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Summary and Implications

Eight pastures on five southern Iowa cow-calf farms were used to evaluate the effects of pasture characteristics and microclimatic conditions on cattle grazing cool-season grass pastures with streams and/or ponds. Pastures ranged from 19 to 309 acres and contained varying proportions of cool-season grasses, legumes, sedge, broadleaf weeds, brush, and bare ground. The percentages of pasture area that were shaded ranged from 19 to 73%. Cows were Angus and Angus-Cross on seven of the pastures, and Mexican Corriente on the remaining pasture. In spring, summer, and fall of 2007, 2008, and 2009, 2 to 3 cows per pasture were fitted with Global Positioning System (GPS) collars to record position at 10 minute intervals for periods of 5 to 14 days. Ambient temperature, black globe temperature, dew point, relative humidity, and wind speed and direction were collected with HOBO data loggers at ten minute intervals over the 2007, 2008, and 2009 grazing seasons on each farm. Streams, ponds, and fence lines were referenced on a geospatial map and used to establish zones in the pastures. Designated zones were: in the stream or pond, within 100 feet, or greater than 100 ft (uplands) from the stream or pond (water source). One hundred thirty-nine data sets were obtained throughout the three-year project. Mean proportions of observations when cattle were in the water source differed ($P<0.0001$) between farms, but not between seasons ($P=0.5824$). Mean proportions of time cattle spent within 100, or greater 100 ft of the water source differed ($P<0.0001$) among farms. The proportion of time cattle were within the streamside zone (defined as being in the water source or within 100 feet of the water source) increased with increasing ambient temperature, increasing the proportion of streamside zone within a pasture, increasing the proportion of total pasture shade within the streamside zone, and decreasing pasture size. Therefore, implementation of grazing management practices for the protection of pasture streams are more likely to be effective on small and/or narrow pastures in which cattle have less opportunity to locate in upland locations.

Introduction

Rathbun Lake is the primary water source for 70,000 residents in 17 counties and 48 communities in southern Iowa and northern Missouri. In addition to providing drinking water, this 11,000 acre lake provides recreation opportunities for one million visitors annually. Fifteen sub-watersheds of the Rathbun Lake watershed have been identified as carrying nearly 73% of all sediment and phosphorus delivered annually to the lake. The primary factor contributing to this pollution has been identified as livestock grazing on pastures, which comprise 38% of the watershed. This pollution could be related to grazing management practices that allow cattle to congregate in and near pasture streams. Thus, non-point source pollution of pasture streams may be controlled by management practices that control the timing, duration, frequency, and intensity of grazing.

Previous research has shown that grazing cattle tend to congregate in streamside zone of pastures to obtain water and shade for thermoregulation. Problems associated with thermoregulation may be increased because of the presence of endophyte-infected tall fescue in pastures. Quantifying the temporal/spatial distribution of grazing cattle in streamside pastures will assess the risk of sediment, nutrient, and pathogen loading into streams and ponds from these cattle Furthermore, defining the relationships between cattle distribution and such pasture characteristics as size, shape, shade distribution, botanical composition, and climatic factors related to heat stress will provide the basis for the development and implementation of management practices which minimize the risk of non-point source pollution from grazing cattle.

Therefore, the objectives of this project were to evaluate the effects of pasture characteristics and botanical composition, and climate on the temporal and spatial distribution of grazing cattle within and outside the streamside zones of pastures.

Materials and Methods

Pastures on five cooperating beef cow-calf farms (A, B, C, D, and E) in the Rathbun Lake watershed were identified as appropriate for the project in the fall of 2006 for measurements in 2007, 2008, and 2009. Three more pastures (N, NE, and S) on farm A utilized in 2009. The three additional pastures were used to evaluate shade location effects of cattle distribution on pastures with approximately the same size. Pastures ranged from 19 to 309 acres. Four of the five farms had Angus or Angus-Cross cattle with Mexican Corriente cattle on the remaining farm. Cows on four of the farms were spring-calving with the remaining farm having both spring- and fall-calving cows. During spring, summer, and fall of 2007, 2008, and 2009, 2 to 3 cows per pasture were fitted with Global Positioning System (GPS) collars to record position at 10 minute intervals for periods of 5 to 14 days. One hundred thirty-nine data sets, all farms combined over three years, were obtained throughout the grazing seasons to determine cattle locations. Collars were not placed on cows on Farm D in spring 2007 and summer 2008, due to flooding in the pasture.

In the summer 2007 and spring 2009, streams and/or ponds and fence lines were referenced in the pasture of each farm using a handheld Garmin GPS72 receiver and a geospatial map using ArcGIS 9.2 software. Upon referencing, points were used to establish zones in the pastures. Designated zones were: in the stream or pond (water source), within 100 feet of a natural water source (100 foot zone), or greater than 100 feet (uplands) from the water. Water sources included streams and ponds on Farms C and E, streams on Farms D and A, which included the N, NE, and S pastures, and ponds on Farm B. Streamside zone was identified as the area of the water source plus the 100 foot zone. Cow distribution across zones was located using the measurements from the GPS collars.

To determine the botanical composition of each pasture, two of the pastures were divided into 164 x 164 ft grid and three of the pastures were divided into 328 x 328 ft grids on aerial photos using ArcGIS 9.2 software. The new 2009 pastures were evaluated by the same previous 328 x 328 ft grid of Farm A, from aerial photos, to maintain consistent evaluation of botanical composition from the two previous years. In late spring of each year, bare ground or forage species were visually identified and sward height measured with a falling plate meter (8.8 lb/yd^2) in the center of each square of the grid in each pasture, as located by a GPS handheld receiver, and at four equidistant locations from the center of each grid. Observations within each grid were divided by the number of vegetative species within the grid and percentages from each grid were combined for determining the total percentage of vegetative species within a pasture. Vegetation species observed included tall fescue, reed canarygrass, Kentucky bluegrass, smooth bromegrass, orchardgrass, timothy, legumes (white and red clover), sedge, weed grasses, broadleaf weeds, brush, and other brush species. The most predominant forage species observed over the five farms was tall fescue, which ranged from 10% to nearly 51% of the vegetation with varying amounts of the remaining vegetative species.

Microclimate data, including ambient temperature, black globe temperature (solar radiation), dew point, wind speed and direction, relative humidity, and rainfall were recorded, at 10 minute intervals using HOBO data logging weather stations over the three grazing seasons on each farm. To evaluate the effects of heat stress, temperature humidity index (THI), black globe temperature humidity index (BGTHI), and heat load index (HLI) were paired with microclimate data for each observation time. For each unit increment of each microclimate variable, the number of observations that a cow was in or within 100 feet of the water source was divided by the total number of observations at that temperature or heat index unit to determine the probability of a cow being in either of these zones at that microclimatic variable increment.

The LOGISTIC procedure of SAS was used to test the effects of microclimate variables on the probability of the cattle being in or within 100 feet of the water by calculating an odds ratio to determine the effect of each unit change in the microclimatic variable on the probability of cows being in or within 100 feet of the water source. The climatic variable that best predicted the presence of cattle in or within 100 feet of the water source was determined using Akaike's Information Criteria (AIC).

The shade distribution of each pasture, including total pasture shade and the proportion of total shade in the streamside zone, was determined from aerial photos using ArcGIS 9.2 software. Total shaded acres were divided by total pasture acres to determine the percentage of pasture shaded. Streamside shade was determined by the acres shaded divided by the total acres within the streamside zone. Streamside shade, as a percentage of the total pasture shade, was determined by dividing the area of streamside shade by the area of shade in the total pasture.

The effects of farm and season on the distribution of cows in pastures was analyzed using the GLM procedure of SAS using years as the replicate. A P-value of 0.05 was used to determine significance.

Results and Discussion

There were no seasonal differences (P=0.5824; Table 1) for the percentage of all observations of cows located in the water source, but there were differences (P<0.0001) between farms and a farm by season interaction (P=0.0002; Table 2). The grazing season had an effect on cows located within the water source of Farms B, C, and Pasture N, but not from cows of Farms A, D, E, and Pastures NE and S. Cows from Farms C and B, the second and third largest pastures of the study, spent a greater percentage of their time in the water during summer than the spring or fall grazing seasons; whereas cows on Pasture N of Farm A, a small-sized pasture with a large percentage of shade located directly on the stream, spent a greater percentage of time in the water during spring and fall grazing seasons than during the summer grazing season, which could have been due to the low ambient temperatures in July when the collars were placed on the cattle. The farms where no seasonal differences were observed for the proportion of time cattle were located in the water source occurred on small-sized or in well-shaded pastures. Implications from the cattle observations are seasonal grazing differences were only found on larger pastures or on pastures with the largest percentage of shade located in the streamside zone. In spite of farm differences for the percentage of time cows were located in the water source (Table 1), cows across all farms spent less than an average 3% of observations in the water source. This presence in the water source is lower than percentages reported by others in the literature. However, pastures used in the previous studies were smaller than the pastures of the current study. In addition, only the 2009 pastures on Farm A were analyzed for the effect of season on grazing distribution within the water source on approximately the same-sized pastures, as there was a seasonal difference (P=0.0255, Table 3) and a farm by season interaction (P=0.0051). Cows on Pasture S, the smallest pasture, spent a greater percentage of time located directly in the water source during spring than fall, but were not different than the summer grazing season. Cows on Pasture NE spent a greater percentage of their time in the water source during fall, compared to spring, but the summer grazing season was not different from either. Whereas cows on Pasture N, the largest pasture of Farm A in 2009, spent a greater percentage of time in the water source during the fall and spring grazing seasons compared to the summer grazing season. The seasonal differences observed within the water source could be due to pasture shape or the distribution of shade within the pastures.

The proportion of all observations when cows were located in the streamside zones of pastures were not different (P=0.1497) between seasons, but differences existed between farms (P<0.0001, Table 4) and a farm by season interaction (P<0.001). The grazing season had an effect on cows located within the streamside zone (the water source plus the 100 foot zone) of Farms D, E, and Pastures N and S, but not from cows of Farms A, B, C, and Pasture NE. Cows from Farms D spent a greater percentage of their time in the streamside during spring than fall grazing seasons, but the summer grazing season was not different from either; whereas cows on Farm E, a small-sized pasture with a large percentage of shade located on the stream, spent a greater percentage of time in the streamside zone during the summer and fall grazing seasons than during the spring grazing season. Furthermore, cows on Pasture N, a small-sized pasture with a majority of the pasture shade located in the streamside zone, spent a greater percentage of their time in the streamside zone during the spring and fall grazing seasons compared to summer, and cows on Pasture S, spent a greater percentage of their time during summer than fall or spring grazing seasons, located in the streamside zones of the pastures. The farms where no seasonal differences were observed for the proportion of time cattle were located in the streamside zones occurred on large pastures or in pastures with a large percentage of alternative shade out of the streamside zone. In addition, only the 2009 pastures on Farm A were analyzed for the effect of season on grazing distribution within the streamside zone, as there was a seasonal difference (P=0.0005, Table 5) and a farm by season interaction (P<0.0001). Cows on Pasture S, the smallest pasture with the largest percentage of pasture shade located directly in the streamside zone, spent a greater percentage of time in the streamside zones during summer than spring or fall, and cows on Pasture NE spent a greater percentage of their time in the streamside zone during the summer and fall, compared to spring. Whereas, cows on Pasture N, the largest pasture of Farm A in 2009, spent a greater percentage of time in the streamside zone during the fall grazing season compared to spring, which was also greater than the summer grazing season. The seasonal differences observed could be due to distribution of shade within the pastures or pasture shape. Implications from the cattle observations in the streamside zone are grazing seasons differences were only found on small-sized pastures or on pastures with the largest percentage of shade located in the streamside zone.

Because differences (P<0.0001) were observed between farms of cows within a water source and within the streamside zone, when using year as the experimental unit, alternative factors influencing cattle temporal/spatial distribution were evaluated. Microclimatic changes and abnormal rainfall amounts that caused flooding in summer 2008, may have contributed to increased variability in cattle distribution within the streamside zone between years.

Botanical composition of pastures in 2007, 2008, and 2009 were evaluated and regressed against cattle locations within the streamside zone, but no relationship existed.

Cattle locations and microclimatic factors were paired to evaluate the temporal/spatial distributions within the streamside zone of a pasture. Of the climatic variables and indices of heat stress measured, ambient temperature most accurately predicted the probability of cow presence in the streamside zone, as determined by the lowest AIC and covariate value.

Using PROC LOGISTIC, each farm was modeled for the 2007, 2008, and 2009 grazing years (Figure 1), for predicting the probability of cattle presence in the streamside zone of a pasture. Probabilities of being within the streamside zone ranged from 2 to 26% at 5^{o}C and from 4 to 46% at 30^{o}C on farm B and pasture S in year 3. The differences in probability curves between farms imply that there may be characteristics of individual pastures affecting cow spatial/temporal distribution.

In order to determine the factors causing the differences in cow distribution in streamside zones, the distribution of pasture shade across all farms was analyzed (Table 6). Total pasture shade ranged from 27.2% on Farm E to 72.8% of the pasture area on Farm D. Streamside shade ranged from 55.5 to 79.1% of the streamside zone and accounted for 2.8 to 58.4% of the total pasture shade. In addition, the three 2009 pastures of Farm A had total percentage of pasture shaded that ranged from 19.4% on Pasture N, to 41.6% of the pasture area on Pasture NE. Proportion of the streamside zone shaded ranged from 36.5 to 89.9% of the streamside zone and accounted for 28.4 to 72.6% of the total pasture shade. In spite of this variation in pasture shade, the proportion of all cow distributions were weakly related to the proportion of total pasture shade within the streamside zone (Figure 2), particularly in the summer when the effects of shade should have been the greatest because the pastures were well-shaded and cattle could congregate under alternative shade outside the streamside zone. However, as the proportion of the total pasture shade increases within the streamside area, the proportion of cattle observations increased in the streamside zone; implying that shade has an influence on cattle distribution. In addition, the 2009 pastures on Farm A were analyzed for the effect of the total proportion of pasture shade within the streamside zone on cattle observations (Figure 3). This accounted for 79, 15, and 95%, of the variation during the spring, summer, and fall grazing seasons, respectively. However, during one week of July when collars were on the cattle, the weather was cooler than normal during summer, which could have been the cause of the low correlation during the summer grazing season. These results, thereby, suggest that shade may influence cattle distribution within approximately the same-sized pastures.

Despite the weak correlation of total pasture shade within the streamside zone during the summer grazing season, the proportion of all cattle observations in streamside zone as affected by the proportion of streamside zone shaded were analyzed (Figure 4). The proportion of streamside zone shaded accounted for 28, 74, and 31% of the variation in all cow observations within the streamside zones of the pastures in the grazing seasons. In addition, when only the 2009 pastures on Farm A were analyzed for the effects of streamside zone shaded on cattle observations, 34, 93, and 5% of the variation in observations during the spring, summer, and fall grazing seasons were accounted for in cattle observations (Figure 5). The high correlation during the summer grazing season implies cattle congregate in the streamside areas of pastures due to shade and the surface water available for thermoregulation and to rid excess body heat during elevated ambient temperatures.

In contrast to the effects of streamside shade, the proportion of cattle observations in streamside zone was related to proportion of streamside zone in total pasture (Figure 6). The proportion of streamside zones in the total pastures accounted for 40, 64, and 39% of the variation in the observations of cows within the streamside zones in the spring, summer, and fall grazing seasons, respectively.

In addition to the proportion of pasture as the streamside zone, the total pasture area was regressed against cattle location in the streamside zones. The total pasture size (Figure 7) accounted for 40, 55, and 59% of the variation in the proportion of observations of cows within the streamside zones of the pastures in the spring, summer, and fall grazing seasons.

Preliminary results imply the presence of cattle in streamside zones of pastures increased with increasing ambient temperature, increasing the proportion of streamside zone within a pasture, increasing the proportion of total pasture shade within the streamside zone, and decreasing pasture size. In approximately the same-sized pastures, the proportion of streamside zone shaded has an influence on cattle distribution. The proportion of time that all cattle were in the streamside zone of the pastures was weakly related to the proportion of the total pasture shade within the streamside zones during the summer grazing season, when the effects of shade should have been greatest. However, these pastures contained considerable shade outside of the streamside zone. Lastly, the presence of cattle in streamside zones was not highly related to proportions of tall fescue in pastures that contained 10 to 51% tall fescue. Pasture size and/or shape may supersede any effects of botanical composition of Midwestern pastures on the temporal/spatial distribution of cattle.

Acknowledgements

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Table 1. Mean percentage of observations of cattle within the water source and streamside zone of pastures on eight farms in 2007, 2008, and 2009.

	2007, 2008, and 2009 Grazing Seasons	
Name	**Water Source**	**Streamside Zone**
	% of observations	
Farm A	0.90^{d}	13.15^{de}
Farm B	1.10^{cd}	4.20^{f}
Farm C	1.33^{cd}	10.33^{ef}
Farm D	1.43^{cd}	23.63^{bc}
Farm E	1.68^{bc}	25.48^{b}
Pasture N	2.36^{ab}	20.77^{c}
Pasture NE	1.48^{cd}	14.53^{d}
Pasture S	2.88^{a}	37.98^{a}

[a,b,c,d,e,f]Within a column, least squares means without a common subscript differ (P<0.05) within water source or streamside zone.

Table 2. Mean percentage of observations of cattle within the water source of pastures in spring, summer, and fall seasons on eight farms in 2007, 2008, and 2009.

Water Source	**2007, 2008, and 2009 Grazing Seasons**		
Name	**Spring**	**Summer**	**Fall**
	% of observations		
Farm A	1.06^{c}	0.73^{d}	0.90^{cd}
Farm B	0.21$^{d, y}$	2.46$^{ab, x}$	0.64$^{d, y}$
Farm C	0.82$^{cd, y}$	2.09$^{abc, x}$	1.08$^{cd, y}$
Farm D	1.80^{bc}	1.43^{bcd}	1.06^{cd}
Farm E	1.37^{c}	2.18^{abc}	1.49^{bc}
Pasture N	2.67$^{ab, x}$	1.13$^{cd, y}$	3.27$^{a, x}$
Pasture NE	1.00^{cd}	1.20^{cd}	2.23^{abc}
Pasture S	3.43^{a}	2.90^{a}	2.30^{ab}
Average	1.62	1.55	1.76

[a,b,c,d,e,f]Within a column, least squares means without a common subscript differ (P<0.05) within season.
[v,w,x,y,z]Within a row, least squares means without a common subscript differ (P<0.05) within farm.

Table 3. Mean percentage of observations of cattle within the water source of pastures in spring, summer, and fall seasons on Farm A pastures in 2009.

Water Source	**2009 Grazing Season**		
Name	**Spring**	**Summer**	**Fall**
	% of observations		
Pasture N	2.67$^{a, x}$	1.13$^{b, y}$	3.27^{x}
Pasture NE	1.00$^{b, y}$	1.20$^{b, xy}$	2.23^{x}
Pasture S	3.43$^{a, x}$	2.90$^{a, xy}$	2.30^{y}
Average	2.37	1.74	2.60

[a,b]Within a column, least squares means without a common subscript differ (P<0.05) within season.
[x,y]Within a row, least squares means without a common subscript differ (P<0.05) within pasture.

Table 4. Mean percentage of observations of cattle within the streamside zones of pastures in spring, summer, and fall seasons on eight farms in 2007, 2008, and 2009.

Streamside Zone	2007, 2008, and 2009 Grazing Seasons		
Name	Spring	Summer	Fall
	% of observations		
Farm A	15.76[d]	10.48[d]	13.20[c]
Farm B	2.43[f]	6.86[d]	3.33[d]
Farm C	10.65[e]	11.40[d]	8.93[c]
Farm D	26.92[ab, x]	23.45[bc, xy]	20.51[b, y]
Farm E	20.71[c, y]	28.40[b, x]	27.31[a, x]
Pasture N	21.23[bcd, x]	12.03[d, y]	29.03[a, x]
Pasture NE	10.07[e]	20.50[c]	13.03[c]
Pasture S	33.80[a, y]	47.57[a, x]	32.57[a, y]
Average	17.70	20.09	18.49

[a,b,c,d,e,f]Within a column, least squares means without a common subscript differ (P<0.05) within season.
[v,w,x,y,z]Within a row, least squares means without a common subscript differ (P<0.05) within farm.

Table 5. Mean percentage of observations of cattle within the streamside zones of pastures in spring, summer, and fall seasons on Farm A pastures in 2009.

Streamside Zone	2009 Grazing Season		
Name	Spring	Summer	Fall
	% of observations		
Pasture N	21.23[b, y]	12.03[c, z]	29.03[a, x]
Pasture NE	10.07[c, y]	20.50[b, x]	13.03[b, x]
Pasture S	33.80[a, y]	47.57[a, x]	32.57[a, y]
Average	21.70	26.70	24.88

[a,b]Within a column, least squares means without a common subscript differ (P<0.05) within season.
[x,y,z]Within a row, least squares means without a common subscript differ (P<0.05) within pasture.

Table 6. Shade distribution and size of pastures in 2007, 2008, and 2009.

	Streamside Shade		Streamside Zone	Pasture Shade	Pasture Size
Name	% of Stream-side zone	% of Total Pasture Shade	% of Pasture Area	% of Pasture Area	Acres
Farm A	79.1	33.3	24.3	57.8	309.4
Farm B	67.2	2.8	2.5	59.6	160.3
Farm C	79.1	44.7	17.2	30.5	227.9
Farm D	68.0	20.9	22.4	72.8	52.7
Farm E	55.5	58.4	28.7	27.2	33.3
Pasture N	89.7	67.6	14.7	19.4	37.2
Pasture NE	66.4	28.4	17.8	41.6	19.8
Pasture S	36.5	72.6	43.4	21.8	24.5

Figure 1. Estimated probabilities of cows within streamside zone as affected by ambient temperature by farm & year with percent streamside zone in the pasture.

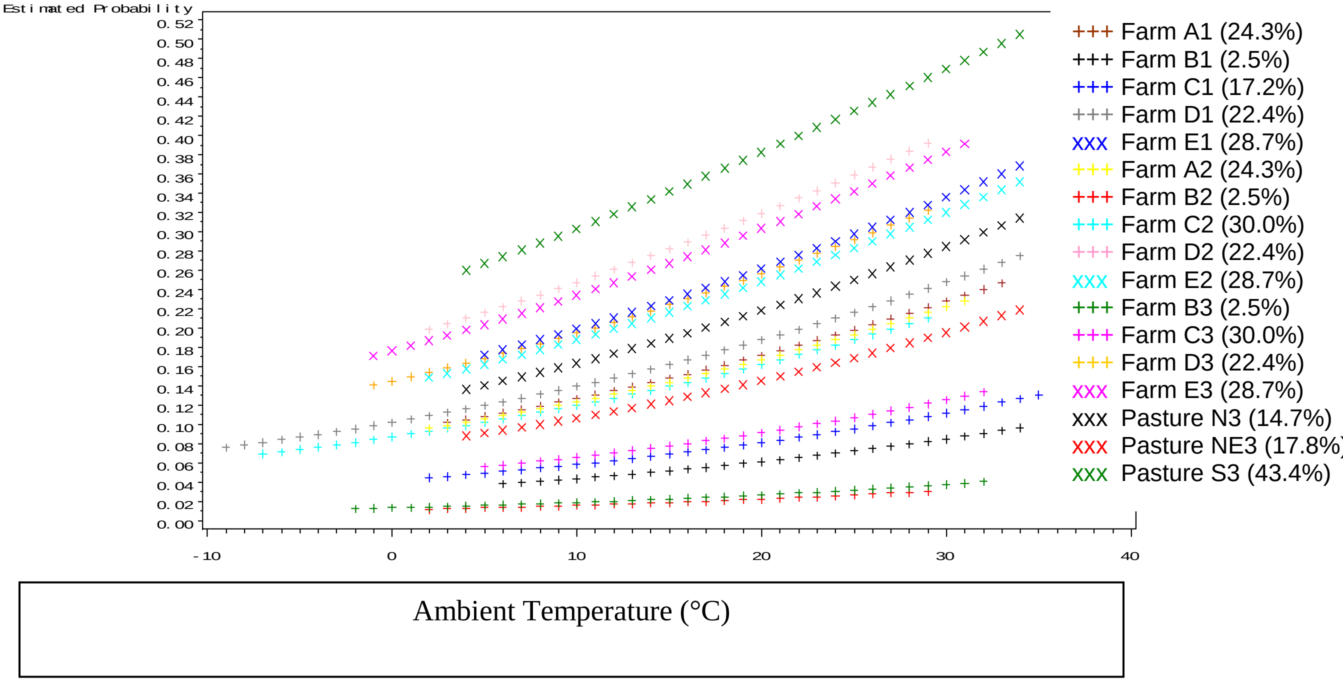
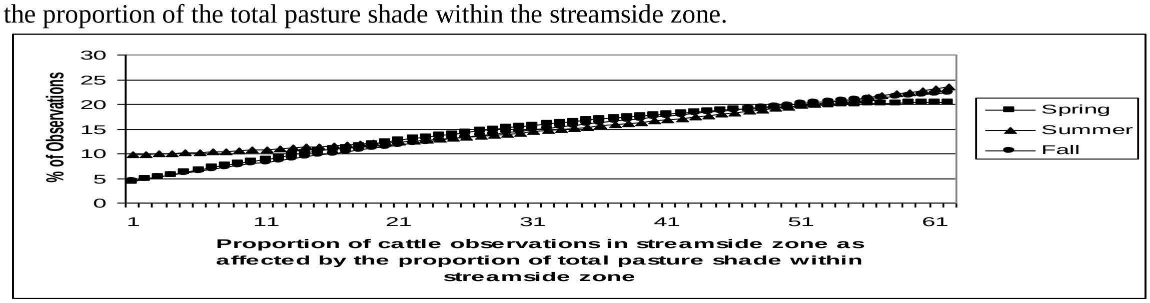
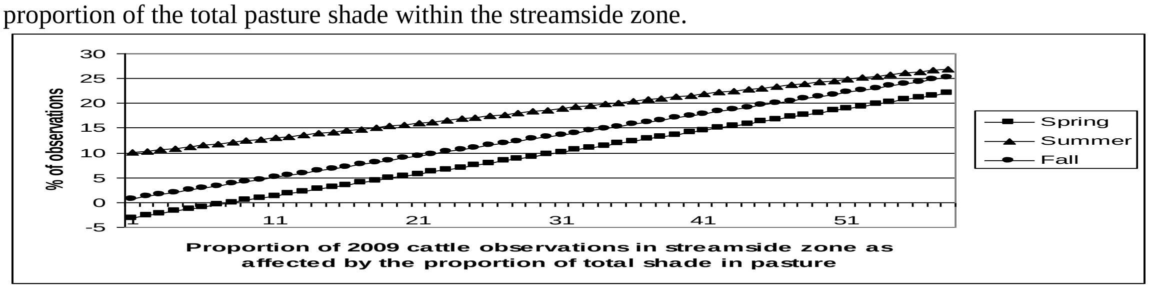


Figure 2. Proportion of all cattle observations in streamside zone in 2007, 2008, and 2009 as affected by the proportion of the total pasture shade within the streamside zone.



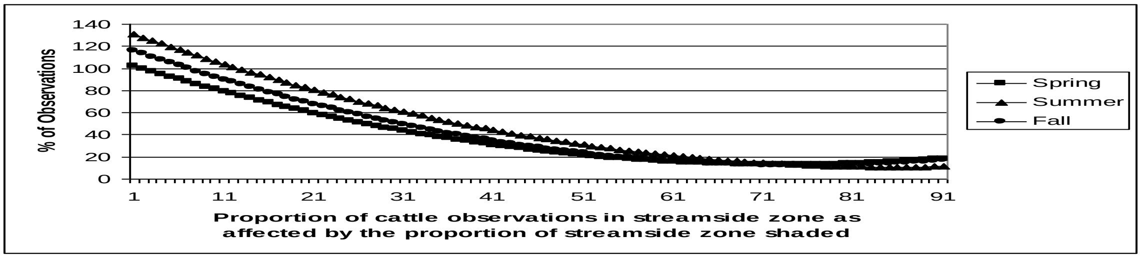
Spring: $Y=0.86+0.89x-0.010x^2$; (r^2=0.34)
Summer: $Y=6.88+0.43x-0.00025x^2$; (r^2=0.23)
Fall: $Y=1.05+0.92x-0.0099x^2$; (r^2=0.36)

Figure 3. Proportion of new 2009 pasture cattle observations in streamside zone as affected by the proportion of the total pasture shade within the streamside zone.



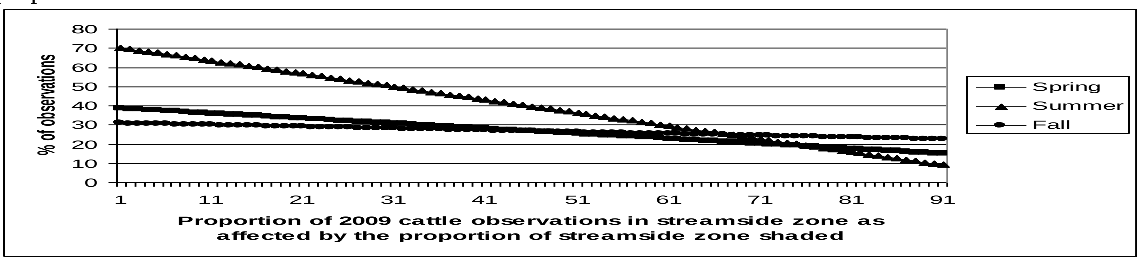
Spring: $Y=-3.07+0.44x$; (r^2=0.79)
Summer: $Y=10.04+0.30x$; (r^2=0.15)
Fall: $Y=0.77+0.42x$; (r^2=0.95)

Figure 4. Proportion of all cattle observations in streamside zone in 2007, 2008, and 2009 as affected by the proportion of streamside zone shaded.



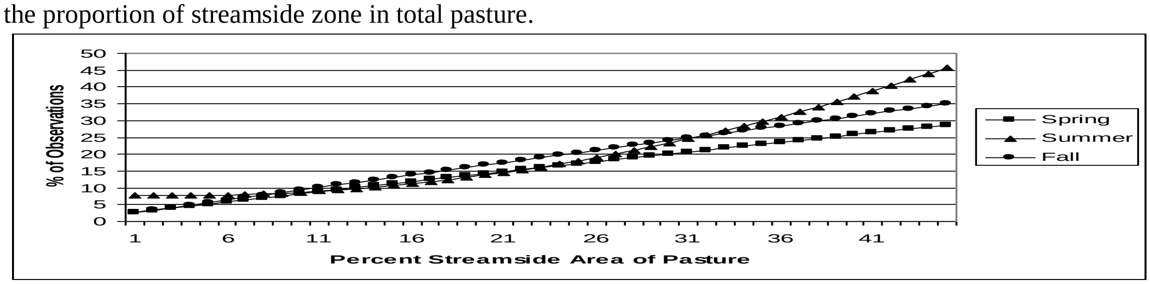
Spring: $Y=102.11-2.47x+0.017x^2$; ($r^2=0.28$)
Summer: $Y=130.67-2.83x-0.017x^2$; ($r^2=0.74$)
Fall: $Y=116.16-2.79x+0.019x^2$; ($r^2=0.31$)

Figure 5. Proportion of new 2009 pasture cattle observations in streamside zone as affected by the proportion of streamside zone shaded.



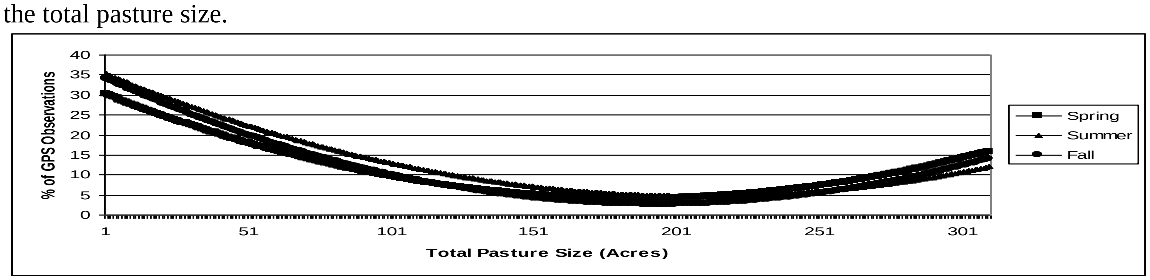
Spring: $Y=38.52-0.26x$; ($r^2=0.34$)
Summer: $Y=70.29-0.68x$; ($r^2=0.93$)
Fall: $Y=30.88-0.09x$; ($r^2=0.05$)

Figure 6. Proportion of all cattle observations in streamside zone in 2007, 2008, and 2009 as affected by the proportion of streamside zone in total pasture.



Spring: $Y=2.69+0.62x-0.00071x^2$; ($r^2=0.40$)
Summer: $Y=7.83-0.11x+0.022x^2$; ($r^2=0.64$)
Fall: $Y=2.64+0.75x-0.0032x^2$; ($r^2=0.39$)

Figure 7. Proportion of all cattle observations in streamside zone in 2007, 2008, and 2009 as affected by the total pasture size.



Spring: $Y=30.15-0.28x+0.00076x^2$; ($r^2=0.40$)
Summer: $Y=35.24-0.29x+0.00071x^2$; ($r^2=0.55$)
Fall: $Y=34.16-0.33x+0.00084x^2$; ($r^2=0.59$)