Sedimentation did not occur in half-logs.

Individual LUNKERS were the most expensive structure to construct and install and had a total cost of US$522 per structure. Rootwad enhancement structures were second most costly ($388) and half-logs were the least expensive ($106) and installed without machinery. The cost per unit area of available cover structure produced was $261/$m^2$ for LUNKERS, $227/$m^2$ for rootwad enhancement structures, and $212/$m^2$ for half-logs.

Structure types differed in mean area ($P = 0.05$, $F = 2.36$) and distance to nearest bank ($P < 0.0001$, $F = 9.71$), but not distance to nearest structure ($P = 0.09$, $F = 1.95$) (Table 1). Mean area of structure type varied from 22.2 m^2 for LWD to 0.5 m^2 for half-logs. Mean distance to nearest bank was greatest for half-logs and differed significantly from natural rootwads and undercut banks (Table 1). Mean distance to nearest structure was lowest for LUNKERS and differed significantly from rootwad enhancement structures (Table 1). Half-logs had the highest mean depth (0.84 m) and undercut banks had the lowest (0.56 m); however, structures did not differ significantly ($P = 0.54$, $F = 0.81$; Table 1).

Of the 26 radio-tagged spotted bass, two were never located, four were located less than 20 times, and nine fish did not have enhancement structures in their home range and were excluded from all analyses. Of the remaining 11 fish used in the study, four were tracked in 2001, and seven were tracked in 2002. Mean TL of the adult fish used in the study was 292 mm (SE = 13).

Table 1. Mean (± SE) for velocity (m/s), depth (m), area (m^2), distance to nearest bank (m), and distance to nearest structure (m) for structure types (undercut bank, LUNKERS, natural rootwad, rootwad enhancement structure, large woody debris [LWD], and half-log) in Otter Creek, Kansas. Structure types with different letters indicate significant differences (P < 0.05).

Structure type	Velocity (m/s)	Depth (m)	Area (m^2)	Distance to nearest bank (m)	Distance to nearest structure (m)
Undercut bank	0.09 (0.05)	0.56 (0.08)	6.1^{ab} (1.4)	0.06^{b} (0.04)	4.50 (1.41)
LUNKERS	0.03 (0.01)	0.61 (0.09)	8.7^{ab} (0.3)	0.58^{ab} (0.22)	3.17 (1.42)
Natural rootwad	0.02 (0.01)	0.59 (0.10)	5.0^{b} (0.8)	0.49^{b} (0.30)	3.35 (0.77)
Rootwad enhancement structure	0.04 (0.01)	0.59 (0.05)	5.0^{b} (0.7)	1.47^{ab} (0.43)	9.06 (2.94)
LWD	0.05 (0.01)	0.66 (0.04)	22.2^{a} (6.1)	2.74^{a} (0.34)	3.63 (0.72)
Half-log	0.04 (0.01)	0.84 (0.06)	0.5^{b} (0.0)	4.00^{a} (0.82)	6.19 (2.62)

Mean tracking location error was 0.79 m (SE = 0.16 m) and varied from 0.05 m to 1.4 m. Mean home range size was 3,158 m^2 (SE = 705 m^2). Half-logs and rootwad enhancement structures were the least available structures in spotted bass home ranges; however, all fish that had half-logs available in their home range used them at some point during the study. The highest percentage of fish (50%) showed positive selection for half-logs and LUNKERS when they were available compared with other structures (Table 2). In addition, half-logs and LUNKERS were the only structures that were not negatively selected by any fish (Table 2). Rootwad enhancement structures were selected negatively by the highest percentage of fish (63%; Table 2).

Experimental Stream

Juvenile spotted bass mean velocity use throughout the experimental stream was 0.03 m/s; in enhancement structure it was 0.02 m/s. Half-log and rootwad enhancement structure had the lowest mean velocities available and were not

Table 2. Summary of chi-square and selection analyses for structures types (undercut bank, LUNKERS, natural rootwad, rootwad enhancement structure, large woody debris [LWD], and half-log) by individual adult spotted bass tracked in Otter Creek, Kansas. A positive sign (+) indicates positive selection, a negative sign (-) indicates negative selection, and an equal sign (=) indicates neutral selection (i.e., use in equal proportion to availability).

Fish	χ^2	df	P	Undercut bank	LUNKERS	Natural rootwad	Rootwad enhancement structure	LWD	Half-log
1	62.1	2	<0.001	a	a	=	+	–	a
2	56.6	4	<0.001	–	+	+	–	–	a
3	5.5	3	0.137	=	=	=	a	=	a
4	0.8	1	0.361	a	a	a	=	=	a
5	69.3	2	<0.001	+	a	a	–	–	a
6	126.8	4	<0.001	=	a	–	–	=	=
7	606.8	4	<0.001	+	a	–	–	=	+
8	32.7	4	<0.001	=	a	=	=	–	=
9	79.1	4	<0.001	=	a	–	–	+	=
10	227.9	1	<0.001	a	a	a	a	–	+
11	161.2	1	<0.001	a	a	a	a	–	+
Positive selection percentage				29	50	14	12	9	50
Negative selection percentage				14	0	43	63	55	0
Neutral selection percentage				57	50	43	25	36	50

[a]Structure not available in home range

significantly different (Table 3). Open water area had the highest mean velocity and was significantly different than half-log and rootwad enhancement structure (Table 3). No significant differences in velocity were detected between experimental and natural stream LUNKERS ($P = 0.97$, $t = 0.033$, $df = 9$), half-logs ($P = 0.19$, $t = 1.4$, $df = 9$), and rootwad enhancement structures ($P = 0.63$, $t = 0.49$, $df = 16$).

Spotted bass mean light intensity use throughout the experimental stream was 184 lx. Mean light used in enhancement structure was 140 lx and most frequently used light intensity was 48 lx. Mean light intensity available was lowest for half-log and differed significantly from rootwad enhancement structure and open water area (Table 3). Open water area had a significantly higher mean light intensity than all other structures (Table 3).

Half-log was the only structure selected positively by juvenile spotted bass (40%, Table 4). Similar to adults, rootwad enhancement structure was selected negatively by the highest percentage of juveniles in comparison to any structure (20%, Table 4). Open water area was selected negatively by the highest percentage of fish (50%, Table 4).

DISCUSSION

Frequent use of structure by adult spotted bass in our study is corroborated by other studies (Smith et al. 1981, Horton and Guy 2002). Large woody debris, natural rootwads, and undercut banks were used frequently by spotted bass and this substantiates previous results by Horton and Guy (2002) in Otter Creek, Kansas.

Table 3. Mean (± SE) for velocity (m/s) and light intensity (lx) of structure types (open water area, half-log, rootwad enhancement structure, and LUNKERS) in an experimental stream. Structure types with different letters indicate a significant difference ($P < 0.05$).

Structure type	Mean velocity (m/s)	Mean light intensity (lx)
Open water area	0.04^{a} (0.01)	457^{a} (27)
Half-log	0.02^{b} (0.00)	46^{c} (7)
Rootwad enhancement structure	0.02^{b} (0.00)	252^{b} (45)
LUNKERS	0.03^{ab} (0.00)	151^{bc} (19)

Table 4. Summary of chi-square and selection analyses for structures types (open water area, LUNKERS, rootwad enhancement structure, and half-log) by individual juvenile spotted bass in an experimental stream. A positive sign (+) indicates positive selection, a negative sign (-) indicates negative selection, and an equal sign (=) indicates neutral selection (i.e., use in equal proportion to availability).

Fish	χ^2	df	P	Open water area	LUNKERS	Rootwad enhancement structure	Half-log
1	10.4	3	0.015	–	=	=	+
2	6.3	3	0.098	–	=	=	=
3	9.3	3	0.025	–	=	–	+
4	2.8	3	0.423	=	=	=	=
5	1.5	3	0.675	=	=	=	=
6	17.2	3	0.001	–	=	–	+
7	1.3	3	0.719	=	=	=	=
8	6.7	3	0.083	–	=	=	+
9	0.4	3	0.934	=	=	=	=
10	4.0	3	0.257	=	=	=	=
Positive selection percentage				0	0	0	40
Negative selection percentage				50	0	20	0
Neutral selection percentage				50	100	80	60

Kansas. Our field study expanded on Horton and Guy (2002) and included enhancement structure types and omitted open water to solely examine structure selection. Therefore, negative selection of natural rootwads and LWD does not imply infrequent use; it does imply negative selection of natural rootwad and LWD relative to installed enhancement structures. Half-logs and LUNKERS were selected positively by the highest percentage of spotted bass in comparison to natural structure types and were the only structures that demonstrated no negative selection. All radio-tagged adult spotted bass in Otter Creek used half-logs during 2002 even though the availability of half-logs was among the lowest of any structure type. However, further study is needed to substantiate adult spotted bass positive selection for these two enhancement structures due to sample size limitations; especially LUNKERS, which were only available to two fish in 2001. We found that it was difficult to anticipate locations of spotted bass home ranges and install enhancement structures within them.

Juvenile spotted bass used half-log structures most frequently. They were the darkest structures and had a similar mean velocity to rootwad enhancement structures. Cover structure typically is associated with low light intensity and current velocity relative to open water. Light intensity and current velocity are major variables affecting juvenile smallmouth bass (*Micropterus dolomieu*) habitat selection (Sechnick et al. 1986) and likely are used by spotted bass. Light intensity in the natural stream varied with time of day and cloud cover; hence, it was not compared to thc experimental stream. However, experimental stream enhancement structure current velocities were similar to those in the natural stream. This similarity substantiated the extrapolation of our experimental stream results to natural streams. Frequent use of half-logs in our study suggested their use in lotic habitat enhancement projects could potentially result in positive selection by juvenile spotted bass in natural streams. In our study juvenile and adult spotted bass positively selected half-logs. Similarly, juvenile and adult cover structure selection has been documented in smallmouth bass (Sechnick et al. 1986). Our results showed that both juvenile and adult spotted bass had similar affinities to cover structure.

Many lowland lotic systems recently have experienced decreased natural LWD recruitment due to de-snagging, deforestation, and maintenance of channels for optimal hydraulic capacity (Bisson et al. 1987, Gippcl et al. 1996). Large woody debris might be especially useful in low gradient systems with small substrates by functionally increasing habitat complexity and providing stable substrate for macroinvertebrates (Wallace and Benke 1984, Benke et al. 1985). Strong evidence also exists supporting the positive influence of LWD on abundance of fish in coldwater (Burgess and Bider 1980, Dolloff 1986) and warmwater streams (Hickman 1975, Angermeier and Karr 1984). Enhancement structures, which function similarly to LWD, have been documented to increase abundance and density of lotic fish (Cederholm et al. 1997, Roni and Quinn 2001). However, several authors have suggested changes in rates of immigration and emigration in enhancement reaches are the mechanism behind short-term increases in local abundance (Hunt 1965, Riley and Fausch 1995). Despite this controversy, the installation of enhancement structure might have other positive effects on fish such as increased growth rates through decreased swimming activity, fewer aggressive acts towards conspecifics, and reduction of predation risk (Hartman 1965, Bustard and Narver 1975, Sundbaum and Näslund 1998). Typical Flint Hills stream discharges are highly variable during spring and fall and commonly receive 50% to 60% of their total annual flow during two months of the year (Metzler 1966). Nevertheless, half-logs were not affected by sedimentation in Otter Creek. Further, half-logs were the most cost-effective enhancement structure, used by adult spotted bass regardless of their low availability, and were the only positively selected structure by juvenile spotted bass in the experimental stream. Therefore, mitigating against the decreased input of LWD with half-log installation likely will have positive effects on spotted bass populations.

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Evaluating Diet Composition of Pronghorn in Wind Cave National Park, South Dakota

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ABSTRACT -- The pronghorn (*Antilocapra americana*) was reintroduced into Wind Cave National Park (WCNP), South Dakota, in 1914, and thus, has inhabited the Park for nearly a century. During the 1990's, a decline in the population raised concern for the continued existence of pronghorn inside WCNP; an investigation into the observed decline was initiated. Primary objectives of our study were to evaluate diet composition and forage selection by pronghorn in WCNP. Microhistological analysis was conducted on 58 fecal samples collected opportunistically from pronghorn during 2002. Blue grama (*Bouteloua gracilis*), common juniper (*Juniperus communis*), and northern bedstraw (*Galium boreale*) were identified as major seasonal food items, representing 14.6, 10.6, and 6.5 % of the annual diet, respectively. Annual diets of pronghorn in WCNP included 41.5 % grasses, 31.1 % shrubs, and 27.4 % forbs. Total forage production in WCNP was 72 % grass, 4 % shrubs, and 23 % forbs. Results indicated strong dietary selection by pronghorn for shrubs.

Key words: *Antilocapra americana*, diet composition, fecal samples, food habits, pronghorn, South Dakota, Wind Cave National Park.

The pronghorn (*Antilocapra americana*) was reintroduced into Wind Cave National Park (WCNP), South Dakota, in 1914, and thus, has inhabited WCNP for nearly a century. Pronghorn numbers in WCNP exceeded 300 individuals in the

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1960's; however, a population decline during the 1990's raised concern for the continued existence of the species within WCNP. Maintaining a healthy pronghorn population in WCNP is of ecological concern. However, the pronghorn population was estimated at 30 individuals in 2002. Thus, an evaluation of potential factors contributing to the population decline within WCNP was warranted.

Sagebrush (*Artemisia* spp.) has been identified as a major food item in pronghorn diets (Mason 1952, Mitchell and Smoliak 1971, Messenger and Schitoskey 1980). Changes in sagebrush density can affect overall health and survival of pronghorn populations. For example, Bayless (1969) noted that a decrease in quality of sagebrush in pronghorn diets contributed to poor body condition and fawn mortality during winter months in Montana. Long-term pronghorn habitat studies in sagebrush/grassland communities in Montana and shrub steppe communities in Oregon and Nevada classified sagebrush as 'survival forage' because of its high availability and nutritional value (crude protein) to pronghorn during critical winter months (Pyrah 1987, Hansen and Anthony 1999, Hansen et al. 2001). O'Gara and Yoakum (2004) suggested that distribution of sagebrush throughout winter range was essential for achieving long-term carrying capacities and population levels throughout the geographic range of this species. Furthermore, they noted that availability of sagebrush during prolonged winters was likely a primary factor affecting pronghorn survival. There also is evidence to suggest that pronghorn meet daily water requirements through consumption of shrubs such as sagebrush (Beale and Smith 1970).

Another factor that might affect pronghorn population dynamics is resource competition with other species. However, interspecific competition between pronghorn and other ruminants for food resources might not significantly influence pronghorn diet selection. For example, O'Gara and Yoakum (2004) noted that American bison (*Bison bison*) and pronghorn lived commensally before the arrival of European settlers; both ungulates often occurred in mixed herds and shared forage and water resources on vast open plains. Chase (1977) and Danvir (2000) suggested that bison foraging strategies might have benefited pronghorn by grazing abundant grasses, which stimulated growth of low growing forbs and shrubs and increased forage availability to sympatric pronghorn populations. Schwartz and Nagy (1976) documented limited competition for food resources between pronghorn and bison in northwestern Colorado, while Krueger (1986) documented that pronghorn selected forbs in proportion to availability on prairie dog (*Cynomys* spp.) towns and that pronghorn preferentially selected prairie dog towns for foraging in WCNP. Furthermore, pronghorn had no effect on prairie dog responses to pronghorn foraging and associated changes in forage quality throughout prairie dog towns (Krueger 1986). Similarly, McCullough (1980) concluded that interspecific competition for food resources between elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*), and pronghorn on the National Bison Range in Montana was minimal due to limited spatial overlap between these species throughout most of the year. Nevertheless, sympatric populations of pronghorn, bison, elk, white-tailed deer, mule deer, and black-tailed prairie dog (*Cynomys ludovicianus*) occurred throughout WCNP. Pronghorn throughout WCNP might occupy niches that minimize or reduce interspecific competition for food resources with potential competitors, particularly larger free-ranging ruminants. The relationship between nutritional health of pronghorn and forage availability has been documented previously throughout western states (reviewed by O'Gara and Yoakum 2004). Past investigations indicated that pronghorn production and survival was influenced by quality and quantity of forage consumed by pronghorn (Beale and Smith 1966, Hockley 1968, Ellis 1972, Hervert et al. 2000, Hansen et al. 2001). However, to our knowledge, the only previously documented investigation of pronghorn food habits in WCNP was by Krueger (1986). That study occurred prior to the population decline and examined interspecific relationships among bison, black-tailed prairie dog, and pronghorn. Our objectives were to evaluate diet composition and forage selection by pronghorn in WCNP.

STUDY AREA

Wind Cave National Park encompassed an area of 115 km^2, with an average elevation of 1,257 m above mean sea level, and was situated in Custer County, South Dakota in the southeastern region of the Black Hills. The Black Hills is an isolated mountain range located in southwestern South Dakota and northeastern Wyoming and encompasses approximately 8,400 km^2 (Fecske and Jenks 2002). WCNP was enclosed by a 2.5-m woven-wire fence, with cattle guards present at all road entrances to prevent movement by ungulates out of WCNP. Wind Cave National Park was characterized by a mosaic of mixed-grass prairie interspersed with a ponderosa pine (*Pinus ponderosa*) dominated forest. Plant species occurring in the mixed grass prairie within WCNP included Kentucky bluegrass (*Poa pratensis*), blue grama (*Bouteloua gracilis*), western wheatgrass (*Pascopyrum smithii*), western snowberry (*Symphoricarpos occidentalis*), common juniper (*Juniperus communis*), and northern bedstraw (*Galium boreale*). Plant nomenclature followed Larson and Johnson (1999) and Johnson and Larson (1999).

METHODS

Fecal samples were collected from January to December 2002 to examine food habits of pronghorn in WCNP. Pellets from fresh defecations were collected opportunistically each month during the study period where pronghorn groups were visually observed. Microhistological fecal analysis was performed on samples to determine coverage within each sample. Preparation of plant pigments for quantification and classification of pronghorn diets followed procedures described by Davitt and Nelson (1980). Fecal samples were dried at 60° C for 48 hours, blended, and washed. Samples were placed in a 95 % ethyl-alcohol solution for 7 days to extract plant pigments and rinsed in a 40 % bleach solution. Extracted plant pigments were stored in a staining solution containing a lactophenol blue agent for 7 to 10 days. Slides of plant pigments were prepared and examined by using 100 fields of view (25 fields of view per slide) to measure area of the fragments contained within each sample (Stewart 1967). Percent coverage of each species or forage class was determined by summing the area occupied by each species and dividing by the total area contained within slides. Confidence intervals (95 %) were constructed for mean values of percent coverage for each forage class.

Total forage production (forage availability) in WCNP was estimated by using a double-sampling method developed and described by the National Resources Conservation Service (National Range and Pasture Handbook 1997). Due to extreme drought conditions throughout WCNP during 2000 to 2004, we assumed that changes in rangeland composition during our study (2002) and in 2004 were minimal. We also assumed that total forage production during our study and data obtained during 2004 were similar. Thus, 2004 forage availability data were used to describe availability of forage during our study. Forage use by pronghorn was compared to forage availability by evaluating overlap in confidence intervals.

RESULTS

Fifty-eight fecal samples were collected between 26 January and 5 December 2002. Eleven species of grasses, 13 species of shrubs, and 3 species of forbs were identified in fecal samples. Pronghorn diets contained 25 plant species in winter and 20 species in summer (Table 1). Sagebrush species, including big sagebrush (*Artemisia tridentata*), fringed sagewort (*A. frigida*), and silver sage (*A. cana*) comprised approximately 4.5 % of the annual diet (Table 1). Blue grama, common juniper, and northern bedstraw comprised 31.7 % of the annual diet (Table 1). Consumption of forbs ranged from 5 to 45 % and was greater than 40 % in June, August, and September (Fig. 1). Shrub consumption ranged from 17 to 49 % and was greater than 40 % in January, February, and December (Fig. 1). Grasses comprised greater than or equal to 39 % of food items during summer and winter months (Fig. 2). Grasses, shrubs, and forbs comprised 41 % (± 1.8, 95 % CI, SE = 0.9), 30 % (± 2.5, 95 % CI, SE = 1.3), and 27 % (± 2.8, 95 % CI, SE = 1.4), respectively, of annual diets during 2002 (Fig. 3). Field data collected during 2004 indicated that

Table 1. Percent composition of pronghorn diets in Wind Cave National Park, South Dakota, 2002.

	% Diet		
Species	Overall	Winter[a]	Summer[b]
Crested wheatgrass (*Agropyron cristatum*)	1.5	tr[c]	2.2
Redtop (*Agrostis stolonifera*)	1.1	1.2	1.0
Sideoats grama (*Bouteloua curtipendula*)	tr	tr	0.0
Blue grama (*Bouteloua gracilis*)	14.6	16.0	13.3
Smooth brome (*Bromus inermis*)	1.7	1.7	1.7
Sedge (*Carex* spp.)	tr	tr	tr
Foxtail barley (*Hordeum jubatum*)	tr	0.0	tr
Indian ricegrass (*Oryzopsis hymenoides*)	4.3	5.1	3.6
Western wheatgrass (*Pascopyrum smithii*)	tr	tr	tr
Needleandthread (*Hesperostipa comata*)	4.8	3.9	5.7
Green needlegrass (*Nassella viridula*)	tr	tr	0.0
Unknown spp.	12.0	13.8	10.5
Total grasses	41.5	43.6	39.6
Serviceberry (*Amelanchier* spp.)	tr	tr	0.0
Silver sagebrush (*Artemisia cana*)	1.4	1.6	1.2
Fringed sagewort (*Artemisia frigida*)	2.0	3.1	1.0
Big sagebrush (*Artemisia tridentata*)	tr	tr	1.2
Bearberry (*Arctostaphylos uva-ursi*)	tr	tr	tr
Mountain mahogany (*Cercocarpus montanus*)	tr	tr	0.0
Ponderosa pine (*Pinus ponderosa*)	2.0	2.3	1.7
Wild plum, sand cherry, pin cherry chokecherry (*Prunus* spp.)	1.3	1.1	1.4
Currant (*Ribes* spp.)	2.8	1.5	3.8

Table 1, continued.

Species	% Diet		
	Overall	Winter[a]	Summer[b]
Wild rose (*Rosa* spp.)	3.6	4.2	3.0
Buffaloberry (*Shepherdia* spp.)	tr	tr	0.0
Western snowberry (*Symphoricarpos occidentalis*)	3.4	4.5	2.5
Unknown spp.	2.6	2.8	2.4
Total shrubs	31.1	33.4	29.1
Sageworts (*Artemisia* spp.)	tr	0.0	tr
Aster (*Aster* spp.)	1.9	1.4	2.3
Northern bedstraw (*Galium boreale*)	6.5	6.9	6.2
Unknown spp.	18.6	14.6	22.1
Total forbs	27.4	23.0	31.3

[a]Winter = October - March
[b]Summer = April - September
[c]tr = trace (< 1% of diet)

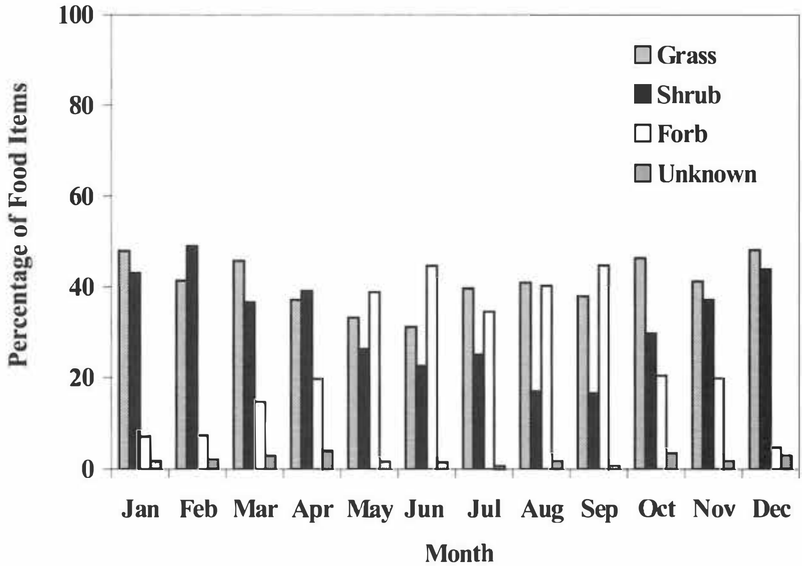

Figure 1. Diet composition of pronghorns (n = 58) by month in Wind Cave National Park, South Dakota, 2002.

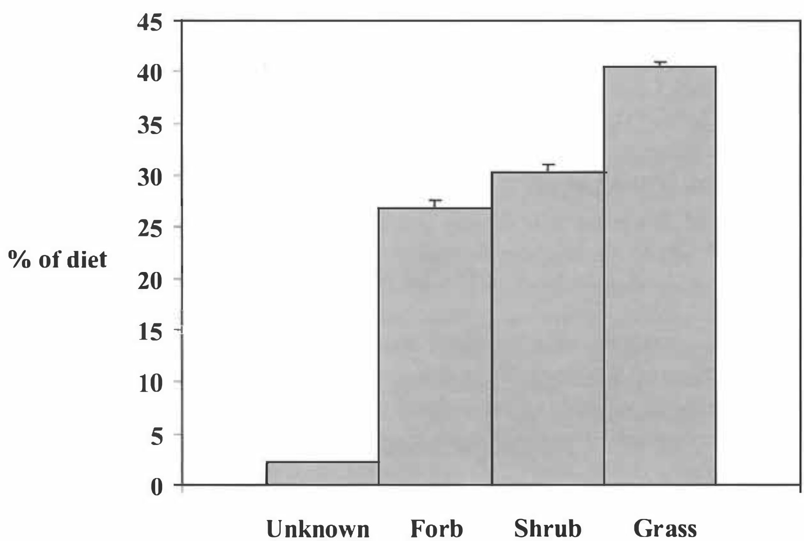

Figure 2. Diet composition of pronghorns (n = 58) in Wind Cave National Park, South Dakota, 2002.

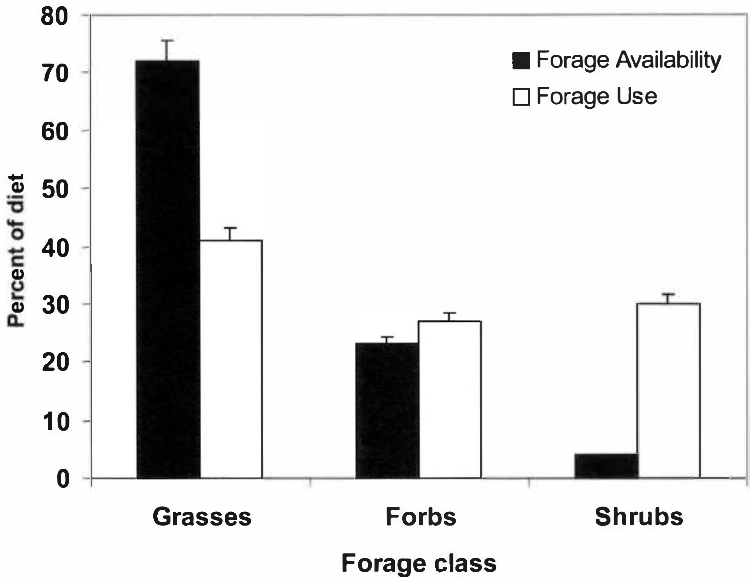

Figure 3. Availability and utilization of forage classes by pronghorns (n = 58) in Wind Cave National Park, South Dakota, 2002.

72 % (± 3.7, 95 % CI, SE = 1.9) of total forage production consisted of grasses, 4 % (± 0.2, 95 % CI, SE = 0.1) shrubs, and 23 % (± 1.2, 95 % CI, SE = 0.6) forbs (Fig. 3). Comparison of use and availability data suggested that pronghorn in WCNP avoided grasses, weakly selected forbs, and strongly selected shrubs.

DISCUSSION

Foraging strategies of pronghorn are selective compared to larger North American herbivores, however, little is known about food selection by pronghorn in habitats similar to WCNP (i.e., grassland-dominated habitats), where distribution of sagebrush is limited. The three most consumed plants by pronghorns in WCNP represented grass, shrub, and forb categories, respectively. Blue grama was observed in pronghorn diets in high quantities throughout the year. Common juniper was a major winter forage item while northern bedstraw was a major summer forage item. Pronghorn frequently consumed shrubs during winter months, but used forbs during summer months. Seasonal shifts in dietary content likely were influenced by increased availability of forbs during the growing season. High digestibility of forbs likely benefited adult females that relied on energy reserves during lactation. Shrub species, including common juniper, were used by pronghorn during winter months, when forbs were less abundant.

Percentage of grasses, shrubs, and forbs in annual diets of pronghorn in WCNP differed from that of other pronghorn populations across western North America. Diet composition of pronghorn in western South Dakota (Messenger and Schitoskey 1980), north-central New Mexico (Stephenson et al. 1985), and Saskatchewan, Canada (Dirschl 1963) contained less than 17 % grasses and greater than 45 % shrubs annually. Knick et al. (2003) noted that although geographic distribution of sagebrush in South Dakota was limited, pronghorn consumed large amounts of sagebrush during all seasons. Messenger and Schitoskey (1980) also found that sagebrush species, including big sagebrush, fringed sagewort, white sage (*A. ludoviciana*), and silver sage, represented greater than 5 % of pronghorn diets during every month of the year in northwestern South Dakota. Yoakum (1990) found that pronghorn consumed sagebrush during all seasons, but most often during autumn and winter because of increased availability and high protein content relative to grasses and forbs. Furthermore, he noted that sagebrush also influenced pronghorn survival on snow covered and drought-stricken rangelands where grasses and forbs were scarce. These studies confirmed the need for sagebrush for overall health and survival of pronghorn. However, only 4 % of total forage production (by weight) in WCNP consisted of shrubs, of which less than 1 % consisted of sagebrush (M. M. Curtin, Wind Cave National Park, Hot Springs, South Dakota, unpublished data). In addition, pronghorn diets contained less than 5 % big sagebrush, fringed sagewort, and silver sage during winter and summer months (Table 1). Thus, our results indicated that distribution and availability of shrubs, particularly sagebrush, to pronghorn throughout WCNP was limited.

The role of grasses in pronghorn diets has been documented poorly in the literature. Yoakum and O'Gara (2000) found that pronghorn grazed grasses heavily during spring and fall "green-up" when new growth was nutritious, however, total use of grasses in annual diets was 10 % throughout all pronghorn habitats. Yoakum (1990) reported that graminoids represented a minor portion of pronghorn annual diets in all biomes throughout western states and that total grass consumption averaged no more than 15 % of annual use throughout North America. However, grasses occurred most frequently in annual and seasonal pronghorn diets during our study. High consumption of grass by pronghorn in WCNP indicated that availability of preferred food items was limited in distribution throughout the year.

Seasonal variation in forage consumption by pronghorn previously has been documented in the literature. Yoakum (1990) suggested that forage preference by pronghorn consisted of a diversity of forb species and that consumption of forbs substantially exceeded consumption of grasses and shrubs in all biomes and for all seasons across western rangelands. Furthermore, he noted that some rangelands contained more than 150 forb species, of which 80 to 90 were consumed by pronghorn.

During our study, pronghorn consumed only three species of forbs and percentage of forbs consumed was less than 32 % during summer months, when forbs would likely be more readily available. Because WCNP was enclosed by a woven-wire fence with cattle guards present at all road entrances to prevent movement by ungulates out of WCNP, pronghorn were dependent on optimal forage within WCNP for survival. However, our data indicated that pronghorn consumed low amounts of optimal forage (e.g., digestible forbs and shrubs) throughout the year, suggesting that habitat quality was a factor that contributed, in part, to the pronghorn population decline in WCNP.

Long-term drought conditions during our study possibly reduced production of optimal forage and consequently, habitat quality. However, influence of drought on forage selection by pronghorn and the observed population decline in WCNP remains uncertain. Nevertheless, we hypothesize that the population decline was associated with reduced distribution and diversity of optimal forage (i.e., habitat quality) and that reduced habitat quality was influenced by long-term drought conditions throughout western South Dakota. Direct measurements of quality of forage consumed by pronghorn within WCNP were not obtained during our study. The population decline in WCNP increases the need for better information on quality of forage consumed both seasonally and annually by pronghorn throughout WCNP. Future investigations should further quantify forage availability and assess quality of forage consumed by pronghorn during years of normal precipitation. This information would enable managers to compare forage quality and quantity during drought conditions and years of normal precipitation, and effects of temporal changes in habitat quality on pronghorn productivity. Future research also should investigate relationships among availability and distribution of sagebrush and spatial distribution of pronghorns throughout WCNP.

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Spatial and Seasonal Variation in Wildlife-Vehicle Collisions

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ABSTRACT -- To understand seasonal variation in the number of wildlife-vehicle collisions and the influence of land cover type on collision distribution we counted road-kill carcasses for 84 weeks along a 40 km route on two state highways in northeastern Kansas. We noted land cover type adjacent to each road-kill and tested the null hypothesis that road-kills were distributed randomly with respect to land cover type. Wildlife-vehicle collisions were not distributed randomly in relation to land cover availability. Instead, collisions occurred more often then expected adjacent to riparian areas and less often than expected adjacent to agricultural fields. Wildlife-vehicle collisions varied seasonally and occurred most frequently during the fall. Seasonal changes in traffic volume were not related to the number of wildlife-vehicle collisions observed. Knowledge of land cover types in which wildlife-vehicle collisions are more likely to occur might help wildlife managers and state transportation departments design strategies to minimize the occurrence of these collisions.

Key words: *Didelphis virginiana*, *Mephitis mephitis*, mortality, *Procyon lotor*, road-kill, roads, *Sciurus niger*, *Sylvilagus floridanus*.

Wildlife-vehicle collisions are detrimental to motorists and wildlife populations. The influence of roads on wildlife includes habitat fragmentation, alteration of movement patterns, and mortality from collisions with vehicles (Forman and Alexander 1998, Trombulak and Frissell 2000, Forman et al. 2003). Roads might influence wildlife populations by reducing dispersal success, reducing gene flow between populations, and constitute a source of mortality for some species

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(Maehr et al. 1991, Trombulak and Frissell 2000). Many of the environmental impacts associated with roads might extend beyond the road surface and associated right-of-way (Forman and Deblinger 2000). Drivers might sustain property damage or personal injury in the event of a wildlife-vehicle collision, particularly when involved in collisions with large ungulates (Conover et al. 1995, Romin and Bissonette 1996, Malo et al. 2004). Collisions with medium-sized mammals also might result in property damage or injury caused by the actual collision or by evasive action taken by drivers to avoid animals in the roadway. Knowledge of how wildlife-vehicle collisions vary seasonally and according to land cover types present along roadways might enhance both wildlife conservation efforts and highway safety.

The locations of wildlife-vehicle collisions might reflect the relative use of particular land cover types by wildlife and indicate how anthropogenic habitat alterations might influence the distribution and richness of wildlife within a landscape (Caro et al. 2000). Anthropogenic habitat alteration is particularly evident in the tallgrass prairie biome, as this system has been reduced to approximately four percent of the area it covered historically (Samson and Knopf 1994). In Kansas, it is estimated that there has been an 86 % decline in tallgrass prairie following settlement, with most of the remaining prairie located within the Flint Hills (Samson and Knopf 1994). In eastern Kansas, analysis of satellite imagery revealed an increase in urban development and woodland areas from 1984 to 2000 (Applegate et al. 2003). Reduction and fragmentation of grassland habitat has been related to population declines of some species while other species increase in abundance in response to forestation and urbanization (Adams 1995, Applegate et al. 2003). Wildlife-vehicle collision patterns might provide insight into how land use patterns influence mammal populations (Caro et al. 2000), and as a possible indicator of changes in the distribution and abundance of wildlife that might occur as a result of increasing road network development and land use change. In our study we examined seasonal changes in the number of wildlife-vehicle collisions and the distribution of collisions among specific land cover types by conducting weekly surveys of mammalian road-kills in the Flint Hills of northeastern Kansas.

METHODS

The locations of wildlife-vehicle collisions were monitored weekly along sections of Kansas state highways K-18 and K-99 in northeastern Kansas from 1 October 2002 to 30 May 2004. The survey route on K-99 was located between Alma and Wamego, Kansas and was 20.1 km in length. The survey route on K-18 was 22.5 km in length, and was located between Manhattan, Kansas and the junction of K-99 and K-18. Both survey routes were two-lane undivided highways.

Survey routes were established along these highways because they encompassed a variety of interspersed land cover types including grassland, cropland, residential, and woodland areas. These survey routes are representative of the type of highways commonly found in the region, and medium-sized mammals appear to be particularly prone to mortality on these types of highways (Hughes et al. 1996, Forman and Alexander 1998). A mowed right-of-way of standard width (4.6 m) was maintained throughout the study period on both survey routes.

Traffic counts for 2002, 2003, and 2004 were obtained from the Kansas Department of Transportation for both survey routes (Terry Barnes, Kansas Department of Transportation, unpublished data). Annual average daily traffic volume was estimated for the combined survey routes by averaging traffic counts from Kansas Department of Transportation recording stations along each highway. During the study period estimates of annual average daily traffic from Kansas Department of Transportation traffic recorder locations ranged from 415 to 565 along K-18, and from 1930 to 3150 along K-99. Annual estimates of daily traffic volume were adjusted for monthly variation by using a regional correction factor for northeastern Kansas (Terry Barnes, Kansas Department of Transportation, unpublished data). Pearson correlation coefficients were calculated (PROC CORR; SAS Institute Inc. 2001) to examine the relationship between monthly estimates of traffic volume and the number of road-kill carcasses found for common species.

Road-kill surveys were conducted by driving slowly (55-65 km/hr) along each highway and recording each road-kill carcass observed along the road or in the right-of-way. For each road-kill carcass observed, the location, species, and land cover type on each side of the roadway was recorded. Road-kill locations were marked by using spray paint to avoid double counting, as road-kills often remained for several weeks. Land cover types on both sides of the road were recorded for each road-kill observed, since it was not always possible to conclusively determine which habitat was being used by the animal prior to the collision (Caro et al. 2000). By counting both sides of the roadway, land cover types were classified as croplands, including row crops and tilled fields, (47.3 km), grasslands (14.5 km), residential areas (12.8 km), woodlands (15.3 km), and riparian areas (3.4 km). Riparian areas were defined as woodlands within 50 m of a stream running either parallel or perpendicular to the roadway. The amount of each land cover type present was recorded during fall 2004 by slowly driving the survey routes and recording the distance of each land cover type on both sides of the roadway based on odometer readings. The mileage recorded for each land cover type on both sides of the road was converted into a proportion of the total linear miles along the survey route to determine overall availability of each land cover type.

A chi-square test was used to determine if road-kills were distributed according to the amount of available land cover, or if they occurred more or less often than expected within certain land cover types. Observed values for chi-square tests were determined by recording the land cover type on both sides of the roadway adjacent to each road-kill carcasses (two cover types were assigned for each road-kill carcass) and adding up the total number of times each land cover type was recorded for each species. Expected values were determined by multiplying twice the total number of road-kill caracasses found for a particular species by the proportion of land cover type found along both sides of the survey routes.

The Shapiro-Wilk statistic and normal probability plots for residuals indicated that our data were not distributed appropriately to meet the assumptions of normality necessary for the use of analysis of variance to test for seasonal differences (Ott and Longnecker 2001). However, Levene's test revealed that variances were homogeneous among seasons for all species. Differences in the number of road-kill carcasses observed seasonally were compared by using a Kruskal-Wallis test (PROC NPAR1WAY; SAS Institute Inc. 2001) with seasonal data pooled across years. This nonparametric procedure was used to test for seasonal differences in the number of road-kills for Virginia opossum (*Didelphis virginiana*), raccoon (*Procyon lotor*), eastern fox squirrel (*Sciurus niger*), eastern cottontail (*Sylvilagus floridanus*), and striped skunk (*Mephitis mephitis*). Seasons were defined as winter (December-February), spring (March-May), summer (June-August), and fall (September-November). The dates for these seasons were chosen because they generally correspond to changes in vegetation phenology, average temperature, and life history characteristics of species in the region.

RESULTS

A total of 172 mammalian road-kill carcasses was recorded from 1 October 2002 to 30 May 2004. Virginia opossum (n = 61) was the most frequently encountered species, followed by eastern fox squirrel (n = 29), eastern cottontail (n = 28), striped skunk (n = 17), raccoon (n = 17) and domestic cat (*Felis catus*) (n = 16). Other species recorded included coyote (*Canis latrans*) (n =1), bobcat (*Lynx rufus*) (n = 1), woodchuck (*Marmota monax*) (n = 1), and white-tailed deer (*Odocoileus virginianus*) (n = 1).

The number of road-kills varied seasonally for Virginia opossum ($\chi^2 = 21.8$, $P < 0.001$), raccoon ($\chi^2 = 15.9$, $P = 0.001$), and all species combined ($\chi^2 = 20.7$, $P < 0.001$) (Table 1). For Virginia opossum and all species combined, significant pairwise differences ($P < 0.05$) were present between the number of road-kills during the fall season and the number of road-kills during the spring, summer, and winter seasons (Table 1). For raccoon, the number of road-kills found during the fall differed from the number found during both the spring and the winter (Table 1). Seasonal variation in road-kills was not evident for striped skunk ($\chi^2 = 3.06$, $P = 0.38$), eastern cottontail ($\chi^2 = 3.7$, $P = 0.29$), or eastern fox squirrel ($\chi^2 = 5.4$, $P = 0.14$)

Table 1. Average number of road-kill carcasses/week found along survey routes on a seasonal basis.

	Season			
Species	Spring	Summer	Fall	Winter
Virginia opossum	0.35 a[1]	0.42 a	1.57 b	0.48 a
Raccoon	0.08 b	0.17 ab	0.52 a	0.04 b
Striped skunk	0.23	0.08	0.30	0.13
Eastern cottontail	0.27	0.17	0.43	0.39
Eastern fox squirrel	0.50	0.17	0.17	0.39
All species combined	1.69 a	1.75 a	3.61 b	1.91 a

[1]The same letter within a row indicates no pairwise differences between seasons ($\propto$ = 0.05). No letters present in a row indicates that pairwise tests were not conducted.

(Table 1). Seasonal variation was not tested for other species due to the limited numbers observed during the study period.

Monthly estimates of annual average daily traffic volume were not correlated with the overall number of road-kill carcasses found for the month ($r^2 = 0.029$, P = 0.48), or for the number of road-kill carcasses found for common species including Virginia opossum ($r^2 = 0.004$, P = 0.80), striped skunk ($r^2 = 0.055$, P = 0.32), raccoon ($r^2 = 0.092$, P = 0.20), eastern cottontail ($r^2 = 0.029$, P = 0.47), or eastern fox squirrel ($r^2 = 0.116$, P = 0.14).

Overall numbers of road-kill carcasses were distributed nonrandomly with respect to land cover type ($\chi^2 = 164.1$, P < 0.001) (Table 2). Road-kills were found more often than expected adjacent to riparian areas and less often than expected adjacent to agricultural fields. Individual species whose road-kill locations were associated with particular land cover types included Virginia opossum ($\chi^2 = 38.03$, P < 0.001), eastern cottontail ($\chi^2 = 45.7$, P < 0.001), eastern fox squirrel ($\chi^2 = 155.11$, P < 0.001), and striped skunk ($\chi^2 = 14.28$. P = 0.006) (Table 2). Virginia opossum was found more often than expected adjacent to riparian areas and less often than expected adjacent to agricultural areas. Eastern cottontail was found more often than expected in pasture and residential areas, and less often than expected adjacent to agricultural areas. Eastern fox squirrel was found more often than expected adjacent to riparian and woodland areas and less often than expected adjacent to agricultural areas. Striped skunk was found more often than expected adjacent to riparian areas.

Table 2. Proportion of land cover types present along survey routes and proportion of land cover types recorded adjacent to road-kill carcasses for each species.

	Land cover type				
	Cropland	Residential	Grassland	Woodland	Riparian
Proportion available	0.507	0.145	0.155	0.164	0.036
Virginia opossum	0.311	0.156	0.205	0.205	0.123
Raccoon	0.265	0.206	0.176	0.294	0.059
Striped skunk	0.323	0.147	0.176	0.206	0.147
Eastern cottontail	0.142	0.250	0.411	0.125	0.071
Eastern fox squirrel	0.069	0.103	0.017	0.569	0.241

DISCUSSION

Seasonal variation in animal behavior and activity patterns might be responsible for observed temporal variation in the number of road-kills. The Virginia opossum was the species most frequently found during our study, and the increase in collisions during the fall season could be related to an increase in movement distances of juveniles during this time (Fitch and Shirer 1970, Gillete 1980). During the summer, young individuals of Virginia opossum move limited distances, but these distances increase as the young mature during October and November (Fitch and Shirer 1970). As temperatures grow colder during late winter, Virginia opossum limits activity and decreases distances traveled (McManus 1974). Increased movement distances during fall by young Virginia opossum might contribute to the increased number of road-kills found during this season. Virginia opossum populations in northeastern Kansas generally peak in abundance during fall, with winter mortalities reducing overall population size until reproduction occurs in the spring (Fitch and Sandidge 1953).

The higher number of raccoon road-kills observed during the fall might be related to juvenile dispersal (Lotze and Anderson 1979, Gehrt 2003) or increased home range sizes (Prange et al. 2004) during this time. Decreased activity by raccoon during colder temperatures (Stains 1956, Gehrt 2003) also might be responsible for the lower number of road-kills observed during the winter compared to the fall.

Our results are consistent with other studies that also have reported a lack of correlation between traffic volume and the number of observed road-kills (Case

1978, Cristoffer 1991, Clevenger et al. 2003). In our study, seasonal changes in traffic volume were not related to the number of road-kill caracasses found. Traffic volumes peaked during the summer while the number of road-kill carcasses observed peaked during the fall. In our study seasonal variation in animal behavior and abundance might have been more influential in determining the frequency of wildlife-vehicle collisions than seasonal changes in traffic volume. However, overall traffic volume along our study routes could be considered relatively low for all seasons (< 3200 AADT), and that large increases in overall traffic volume over time might result in an increase in the number of wildlife-vehicle collisions and decreased highway permeability (Alexander et al. 2005).

Wildlife-vehicle collisions were distributed non-randomly with respect to land cover type; they occurred most often adjacent to riparian areas. Riparian zones often occurred as linear corridors within the landscape matrix, and possibly were used as travel corridors by species that prefer woodland areas such as Virginia opossum (McManus 1974), raccoon, and eastern fox squirrels (Rosenblatt et al. 1999). Since riparian zones often were isolated woodlands that ran perpendicular to the roadway, they might have acted as conduits for animal movements across the road. Woodland areas not associated with streams usually consisted of larger habitat patches that not necessarily were oriented perpendicular to the roadway. This could explain why the number of road-kills was higher within riparian areas than within woodland areas not associated with streams.

Cropland did not appear to be used frequently by the species we detected, as the fewest number of road-kills for all species occurred adjacent to this land cover type. Although agricultural crops are often used in summer and fall for food by raccoon (Stains 1956), other mammalian species might not use large cropland areas consistently due to the lack of suitable cover, den sites, or preferred forage (Chapman et al. 1980, Mankin and Warner 1999). An alternative interpretation is that some species are less likely to enter the roadway when traversing cropland areas and might prefer to use areas with more cover as crossing locations. Further study is needed to determine species-specific movement patterns and habitat use in relation to road crossing locations.

Grasslands and residential areas were often the land cover types adjacent to eastern cottontail road-kills. Residential areas along our survey routes might have been suitable habitat for eastern cottontail, because they consisted primarily of scattered farmsteads interspersed with other habitats. Patches of shrubs, including smooth sumac (*Rhus glabra*) and rough-leafed dogwood (*Cornus drummondii*), were frequently present within grassland areas along the survey routes. These shrub patches interspersed with grasslands provide cover and preferred habitat for eastern cottontail (Chapman et al. 1980, Chapman and Litvaitis 2003).

Wildlife-vehicle collisions are a considerable source of mortality for medium-sized mammals (Kamler and Gipson 2004) and thus, there is a need to understand the conditions that might influence the location and timing of collisions. Wildlife-vehicle collisions in our study varied seasonally with the highest totals occurring during the fall. We suggest that this pattern was not related to traffic volume, but was primarily due to seasonal variation in population size and behavior. Riparian areas might enhance connectivity on a landscape by acting as corridors for medium-sized mammals. Since riparian areas have been identified as potential high likelihood crossing locations, placing culverts along riparian areas or enhancing the crossing suitability of existing underpasses to increase landscape connectivity might mitigate against wildlife-vehicle collisions (Clevenger et al. 2001, Forman et al. 2003). Few animals were killed adjacent to cropland, which suggested that further conversion of grassland and woodland habitat to row crop agriculture might not benefit medium-sized mammals.

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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 distributed widely 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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Manuscript submissions and correspondence should be directed to Elmer J. Finck, Editor, *The Prairie Naturalist*, Department of Biological Sciences, Fort Hays State University, 600 Park Street, Hays, KS 67601-4099, e-mail: efinck@fhsu.edu More detailed instructions for authors can be found on *The Prairie Naturalist* web site at: http://www.fhsu.edu/biology/pn/prairienat.htm.

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