Physical Characteristics, Shade Distribution, and Tall Fescue Effects on Cow Temporal/Spatial Distribution in Midwestern Pastures

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Abstract

Nonpoint source (NPS) pollution of water resources may occur from congregation of cattle near streams or ponds. Therefore, relationships of physical characteristics, shade distribution, and tall fescue (*Festuca arundinacea* Schreb.) prevalence in cool-season grass pastures to the temporal/spatial distribution of grazing cattle were evaluated in two studies on beef cow/calf farms. Global positioning system (GPS) collars recorded the location of 2–3 cows per pasture at 10-min intervals for 5–14 d in the spring, summer, and fall annually. Pasture botanical composition was visually assessed annually. In Study 1, cow location was recorded on five pastures ranging in size from 13 ha to 125 ha with 1.9–3.8% of the pasture area in a stream or pond (water source) and 2–30% of the pasture area within 30.5 m of the water source (waterside zone) for 3 yr. Shade covered 27–73% of the pasture area with 3–64% of shade located within waterside zone. In Study 2, cow location was recorded in three pastures with areas of 8 ha, 10 ha, and 15 ha with 17.8%, 43.4%, and 14.7% of the total area and 28%, 73%, and 68% of the total shade in the waterside zone for 1 yr. In Study 1, proportions of cow observations within the waterside zone increased with decreasing pasture area ($r^2=0.61$) and increasing proportions of the total pasture area ($r^2=0.37$) and shade ($r^2=0.29$) within the waterside zone. In Study 2, proportion of cow observations in the waterside zone increased as the proportion of total area ($r^2=0.62$) and shade ($r^2=0.42$) in the waterside zone increased. Results imply more restrictive measures to minimize the risks of NPS pollution of water resources may be most effective in smaller and narrow pastures.

Resumen

La contaminación de origen no identificado (NPS) de los recursos hídricos, puede ocurrir debido a la congregación del ganado cerca de los arroyos o estanques. Por lo tanto, las relaciones de las características físicas, distribución de la sombra y la incidencia de Festuca alta (*Festuca arundinacea* Schreb.) en potreros con gramíneas de crecimiento invernal en la distribución temporal/espacial del pastoreo del ganado se evaluaron en dos estudios en una granja de vaca-becerro. Collares de sistema de posicionamiento global (GPS) registraron la ubicación de 2 a 3 vacas por potrero a intervalos de 10 minutos de 5 a 14 en la primavera, verano y otoño anualmente. La composición botánica de los potreros se evaluó visualmente cada año. En el estudio 1, conducido durante tres años, la ubicación de las vacas se registró en cinco potreros con un rango de 13 a 125 hectáreas de extensión, con 1.9 a 3.8% de la superficie del potrero en arroyos o estanques (fuente de agua) y 2 a 30% de la superficie del potrero dentro de 30.5 m de distancia de la fuente de agua (zona de agua) para 3 años. Los sombreaderos cubrieron de 27 a 37% del área del potrero con 3 a 64% de la sombra ubicada dentro de la zona del agua. En el estudio 2, la ubicación de las vacas se registró en tres potreros con áreas de 8, 10, y 15 hectáreas con 17.8, 43.4 y 14.7% de la superficie total y 28, 73 y 68% de la sombra total en la zona del agua y se evaluó durante un año. En el estudio 1, las proporciones de las observaciones de las vacas dentro de la zona del agua aumentaron con la disminución de la superficie del potrero ($r^2=0.61$) y aumentaron las proporciones de la superficie total del potrero ($r^2=0.37$) y con la sombra ($r^2=0.29$) dentro de la zona del agua. En el estudio 2, aumento la proporción de observaciones de vaca en la zona del agua conforme la proporción de la superficie total ($r^2=0.62$) y sombra ($r^2=0.42$) en la zona del agua aumentó. Estos resultados sugieren medidas más preventivas para minimizar los riesgos de contaminación de NPS en los recursos hídricos y puede ser más eficaz en potreros más estrechos y pequeños.

Key Words: beef cows, GPS pasture size, grazing, shade, water quality

INTRODUCTION

Much of the heat gained by cattle from the environment during daylight hours occurs by solar radiation (Fuquay 1981). Therefore, providing shade for cattle reduces the deleterious effects of heat stress (Tucker et al. 2008). Because both shade and water are present in pasture riparian areas, grazing cattle congregate near pasture streams to maintain thermoregulation (Kauffman and Krueger 1984; Bailey 2005; Franklin et al. 2009). Because distribution of cattle and nutrient excretions are related (Tate et al. 2003), congregation of cattle will increase concentrations of fecal nutrients and pathogens near shade and water resources (White et al. 2001; Ballard and Krueger 2005).

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Research on western rangelands implies that overutilization of pasture riparian areas by livestock negatively impacts riparian ecosystems (Kauffman and Krueger 1984; DelCurto et al. 2005; Ganskopp and Bohnert 2009) and surface water quality (Belsky et al. 1999). Because the impairment of thermoregulation in grazing cattle is exacerbated by increased environmental temperatures (Zuo and Miller-Goodman 2004) and endophyte-infected tall fescue (*Festuca arundinacea* Schreb.; Al-Haidary et al. 2001) common to the humid eastern United States, risks of sediment, nutrient, and pathogen loading of water resources may be elevated in this region.

Relationships have been established between distribution of grazing livestock and pasture characteristics such as size and shape (Bryant 1982; Hart et al. 1993; Sevi et al. 2001), shade distribution (McIlvin and Shoop 1971; Blackshaw and Blackshaw 1994), and botanical composition (Bailey et al. 1996; Ganskopp and Bohnert 2009) on western rangelands. But because rangeland pastures tend to be large and more heterogeneous in botanical composition and terrain (Bailey 2005; Bailey et al. 2008; Ganskopp and Bohnert 2009), and to contain less tall fescue than midwestern pastures (DelCurto et al. 1999; McInnis and McIver 2001), it is unclear whether these relationships apply to midwestern pastures.

Therefore, objectives of this project were to evaluate the effects of pasture physical characteristics, shade distribution, and tall fescue prevalence in relation to climatic factors on the temporal/spatial distribution of grazing cattle in midwestern pastures. These objectives were addressed through two studies to provide site-specific information in midwestern pastures to assist producers with management decisions to further minimize grazing cattle's impact on water quality.

MATERIALS AND METHODS

Site Description

Study 1. Five pastures in the Rathbun Lake watershed in southern Iowa on cooperating beef cow/calf operations were identified as appropriate for the project in the fall of 2006. Sites selected for the project were based on the producer's willingness and ability to handle cattle for attaching and detaching GPS collars two times during the spring, summer, and fall grazing seasons over a 3-yr period (2007–2009) and if the pasture contained a perennial flowing stream or pond in which cattle had uncontrolled access. However, only four of original five pastures were used during the 2009 grazing season, as Farm A was subdivided and used as described in Study 2. Pastures ranged in size from 13.5 ha to 125.2 ha (Table 1). The landscape within the Rathbun Lake watershed is characterized by rolling uplands, integrated drainage, and some occasional broad alluvial plains, which limits use, as soils are moderately and highly erosive, root-restricted, excessively wet, and low in fertility (Rathbun Land and Water Alliance [RLWA], 2001). Major soil types within the pastures of the study included Adair, Caleb, Clarinda, Colo, Gara, Kniffin, Lawson-Nodaway, Olmitz-Vesseler-Colo, and Seymour with slopes ranging from 0% to 30% (NRCS Web Soil Survey[1]). Water sources in these pastures included both streams and ponds on Farms C and E, streams on Farms A and D, and ponds on Farm B. In analysis of aerial photos with a maximum resolution of 1 m with the use of ArcGIS 9.2 (ESRI, Redlands, CA), a 10-m buffer from the center of each stream or edge of each pond was designated as the area of the water source. Areas within 30.5 m and greater than 30.5 m from a water source were referred to as the waterside zone and upland zone, respectively. Total pasture shade area and the proportion of total shade in the waterside zone were determined from aerial photos with the use of ArcGIS 9.2 (ESRI) software. The percentage of shade in the total pasture or waterside zone was determined by dividing the shaded area by the area in the total pasture or waterside zone, respectively. Waterside shade, as a percentage of the total pasture shade, was determined by dividing the area of waterside shade by the area of shade in the total pasture. Waterside zone comprised 2–30% of the total pasture area and contained 3–64% of the pasture shade.

Because of the limited number of producers willing to handle their cattle as frequently as required, there was considerable variability in cattle and pasture management. Cattle on Farm A

[1]http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

Table 1. Physical characteristics of pastures in Studies 1 and 2.

Farm/pasture	Year	Pasture size (ha)	Cattle breeds	Water source	Pasture shade (% of pasture area)	Waterside zone (% of pasture area)	Waterside zone shade (% of waterside zone)	Waterside zone shade (% of total pasture shade)
Study 1								
A	2007–2008	125.2	Angus	Stream	57.8	24.3	79.1	33.3
B	2007–2009	64.9	Angus	Ponds	59.6	2.5	67.2	2.8
C	2007	92.2	Angus Cross	Stream and ponds	30.5	17.2	79.1	44.8
	2008–2009	29.2	Angus Cross	Stream and ponds	39.9	30.0	84.8	63.8
D	2007–2009	21.3	Angus	Stream	72.8	22.4	68.0	20.9
E	2007–2009	13.5	Mexican Corriente	Stream and ponds	27.2	28.7	55.5	58.4
Study 2								
1N	2009	15.1	Angus	Stream	19.4	14.7	89.7	67.6
2NE	2009	8.0	Angus	Stream	41.6	17.8	66.4	28.4
3S	2009	9.9	Angus	Stream	21.8	43.4	36.5	72.6

Figure 1. Aerial photo of pastures created on Farm A in 2009.

consisted of multiparous fall-calving Angus cows (*Bos taurus* L.) during the spring grazing seasons, and spring-calving cows during the summer and fall grazing seasons. Spring-calving heifers were used during the fall of 2007, because mature cows were unavailable. Farm D used multiparous fall-calving Angus cows during spring of 2007 and 2008 and multiparous spring-calving cows during spring 2009. During summer of 2007 and 2009 and fall of 2007, 2008, and 2009, multiparous spring-calving cows were used on Farm D. Cows used during the spring, summer, and fall grazing seasons of 2007–2009 were spring-calving, multiparous Angus, Angus-cross, and Mexican Corriente cows on Farms B, C, and E, respectively. Cows were rotationally stocked from March through November at 0.6 cows $\cdot$ ha^{-1}, 0.7 cows $\cdot$ ha^{-1}, and 1.5 cows $\cdot$ ha^{-1} on Farms A, C, and E, whereas cows were continuously stocked from March through November at 0.5 cows $\cdot$ ha^{-1} and 1.9 cows $\cdot$ ha^{-1} on Farms B and D, respectively, during the 3-yr grazing trial.

Study 2. In 2009, an additional study was conducted to evaluate the effects of shade distribution in pastures of more comparable sizes on cattle distribution. Part of the pasture on Farm A was divided into three pastures with sizes of 8.0 ha, 9.9 ha, and 15.1 ha (Table 1 and Fig. 1). The waterside zone comprised 17.8%, 43.4%, and 14.7% of the total pasture area and contained 28.2%, 72.6%, and 67.6% of the pasture shade, respectively. Mature fall-calving Angus cows were rotationally stocked during spring and summer and mature spring-calving cows were rotationally stocked during the fall with uncontrolled access to the streams at 1.0 cows $\cdot$ ha^{-1}, 1.9 cows $\cdot$ ha^{-1}, and 1.5 cows $\cdot$ ha^{-1}, respectively.

Cattle Distribution

Because of the need to synchronize the timing of attachment and detachment of the GPS collars with each cooperating producer's management schedule, GPS measurements were not conducted simultaneously on all farms. Instead, measurements among farms were grouped into the spring, summer, or fall seasons. Spring was defined as the vernal equinox to the summer solstice. Summer was defined as the summer solstice to the first day of the autumnal equinox. Fall was defined as the autumnal equinox to the winter solstice. In each season of both studies, two to three cows on each farm were randomly selected from the herd and fitted with custom prototype GPS collars (Engineering Services Group [ESG], Ames Laboratory, US Department of Energy, Ames, IA) with LEA-4S receivers (U-Blox AG, Switzerland) that recorded cattle locations at 10-min intervals 24 h $\cdot$ d^{-1} for periods of 5–14 d. The GPS collars weighed approximately 1.65 kg, less than 0.3% of a cow's body weight. Custom prototype collar accuracies have been previously reported by Schwarte et al. (2011). If collars stopped recording cattle locations before four complete days, the data set was not analyzed. Four days of data collection was an arbitrary number selected to allow adequate time for cattle to adjust to the collar and, if necessary, pasture. During the 3-yr study, technology failure of GPS collars occurred 10.9% of the time.

Collars were placed on two cows on Farm D during spring 2007, but both collars malfunctioned and did not collect data. During fall 2007, bred heifers were improperly fitted with collars on Farm A and two of the three collars were lost in the 125-ha pasture. During summer 2008, collars were not placed on cattle from Farm D, as flooding removed pasture fences. For determination of temporal/spatial distribution of the cattle, position coordinates of each GPS measurement were located on aerial maps with the use of ArcGIS 9.2 software (ESRI) and categorized as being located in the water source, waterside zone, or upland zone. The proportion of GPS observations within each zone was determined by the number of observations in each zone divided by the total number of GPS observations during the deployment of the collar. The proportion of observations in each zone was averaged from all collared cows in a pasture to determine the proportion of time in each zone in each season.

Microclimatic Data

A HOBO weather station (Onset Comp. Co., Bourne, MA), placed adjacent to the pastures on each of the five farms, recorded microclimate factors of ambient temperature (Temp), black globe temperature (BGTemp), dew point (DP), wind speed (WS) and direction, and relative humidity (RH) at 10-min intervals during the grazing seasons. During summer 2008, three of the five weather stations were damaged by lightning and stopped recording data for approximately 4 wk. Therefore, the remaining two functioning weather stations in the closest proximity to the farms where cattle location was being determined at that time were used to replace missing data for the damaged weather stations. Microclimate factors were used to calculate effective temperature (ET; Yamamoto et al. 1994), temperature humidity indexes (THI; Buffington et al. 1981; Yousef 1985; Mader et al. 2006), and black globe temperature humidity indexes (BGTHI; Buffington et al. 1981; Meat and Livestock Australia 2002; Castañeda et al. 2003; Mader et al. 2006; Gaughan et al. 2008).

Vegetative Composition and Cover

In the spring of 2007, vegetative composition of each pasture in Study 1 was determined by dividing the three largest pastures (Farms A, B, C) into 100×100 m grids and the two smaller pastures (Farms D and E) into 50×50 m grids on aerial photos with the use of ArcGIS 9.2 software (ESRI). The pastures in Study 2 were evaluated with the use of the same 100×100 m grid of the pasture on Farm A to maintain consistent evaluation of botanical composition from the two previous years. In late spring of each year, vegetative species of individual plants or bare ground at the center and at four equidistant locations from the center of each square of the grid in each pasture, as located by a handheld GPS receiver (Garmin 72, Overland Park, KS) were visually identified. Observations of individual forage species were divided by the number of herbaceous species within each grid and proportions of each herbaceous species from all surveyed grids were summed and divided by the total number of vegetated sites to determine the total percentage of herbaceous species within each pasture. The proportion of sites with shrubs or bare ground was calculated as a proportion of sites with these characteristics and divided by the total number of sites surveyed over the entire pasture. Because the majority of cool-season grasses were identified as tall fescue and reed canarygrass (*Phalaris arundinacea* L.) within the pastures, the remaining minimal proportions of cool-season grasses were combined and labeled as other cool-season grasses.

As vegetative composition was being determined in 2009, vegetative tillers of each tall fescue plant were hand plucked when identified in a grid within each pasture, placed in bags, and stored on ice for transport to the laboratory. One hundred fresh tall fescue tillers from each farm were randomly selected and evaluated for the presence of the ergot alkaloid-producing endophyte fungus (*Neotyphodium coenophialum*) by the procedure of Franklin et al. (2009). Samples testing positive for the endophyte were divided by total samples tested to determine the percentage of infected samples within each pasture.

Statistical Analysis

Effects of farm and season on the proportion of GPS observations within the water source or waterside zone of pastures in Study 1 were analyzed with the use of the MIXED procedure of SAS (SAS Institute Inc., Cary, NC) with a model statement including farm and season and farm by season with a random effect of farm by season by year interaction using year as the replicate. Effects of pasture on the proportion of GPS observations within the water source or waterside zone of pastures in Study 2 were analyzed with the use of the MIXED procedure of SAS with a model statement of pasture and season and a random effect of pasture by season with season used as the replicate. Differences in botanical composition of farm pastures in Study 1 were analyzed by the MIXED procedure of SAS with a model statement that included farm and year using year as the blocking factor and farm within year as the random effect. Differences between means of farms or pastures with significant effects were determined by comparing the least-squares means (LSMeans) with the use of the probability of difference (PDIFF) statement along with a Tukey adjustment. Significance was determined at a level of $P < 0.05$ with a tendency expressed as $0.05 < P \leq 0.10$.

The LOGISTIC procedure (SAS Institute) was utilized to analyze the effects of Temp, BGTemp, ET, THI, and BGTHI on the probability of cattle being in the waterside zone in both studies. Each GPS observation within the waterside zone was paired with each temperature or heat index and an odds ratio was calculated as the number of observations that a cow was within the waterside zone divided by the total number of observations at that temperature or heat index unit. The microclimatic variable that best predicted the presence of cattle within the waterside zones of each pasture was ambient temperature, as determined with the use of Akaike's information criteria (AIC; data not shown). Therefore, ambient temperature was used to compare differences between pastures for the probabilities that cattle were within the waterside zone.

To quantify the effects of pasture physical and botanical characteristics on the temporal/spatial distribution of grazing cattle in Study 1, regressions using the proportion of GPS measurements in the water source or waterside zones of pastures as dependent variables were calculated with independent variables of pasture size, proportion of waterside zone in each pasture, proportion of the total pasture shade located in the waterside zone, and proportion of tall fescue in the herbaceous vegetation of pastures (SAS Institute). To quantify the effects of pasture physical characteristics and shade distribution on the temporal/spatial distribution of grazing cattle in Study 2, regressions using the proportion of GPS measurements in the water source or waterside zones of pastures as dependent variables were calculated with independent variables of proportion of waterside zone in each pasture and the proportion of the total pasture shade located in the waterside zone (SAS Institute). In order to determine significant regression variables from the limited number of farms in the study, a Bonferroni adjustment was performed (0.05 divided by the number of regressions performed) to determine significant pasture characteristic effects. Significance was determined at a level of $P < 0.0125$ and $P < 0.025$ for Studies 1 and 2, respectively.

RESULTS AND DISCUSSION

Study 1: Factors Influencing Cattle Distribution

Cattle Distribution. Cattle from all pastures tended ($P < 0.10$) to spend a greater proportion of time in the water source during the summer (4.24%) than fall (2.79%) seasons, but were not different than spring (3.20%; data not shown). The proportion of time that cattle spent in the water source differed ($P < 0.05$) by farms. Cows on Farm D spent a greater proportion of time in the water source than cows on Farms A, B, and C, but were

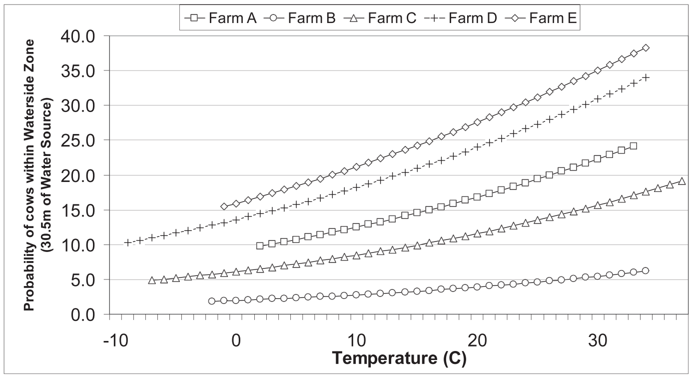

Figure 2. Effect of ambient temperature on the probability of cows in Study 1 located within the waterside zone (30.5 m of water source) by farms over the 3-yr study.

similar to cows on Farm E. Cows on Farm E were located in the water source a greater percentage of observations ($P < 0.05$) than cows on Farms A and B, but not different ($P > 0.10$) from cows on Farm C. Cows on Farms A, B, and C were located in the water source a similar percentage of observations. However, season did not affect ($P > 0.10$) the proportion of time that cattle were located in the waterside zone. Cows on Farms D and E spent a greater percentage of time ($P < 0.05$) in the waterside zone compared to cows on Farms A and C, which spent a greater proportion of time in the waterside zone than cows on Farm B. The differences in the probabilities of being within the waterside zone among farms occurred across the range of ambient temperatures that occurred during the study (Fig. 2).

The proportions of time that cattle in this study spent in the water source are less than the results of other studies. Agouridis et al. (2004) found that cattle in 2.0- and 3.0-ha pastures in Kentucky spent nearly 8% and 14% of the time within 5 m of a stream. Byers et al. (2005) reported that cattle spent 5–13% of the time in the riparian area, defined as 12 m from the center of the stream, on 3.8–5.5-ha endophyte-infected tall fescue and common bermudagrass pastures in Georgia from May to August. Differences in vegetation, pasture characteristics, and climate may be responsible for the observed differences in cattle distribution.

Botanical Composition. The pastures primarily contained tall fescue and reed canarygrass with smaller proportions as other cool-season grasses: Kentucky bluegrass (*Poa pratensis* L.), smooth bromegrass (*Bromus inermis* L.), and orchardgrass (*Dactylis glomerata* L.), along with legumes: white clover (*Trifolium repens* L.), red clover (*Trifolium pretense* L.), and birdsfoot trefoil (*Lotus corniculatus* L.), and squarrose sedge (*Carex squarrosa* L.), broadleaf weeds, and shrubs. The proportions of reed canarygrass and legumes in the herbaceous vegetation and proportions of bare ground and shrubs in the pastures differed ($P < 0.01$; Table 2) among farms. There also tended ($P < 0.10$) to be differences for the proportion of tall fescue, other cool-season grasses, and sedge in the herbaceous vegetation among farms. There were no differences ($P > 0.10$) in proportion of broadleaf weeds in the herbaceous vegetation among farms. The most predominant forage species observed on four of the five farms was tall fescue, which ranged from 20% to 51% of the herbaceous vegetation. The predominant forage species on the remaining farm was reed canarygrass. In spite of each pasture having some area within and outside the physical riparian zone, herbaceous vegetation composition across each pasture was relatively homogeneous. Of the tall fescue tillers sampled from each pasture, 97, 85, 87, 84, and 84% were endophyte-infected on Farms A, B, C, D, and E, respectively.

Surprisingly, despite confirmation of endophyte-infected tall fescue in pastures, the proportion of tall fescue in the herbaceous vegetation only had a minimal influence on cattle distribution in the water source and did not influence ($P > 0.10$) cattle distribution in the waterside zone. Tall fescue containing the endophyte has been documented to cause severe vasoconstriction (Rhodes et al. 1991; Oliver et al. 1993; Aiken et al. 2007) and elevated body temperatures and respiration rates when livestock are under heat and humidity stress, such as late spring or summer periods (Hemken et al. 1981; Sprinkle et al. 2000; Al-Haidary et al. 2001). Because the proportion of time cattle were observed in water sources differed by farms in this study, the high proportion of endophyte-infected tall fescue observed in this study may have aided and caused heat stress, which could have caused congregation of the cattle near water sources during periods of increased temperatures or humidities. The lack of significant regressions between the proportion of time that cattle were in the waterside zone and the proportion of tall fescue in the herbaceous vegetation might be attributed to the limited range in this variable and/or the limited number of farms used. Lack of substantial effects of tall fescue on cattle observations in the water source and waterside zones may infer

Table 2. Proportion of sites with major forage species, sedge, broadleaf weeds, shrubs, or bare ground in pastures determined by visual observation to evaluate temporal/spatial distribution (Study 1).

Farm	Tall fescue	Reed canarygrass	Other cool-season grasses	Legumes	Sedge	Broadleaf weeds	Shrubs	Bare ground
	% of vegetated sites						% of all sites	
A[1]	20.1 y	45.5 a	3.8 y	3.5 b	6.4 x	20.7	7.0 b	12.9 a
B[1]	37.0 xy	1.1 c	4.6 y	10.5 b	4.6 x	42.2	17.0 a	13.7 a
C[1]	51.5 x	0.7 c	4.2 y	18.4 a	3.9 x	21.3	2.6 b	5.0 b
D[2]	42.0 x	13.0 b	8.6 xy	9.3 b	4.2 x	22.9	13.6 a	12.5 a
E[2]	44.1 x	0.9 c	14.4 x	19.2 a	1.3 y	20.1	2.1 b	9.2 ab

[1]Species of the individual plant or bare ground located at the center and four equidistant locations from the center of each square of a 100×100 m grid across each pasture.
[2]Species of the individual plant or bare ground located at the center and four equidistant locations from the center of each square of a 50×50 m grid across each pasture.
[a,b,c]Within a column, least-squares means without a common subscript differ ($P < 0.05$) by farm.
[x,y]Within a column, least-squares means without a common subscript tended to differ ($P < 0.10$) by farm.

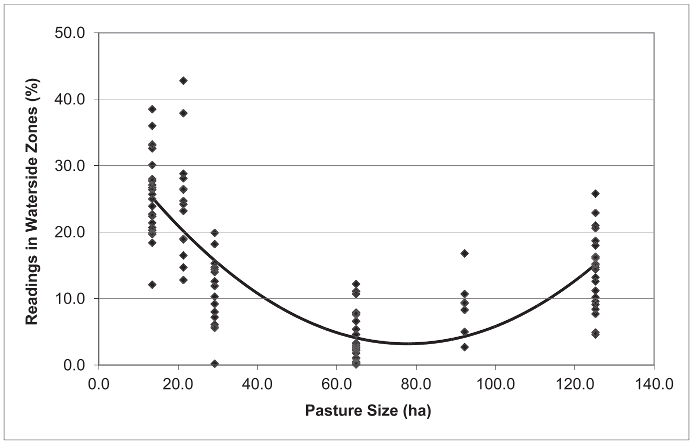

Figure 3. Effect of size of pastures on the percentage of GPS collar readings of cattle distribution patterns in the waterside zones of pastures (Study 1). $Y = 35.40 - 0.83x + 0.0053x^2$; ($r^2 = 0.61$)

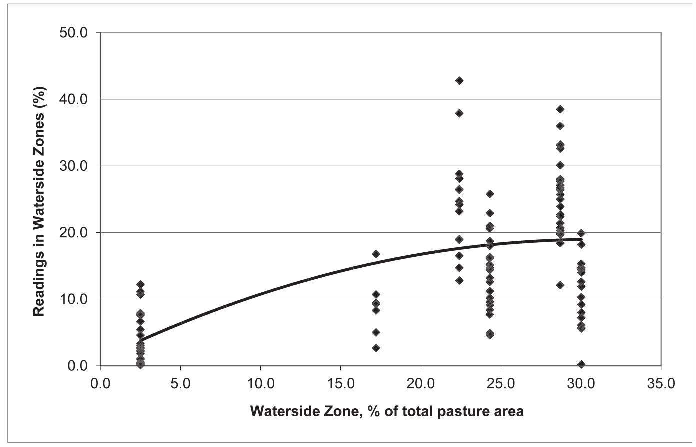

Figure 4. Effect of proportion of total pasture area in the waterside zones of pastures on the percentage of GPS collar readings of cattle distribution patterns in the waterside zones of pastures (Study 1). $Y = 0.99 + 1.169x - 0.019x^2$; ($r^2 = 0.36$)

that additional pasture characteristics were superseding the effects of tall fescue on cattle distribution.

Pasture Size and Shape. Pasture size influenced ($P < 0.0001$) the proportion of time grazing cattle were located in the water source and waterside zones of the pastures. Pasture size accounted for 22% and 61%, respectively, of the variation of total GPS observations within the water source (data not shown) and waterside zone (Fig. 3). Because reducing pasture size may alter forage utilization patterns and reduce the distance livestock travel to water (Hart et al. 1993), the disproportional amount of time livestock may spend in waterside zones of small pastures may impact residual forage height (Clary and Leininger 2000; DelCurto et al. 2005), hoof traffic (Betteridge et al. 1999), and the amounts of fecal and urinary nutrients excreted in the waterside zones of small pastures compared to larger pastures (Tate et al. 2003).

The proportion of the total pasture area within the waterside zone influenced GPS observations of cattle in waterside zones, accounting for 36% (Fig. 4) of the variation of GPS observations of cows in the waterside zones of pastures during Study 1.

Shade Distribution. The proportion of the total pasture shade within the waterside zone accounted for 29% (data not shown) of the variation in the proportion of GPS observations within the waterside zone over the 3 yr. Confounding effects of pasture size and shape in varying-sized pastures in Study 1 may have superseded shade effects influencing cattle distribution. However, because only five pastures with widely varying characteristics were utilized in this project, any relationship inferred by these data should be interpreted with some caution.

Study 2: Pasture Shape and Shade Distribution Effects on Cattle Distribution

Pasture Shape. Although it was intended to have pastures of comparable size, the three pastures in Study 2 varied by 8.0–15.1 ha. The variation in pasture size was due to the pasture location along a major river with streams in an attempt to minimize the number of water gaps while controlling the shade distribution within the pastures. However, in these pastures, the proportion of the pasture within the waterside zone accounted for 62% (Fig. 5a) of the variation of GPS cow observations in the waterside zone during the 1-yr grazing trial. Similar to the current study, pasture shape, orientation, and location influence grazing behavior of livestock (Hart et al. 1993), which may influence the proportion of time cattle are within the water source and waterside zone. Without the opportunity to distribute in other areas, greater nutrient excretion (Tate et al. 2003) and treading damage (Elliott et al. 2002) from livestock near surface waters may increase the risk of nonpoint source (NPS) pollution occurring from grazed pastures.

Shade Distribution. The proportion of total pasture shade located within the waterside zone accounted for 42% (Fig. 5b) of the variation of GPS observations in the waterside zone of pastures of comparable size, implying that shade distribution influenced cattle distribution. However, similar to Study 1, these relationships are being inferred from a limited number of pastures and limited ranges in the proportions of total pasture area and shade. The mean proportion of cow observations in Pastures 1N and 3S were in the waterside zone differed by 0.52%. Because the differences in the proportions of total pasture area and shade in waterside zone of Pastures 1N and 3S were 28.7% and 5.0% units, it seems that pasture shape was a more important determinant of cow distribution than shade in this study.

Shade is an important management strategy that producers may utilize in pastures during high ambient temperatures (Schmidt and Osborn 1993; Sigua and Coleman 2007), periods of high solar radiation (Tucker et al. 2008), and periods of increasing relative humidity (Black Rubio et al. 2008) to reduce the heat load in an attempt to maintain thermal equilibrium (Blackshaw and Blackshaw 1994). Providing nonriparian shade in pastures may encourage cattle to distribute away from surface waters, decreasing the risk of fecal loading (Byers et al. 2005) and promoting more uniform grazing within a pasture (McIlvin and Shoop 1971; Hacker et al. 1988; Laca 2009).

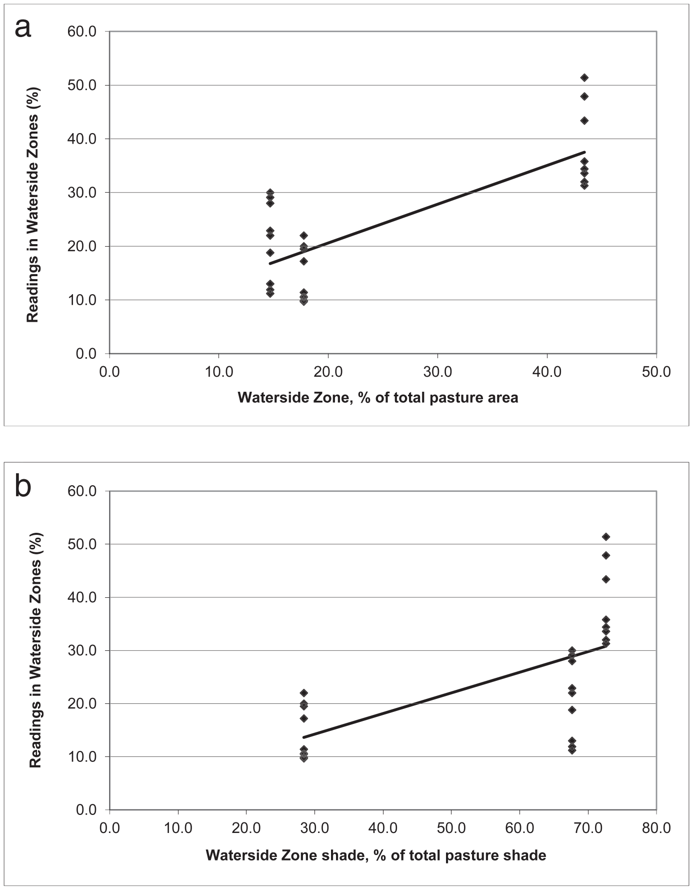

Figure 5. Proportion of GPS cattle observations in waterside zone as affected by the **a**, proportion of total pasture area in the waterside zone, and **b**, proportion of total pasture shade in the waterside zone of each pasture (Study 2). (a) $Y = 6.16 + 0.72x$; ($r^2 = 0.62$). (b) $Y = 2.58 + 0.39x$; ($r^2 = 0.42$).

It can be inferred by the results of these two studies that more restrictive management practices such as establishing the riparian buffers (McKergow et al. 2003; Muenz et al. 2006; Webber et al. 2010), restricting stream access to stabilized crossings (Haan et al. 2010), or limiting grazing of riparian paddocks (Haan et al. 2010) may be necessary to minimize nonpoint source pollution of streams in small or narrow pastures. In future studies evaluating the temporal/spatial distribution of grazing cattle, it would be advantageous for researchers to report pasture size, shape, and shade distribution with any treatments that are being tested to influence cattle distribution. Further studies are necessary to define the optimal pasture size and identify the best management practices appropriate for pastures with different sizes, shapes, and shade distributions to provide the most cost-effective approach to minimize NPS pollution risks from midwestern pastures.

MANAGEMENT IMPLICATIONS

Exclusion from streams within riparian buffers (McKergow et al. 2003; Muenz et al. 2006; Webber et al. 2010) or limiting stream access to stabilized access sites (Haan et al. 2010; Schwarte et al. 2011) or within riparian paddocks of a rotational stocking system (Haan et al. 2010; Schwarte et al. 2011) have been effective in reducing the proportion of time grazing cattle are near or in pasture streams and, thereby, the risks of sediment, nutrient, and pathogen loading of streams. However, results of this study revealed that the proportion of time that cattle are near streams in midwestern pastures is highly related to pasture size and shade distribution. Therefore, implementation of management practices to limit NPS pollution of streams in midwestern pastures should be based on the physical characteristics of each site. In large pastures, use of fences to prevent or limit access of grazing cattle to pasture streams may not be necessary to minimize NPS pollution of pasture streams by congregation of cattle near streams, particularly if shade is present outside the riparian zone. But management practices that utilize fences to prevent or limit access of cattle to pasture streams may be necessary to minimize the risks of NPS pollution of streams resulting from cattle congregating near streams in small or narrow pastures in which cattle have less opportunity to travel to upland locations.

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