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# Impact of water troughs on cattle use of riparian zones in the Georgia Piedmont in the United States[1]

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**ABSTRACT:** Cattle use of riparian areas may lead to stream water contamination with nutrients, pathogens, and sediments. Providing alternative water away from the stream may reduce the amount of time cattle spend near streams and therefore reduce contamination. We conducted this study to 1) evaluate the effect of providing water troughs outside of the riparian zones on the amount of time cattle spend in riparian zones, and 2) evaluate if environmental factors such as temperature and humidity affect the impact of water trough availability on the amount of time cattle spend within riparian and nonriparian locations. Global positioning system (GPS) collars were used to document cow locations every 5 min in 2 mixed tall fescue/common bermudagrass pastures of the Georgia Piedmont in the United States. We found that when the temperature and humidity index (THI) ranged between 62 and 72, providing cattle with water troughs outside of riparian zones tended to decrease time cattle spent in riparian zones by 63% (52 $\text{min}\cdot\text{d}^{-1}$; $P = 0.11$) . When THI ranged between 72 and 84, nonriparian water availability did not have a significant impact on the amount of time cattle spent in the riparian zone or in riparian shade. These results suggest that water troughs placed away from unfenced streams may improve water quality by reducing the amount of time cattle spend in riparian zones when environmental conditions as evaluated by THI are not stressful.

**Key words:** beef cattle, global positioning system collar, riparian zone, tall fescue

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## INTRODUCTION

Cattle use of riparian areas may lead to depletion of needed nutrients and top soil from stream-side grasslands (Butler et al., 2006, 2007), which in turn would result in less productive grasslands and concomitant stream water contamination with nutrients, pathogens, and sediments (Line et al., 2000). Cattle grazing in riparian areas may also affect stream hydrology, stream morphology, and soil properties (Belsky et al., 1999). Thus, management practices that reduce the amount of time cattle spend in riparian areas may help maintain vegetative cover and reduce stream contamination. Because cattle use riparian areas mainly for drinking and cooling, we hypothesized that providing water troughs away from streams would reduce the amount of time cattle spend near streams. Currently, information on the impact of water trough availability on cattle behavior is very limited in the southeastern United States.

Monitoring cattle behavior in pastures has long been of interest to scientists, and the methods used reflect

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the evolution of technology. Visual observations were used from 1960 to early 1990s, whereas very high frequency telemetry was used in the late 1990s. Currently, global positioning systems (**GPS**) allow frequent observations and are quickly becoming the standard method in cattle behavior studies (Bailey, 1999; Ganskopp et al., 2000; Turner et al., 2000; Bicudo et al., 2003). We conducted this study to 1) evaluate the effect of providing water outside of the riparian zones on the amount of time cattle spend in riparian zones and 2) evaluate if environmental factors such as temperature and humidity affect the impact of water trough availability on time cattle spend within riparian and nonriparian locations.

## MATERIALS AND METHODS

This research was carried out under the authority of the Georgia Agricultural Experiment Station and followed the guidelines stated in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1999).

### *Site Description*

The pastures used for this study (G5 and G8; Figure 1) were located at the Central Research and Education Center of the University of Georgia (Eatonton; latitude 33°24′ N, longitude 83°29′ W, elevation 150 m). The soils have been classified as Iredell sandy loam (fine, montmorillonitic, thermic, Typic Hapludalfs); Mecklenburg sandy loam and sandy clay loam (fine, mixed thermic Ultic Hapludalfs); Chewacla silty clay (fine-loamy, mixed, active, thermic Fluvaquentic Dystrudepts); and Wehadkee silty clay loam (fine-loamy, mixed, active, nonacid, thermic Fluvaquentic Endoaquepts; Perkins et al., 1987).

The streams draining pastures G5 and G8 had average daily flows of 641 and 622 $m^3 \cdot d^{-1}$, respectively, during baseflow (Byers, 2004). The average stream slope was 0.4% in G5 and 0.6% in G8, and the average slope perpendicular to the stream was 4% in G5 and 2% in G8. The stream length was approximately 397 m in G5 and 506 m in G8, and the riparian zones of both pastures had been unfenced for over 10 yr (Byers, 2004).

Pastures were stocked with 20 Angus and Angus-Hereford cow-calf pairs (*Bos taurus* L.) per pasture (1.14 cow-calf $pairs \cdot ha^{-1}$ for G5 and 1.31 cow-calf $pairs \cdot ha^{-1}$ for G8). The same group of cows was used for the 3-yr study. Single strand, electric cross fences with gaps were installed before the project began and were used to rotationally graze the pastures on either side of the riparian area; however, cattle were allowed access to the entire riparian area throughout the duration of the study (Figure 1). There were 3 gaps (4.8 m ea) in each cross fence, 2 against either end of the fence and one in the middle. The rotational grazing strategy was based on pasture condition, which was at all times optimally available based on visual evaluation.

Two water troughs were installed in each pasture before the project began. The average distance from the water troughs to the stream was 91 m in G5 and 81 m in G8 (Figure 1). Monitoring of cattle behavior and location with GPS collars took place both when troughs were available and not available (Table 1). When water troughs were not available, an electric fence around each water trough prevented cattle access.

### *Grass Species and Endophyte Survey*

A grass species survey was carried out in each pasture with the step-point method in September, 2003. Twelve southwest-northeast transects were run approximately 30 m apart in each pasture. Within each transect, a point sample was taken every 5 m for a total of 1,200 points in G5 and 960 points in G8. At each point sample, the species present was identified and recorded.

For the endophyte survey, 2 subsamples of 50 tall fescue tillers were randomly selected in each pasture while systematically traversing regions within the field. The tillers were harvested by excising the pseudostem at the soil surface, removing dead leaf or sheath tissue, and placing on ice for transport back to the laboratory. Endophyte analysis was performed using a commercial immunoblot test kit (ENDO797–3, Agrinostics Ltd. Co., Watkinsville, GA). The tillers were prepared for analysis by cutting a fresh 3-mm cross section at the base of the pseudostem immediately above the point of excision of the tiller. The pseudostem cross sections were placed on a nitrocellulose membrane that was saturated with extraction buffer, and the membrane with pseudostem cross sections incubated at 4°C overnight. Pseudostem pieces were removed from the membrane, the membrane dried in an oven set at 70°C for 10 min, and the immunoblot performed according to test kit procedures. Separate cross sections of pseudostem were qualitatively analyzed for ergot alkaloids using a commercial ELISA test kit (ENDO899–2t, Agrinostics Ltd. Co.).

### *Pasture Survey—Geographic Information System*

Map features were delineated and managed using geographic information systems (**GIS**). To delineate the riparian area, the banks of the 2 streams were surveyed using a submeter Leica 344 GPS unit (Leica Geosystems AG, St. Gallen, Switzerland), and a 12-m buffer area centered on the stream was created in ArcView GIS 3.2 (Environmental Systems Research Institute Inc., Redlands, CA). A submeter Trimble (model TSC1) GPS unit (Trimble, Sunnyvale, CA) was used to delineate pasture, stream, and cross fences as well as determine the position of the water troughs in the 2 pastures. To delineate the extent of tree shade, the crown circumference of each tree was surveyed with the Trimble unit after leaf-out, and a 6-m buffer around the edge of the crown was created in ArcView GIS 3.2 using

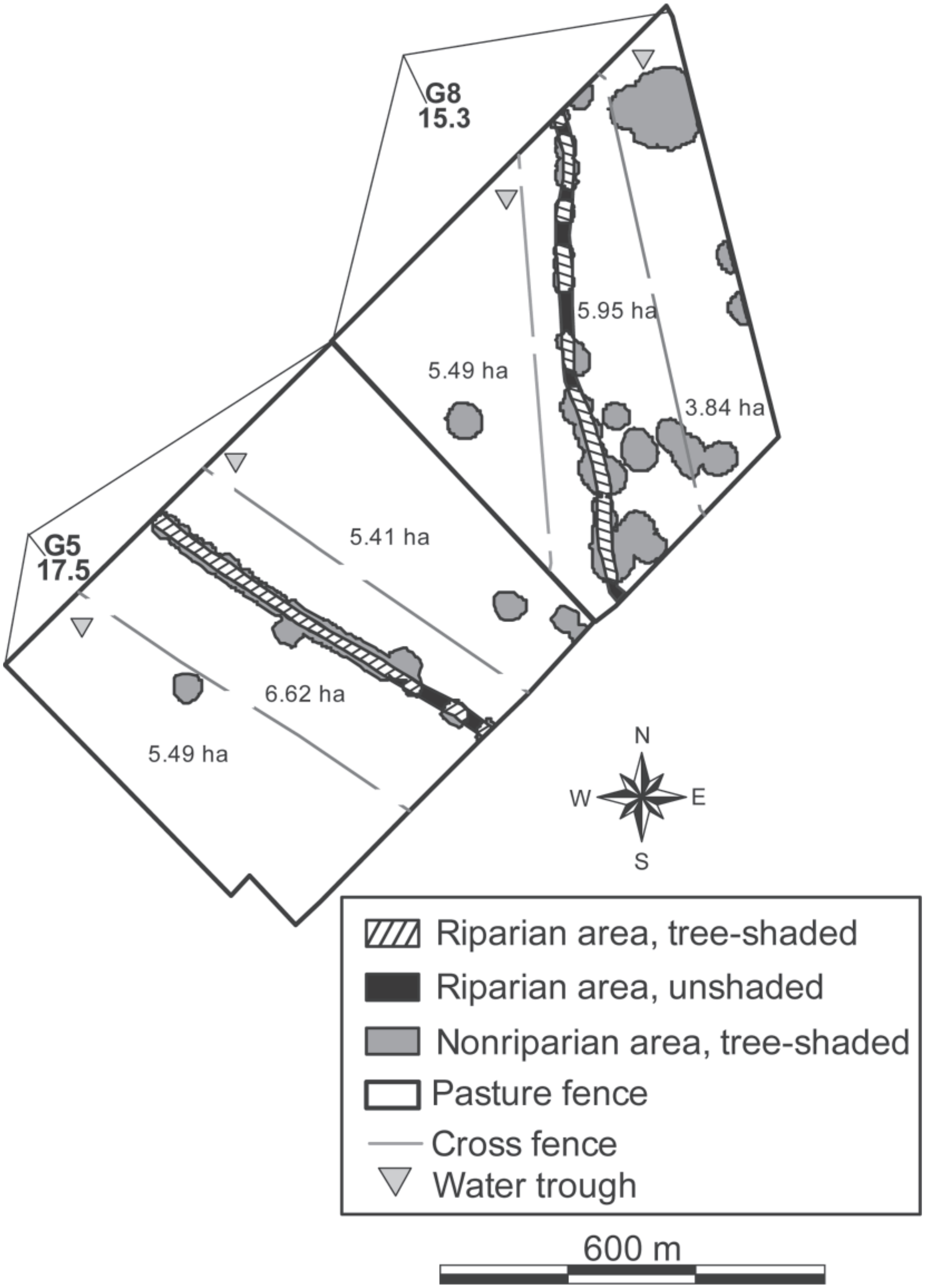

**Figure 1.** Map of 2 pastures showing tree-shaded areas, riparian areas, and fences. Riparian areas are defined as 12-m buffers centered on the stream. Tree-shade is defined as the circumference of the crown plus a 6-m buffer extending from the outer edge of the crown.

the Spatial Analyst (Environmental Systems Research Institute Inc.) and the Xtoolsmh extensions (Oregon Department of Forestry, Salem).

### *GPS Collars*

Model GPS2200LR Livestock GPS Collars (Lotek Wireless Inc., Newmarket, Ontario, Canada) were used to monitor cattle location in the pastures. Because the collars were programmed to take a location fix every 5 min and the memory could hold about 5,000 data points, each collection period was limited to 17 d.

To test the accuracy of the collars, a benchmark was established nearby pasture G5 by geo-referencing it with respect to a US Geological Survey benchmark. Two GPS collars were placed on the benchmark for 2 wk, after which the data from the collars were differentially corrected using data from a US Coast Guard

**Table 1.** Start dates for 17-d global positioning system collar measurement periods in 2 pastures, number of monitored cows, and water trough availability during each period

| Pasture | Start date | Number of cows | Water troughs |
|---|---|---|---|
| G5 | May 8, 2001 | 3 | Available |
| | June 7, 2001 | 3 | Available |
| | July 5, 2001 | 3 | Available |
| | August 2, 2001 | 3 | Available |
| | November 8, 2001 | 3 | Available |
| | December 18, 2001 | 2 | Available |
| | March 8, 2002 | 3 | Available/not available |
| | March 29, 2002 | 3 | Not available |
| | April 22, 2002 | 3 | Not available |
| | May 13, 2002 | 4 | Not available |
| | December 16, 2002 | 3 | Available/not available |
| | May 19, 2003 | 3 | Not available |
| | June 30, 2003 | 4 | Not available |
| | July 21, 2003 | 3 | Not available/available |
| | August 26, 2003 | 4 | Available |
| G8 | April 24, 2001 | 3 | Available |
| | May 24, 2001 | 3 | Available |
| | June 21, 2001 | 3 | Available |
| | July 19, 2001 | 3 | Available |
| | August 20, 2001 | 3 | Available |
| | November 8, 2001 | 2 | Available |
| | December 18, 2001 | 2 | Available |
| | March 8, 2002 | 3 | Available/not available |
| | March 29, 2002 | 3 | Not available |
| | April 22, 2002 | 2 | Not available |
| | May 13, 2002 | 3 | Not available |
| | December 16, 2002 | 3 | Available/not available |
| | May 19, 2003 | 4 | Not available |
| | June 30, 2003 | 3 | Not available |
| | July 21, 2003 | 3 | Not available/available |
| | August 26, 2003 | 3 | Available |

reference station in Macon, GA. Once differentially corrected, 95% of the data points taken by the collars were accurate to within 3 m of the established benchmark.

***Comprehensive Study.*** Two to 4 cows (*Bos taurus* L.) from each pasture were randomly selected and fitted with GPS collars for 17-d measurement periods during times when troughs were available or not available (Table 1). The periods with or without water troughs were set to allow for cattle adaptation to drinking water sources. Throughout the study period, 15 of the 20 cows per pasture were fitted at least once with collars. At the end of each collection period, collars were removed and the data downloaded using Lotek's proprietary software. Data from a US Coast Guard reference station in Macon, GA, were used to differentially correct the collar data using N4, a proprietary software program from Lotek. Once corrected, the data were projected to UTM coordinates using CorpCon version 5.11 (US Army Corps of Engineers, Topographic Engineering Center, Alexandria, VA) and were imported as event themes into ArcView GIS 3.2. Compilation of all collection periods will be referred to as the comprehensive study (Table 1). The total number of deployed collars for compiled measurement periods in the comprehensive study was 49 in pasture G5 and 47 in pasture G8. This resulted in a total number of differentially corrected GPS data points of 167,641 in pasture G5 and 169,349 in pasture G8.

***Controlled Study.*** A substudy was conducted in March 2002, December 2002, and July 2003 to reduce variability caused by environmental conditions and animals. Compilation of collection periods in which trough availability was changed within 17-d measurement periods are referred to as the controlled study. The total number of deployed collars for periods in the controlled study was 9 in pasture G5 and 9 in pasture G8.

For each time period within this substudy, cattle in pastures G5 and G8 were monitored for at least 6 d with water troughs available and at least 7 d without water troughs. This helped assure that for at least 3 collection periods the same animals would experience both water trough conditions, thereby decreasing variability due to animal. In March 2002 and December 2002 there were 6 d with water troughs available, followed by 7 d without water troughs. It is important to note that water troughs had been available before this portion of the study, thus cattle had become accustomed to drinking from troughs at these locations. In this portion of the study, we evaluated the initial reaction of cattle being forced to drink from the stream. In July 2003, a reversal of the water trough availability was initiated. Cattle were monitored for 7 d while wa-

**Table 2.** Area for riparian zone, riparian shade, nonriparian shade, total shade, and total area of pastures used in the study

| | Pasture | |
|---|---|---|
| Description | G5 | G8 |
| Riparian zone, $m^2$ | 4,961 | 6,406 |
| Pasture area, $m^2$ | 175,200 | 152,800 |
| Nonriparian shade, $m^2$ | 6,425 | 18,523 |
| Riparian shade, $m^2$ | 4,212 | 5,010 |
| Total shade, $m^2$ | 10,637 | 23,553 |

ter troughs were not available followed by at least 10 d with troughs available (Table 1). In this portion of the study water troughs were not available immediately before the July 2003 collection period. Thus, this study evaluated cattle response or reaction to water troughs becoming available.

### *Data Processing*

ArcView GIS was used to identify and export attribute tables (date, cow identification number, time, field position) of the points gathered from each cow-collar that intersected with delineated riparian zone (**RZ**), tree-shaded riparian area (**RS**), tree-shaded nonriparian area (**NRS**), and total shade (**TS**, equal to RS + NRS). Attribute tables were then imported into Excel (Microsoft, Redmond, WA), and the attributes were sorted and averaged daily for all cows in each pasture.

### *Statistical Analysis*

To determine if water trough condition (available or not available) affected the time cattle spent in RZ, RS, NRS, or TS, data collected in the comprehensive study (described in Tables 1 and 2) were analyzed using PROC MIXED (SAS Institute Inc., Cary, NC) with trough availability (available or not available) as the treatment, pasture (G5 and G8) as experimental unit (random variable), and average daily observations as repeated measurements using a compound symmetry (**CS**) covariance structure. Data from the controlled study were also analyzed using PROC MIXED with trough availability as treatment, pasture as experimental unit, and daily observations as repeated measurements, also using a CS covariance structure.

***Effect of Temperature and Humidity.*** Valtorta et al. (1997) noted heat dissipation by cattle is a function of radiation, wind speed, air temperature, and humidity; therefore, the temperature humidity index (**THI**; National Oceanic and Atmospheric Administration, 1976) has been used to develop the Livestock Weather Safety Index (LCI, 1970). The THI is calculated using the daily maximum temperature in Celsius (T) and daily minimum humidity expressed as a percentage (H):

$$\text{THI} = (9/5 \times \text{T} + 32) - \{0.55 - [0.55(\text{H}/100)]\} \times [(9/5 \times \text{T} + 32) - 58].$$

While THI has been shown to have limitations (Gaughan et al., 2008), it is widely used as a key variable in analyzing behavioral responses to weather in animals. Animal stress threshold quantities in the Livestock Weather Safety Index are as follows: $\leq 74$, normal; $75 >$ alert $\leq 79$; $79 >$ danger $< 84$; and $\geq 84$, emergency. Because cow-calf pairs were used, heat stress thresholds were adjusted to a range closer to that developed by Armstrong (1994) for lactating dairy cattle. Separation between stress-free and stressful THI was therefore adjusted downward in consideration of lactating animals. In this study, we explored the impact of temperature and humidity for 2 stress levels: stress-free and stressed with corresponding THI ranges: THI $_{62–72}$ (62 > stress-free <72) and THI $_{72–84}$ ($72 \leq$ stressed $\leq 84$) on the time cattle spent in RZ, RS, NRS, and TS. Analysis of time spent by cattle in the riparian zone during colder months (November, December, and March) averaged approximately 1 h (55 min; SE = 11 min). Thus, a time of 1 h was used as a threshold as described below.

To analyze the impact of trough availability (available or not available) under different environmental conditions on cattle location, daily observations from both pastures were divided into 4 locations or groups: RZ, RS, NRS, and TS. Data were analyzed for 2 THI ranges (THI $_{62–72}$ THI$_{72–84}$) using PROC MIXED as described above and using PROC FREQ (SAS Institute Inc.) as described below. These 2 statistical tests were run to better understand cattle response to trough availability within each THI range. For PROC FREQ, within each location, proportions of cattle spending <1 h or $\geq 1$ h in each of the 2 THI ranges (THI $_{62–72}$ THI$_{72–84}$) were analyzed. The odds of cattle spending $\geq 1$ h in RZ, RS, NRS, or TS when troughs were available and not available was computed as the number of observations with time $\geq 1$ h over the number of observations with time <1 h:

$$\text{Odds (time} \geq 1 \text{ h)} = \text{observations with time} \geq 1 \text{ h/observations with time} < 1 \text{ h.} \quad [1]$$

The odds ratio for time $\geq 1$ h was estimated by dividing the odds when troughs were not available by the odds when troughs were available:

$$\text{Odds ratio} = \text{odds (time} \geq 1 \text{ h}_{\text{trough not available}})/\text{odds (time} \geq 1 \text{ h}_{\text{trough available}}). \quad [2]$$

The odds ratio was tested with PROC FREQ (SAS Institute Inc.) with a chi-square statistic. A significant chi-square coupled with a 95% confidence interval (for the odds ratio) that does not include 1 would indicate that the proportion of observations with time $\geq 1$ h in RZ, RS, NRS, or TS was larger when troughs were not

**Table 3.** Time spent by cattle (min·d$^{-1}$) in riparian zones (RZ), riparian shade (RS), nonriparian shade (NRS), and total shade (TS) as a function of water trough availability[1]

| | | | | | THI | | | |
|---|---|---|---|---|---|---|---|---|
| Item | RZ | RS | NRS | TS | Average | Min | Max | SD |
| Trough | | | | | | | | |
| Not available | 104 (6) | 90 (4) | 230 (6) | 320 (94) | 75 | 46 | 89 | 8 |
| Available | 84 (5) | 78 (4) | 233 (6) | 311 (94) | 75 | 46 | 91 | 10 |
| *P*-value | 0.14 | 0.17 | 0.98 | 0.95 | | | | |

[1] Time is presented as daily minutes with SE in parentheses. Temperature and humidity indices (THI) presented are average, minimum (min), maximum (max), and SD. Data are averaged from all collection or deployment periods (comprehensive study).

available than when troughs were available. This would indicate that cows tended to spend more time in the RZ, RS, NRS, or TS when troughs were not available.

## RESULTS AND DISCUSSION

The forage species composition in G5 was 39% bermudagrass (*Cynodon dactylon* L.), 38% tall fescue [*Lolium arundinaceum* (Schreb.) Darbysh.], 15% dallisgrass (*Paspalum dilatatum* Poir.), and 8% other species. In G8, the composition was 32% bermudagrass (*Cynodon dactylon* L.), 25% tall fescue [*Lolium arundinaceum* (Schreb.) Darbysh.], 37% dallisgrass (*Paspalum dilatatum* Poir.), and 6% other species. This composition likely varied with season during study, but was only assessed at one time point during the summer. The endophyte survey indicated 95% wild type endophyte-infected (*Neotyphodium coenophialum* Morgan-Jones and Gams) in Kentucky 31 tall fescue.

### *Comprehensive Study*

In the comprehensive study, which combined all deployment periods, water troughs showed a trend to reduce the time spent by cattle in RZ ($P = 0.14$) and in RS ($P = 0.17$; Table 3). On average, cattle spent 104 min·d$^{-1}$ in RZ when troughs were not available compared with 84 min·d$^{-1}$ when troughs were available. Cattle spent 90 min·d$^{-1}$ in RS when troughs were not available and 78 min·d$^{-1}$ when troughs were available.

***Effect of THI on Water Trough Impact.*** Figure 2 illustrates the relationships between time spent by cattle in riparian zones (upper graph) and in total shade (lower graph) as a function of THI for pastures G5 and G8 (data from the comprehensive study). Overall, when THI increased, time cattle spent in riparian zone also increased, but the effectiveness of trough availability varied depending on the temperature and humidity stress of the cattle. When THI ranged between 62 and 72 (THI $_{62–72}$), cattle tended to spend less daily time in RZ (30 vs. 82 min; $P = 0.11$), and in RS (23 vs. 72 min; $P = 0.11$) when water troughs were available (Table 4). When THI ranged between 72 and 84 (THI $_{72–84}$), water trough availability did not have an impact on the amount of time spent by cattle in the RZ or RS. The significance level of the water trough effect on time in RZ was thereby improved from $P = 0.14$ (Table 3) to $P = 0.11$ (Table 4) by including the influence of temperature and humidity as measured in part by THI. Cattle grazing endophyte-infected tall fescue under stressful environmental conditions have difficulty dissipating heat (Al-Haidary et al., 2001) and consequently get in the stream water to help control their body temperatures. These results indicate that the cattle used RZ for cooling and drinking during times of thermal stress (THI <72), but only for drinking during periods of thermal comfort.

Whereas the effect of water troughs on animal behavior had a significance level of $P = 0.11$, the 63% reduction in time spent by cattle in RZ (from 82 to 30 min·d$^{-1}$) did result in an improvement in water quality with greater significance levels. Complementary data collected in this study and reported by Byers et al. (2005) showed that in pasture G5, baseflow loads of total suspended solids and *Escherichia coli* were both reduced by 95% ($P < 0.01$), dissolved reactive P (**DRP**) by 85% ($P < 0.01$), and total P by 57% ($P < 0.01$) when troughs were available. In pasture G8, baseflow loads were reduced by 64% for total suspended solids ($P < 0.06$) and by 85% for *E. coli* ($P < 0.08$), but there were no effects on DRP or total P as a result of water trough availability. Water quality results are for annual loads and include periods of hot and cool weather. We speculate that water quality changes were greatest during the cooler seasons (seasons during which water troughs seemed to be most effective) when rainfall and subsequent overland flow are most likely to transport pathogens and nutrients from stream-side fields into streams.

Evaluating the odds ratio of cattle spending more than 1 h in RZ, we found that when weather conditions resulted in THI $_{62–72}$, there was almost 9-fold the number of observations above 1 h in RZ ($P = 0.0001$) and >6-fold the number of observations above 1 h in RS ($P = 0.0005$) when troughs were not available compared with when they were available (Table 5). When the proportion of observations is greater in a given area than the 1-h threshold, this indicates that cattle are spending more time in that area. When THI ranged between 72 and 84 (THI $_{72–84}$) the proportion of observations above 1 h in RZ, RS, NRS, or TS were not significantly greater when water troughs were not avail-

**Table 4.** Time spent by cattle (min·$d^{-1}$) in riparian zones (RZ), riparian shade (RS), nonriparian shade (NRS), and total shade (TS) as a function of water trough availability by temperature and humidity index (THI) range (62–72 and 72–84)[1]

| | RZ | | RS | | NRS | | TS | |
|---|---|---|---|---|---|---|---|---|
| Item | $THI_{62-72}$ | $THI_{72-84}$ | $THI_{62-72}$ | $THI_{72-84}$ | $THI_{62-72}$ | $THI_{72-84}$ | $THI_{62-72}$ | $THI_{72-84}$ |
| Trough | | | | | | | | |
| Not available | 82 (13) | 114 (8) | 72 (12) | 99 (7) | 213 (95) | 235 (79) | 286 (106) | 335 (75) |
| Available | 30 (13) | 113 (8) | 23 (13) | 105 (7) | 168 (96) | 237 (79) | 190 (107) | 342 (75) |
| *P*-value | 0.11 | 0.91 | 0.11 | 0.64 | 0.77 | 0.99 | 0.59 | 0.95 |

[1] Time is presented as daily minutes with SE in parentheses. Data are averaged from all collection or deployment periods (comprehensive study).

able as opposed to available. This analysis confirms our previous results.

As stated earlier, dairy cattle are considered to be experiencing stress at THI >72 (Armstrong, 1994). In Africa, King (1983) revealed the utility of the THI for the distribution of beef cattle breeds, whereas Howden and Turnpenny (2003) suggested that other factors such as animal coat color should be factored into a heat stress index. Howden and Turnpenny (2003) also indicated that the THI was as effective as other more complex models and suggested a THI of 80 as the threshold for significant heat stress in cattle. In this study it is clear that when THI is above 72 cattle spend much more time in the riparian zone. In a water intake study, Bicudo et al. (2003) showed a sharp increase in water consumption at THI >75. A grazing study in Oregon suggested cattle go to water between 23.4 ± 1.2°C and 21.3 ± 1.1°C, depending on terrain (Bailey et al., 2004).

In general, our results indicate that in cooler seasons, when THI is low, cattle spend only a small amount of time in riparian zones, especially when troughs are not available. In warmer weather, when heat stress is greater, cattle tend to spend a more significant amount of time (>300 min) in the riparian zone regardless of trough condition.

## *Controlled Study*

In the controlled study, we found that when water troughs were available cattle spent more than twice the time (83 vs. 36 min·$d^{-1}$) in the riparian zone than when water troughs were not available (Table 6). Although water trough availability significantly reduced time cattle spent in riparian shade from 74 to 26 min·$d^{-1}$, the total time spent by cattle in shade (riparian plus nonriparian shade) was not significantly affected (Table 6).

These results agree with previous research showing that providing water troughs can reduce the amount of time spent cattle spend in the riparian areas. In Virginia, Sheffield et al. (1997) made 5-min observations of Angus × Hereford or Angus × Brahman cattle between daybreak and dark. Sheffield et al. (1997) found that after installing water troughs, cattle reduced the amount of time in the stream area from 13 min·$cow^{-1}$·$d^{-1}$ to 6 min·$cow^{-1}$·$d^{-1}$, which corresponds to a 54% reduction. Godwin and Miner (1996) observed 4 beef cows in Oregon between August 7 and September 18, 1993, and noted a 75% reduction in the time cattle spent in the stream after the installation of a water trough. Porath et al. (2002) observed cattle in Oregon and noted that cattle spent the afternoon in the same area as they drank, the implication being that the presence of an

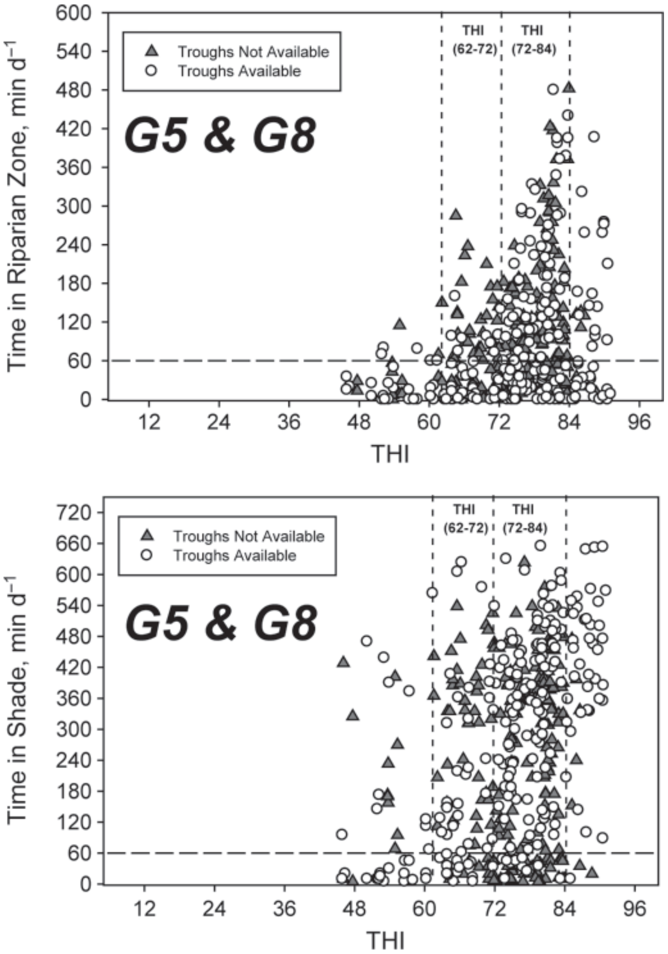

**Figure 2.** Minutes per day cattle spent in riparian zone (upper) and total shade (lower) as a function of the temperature and humidity index (THI) when water troughs were available and when water troughs were not available. Data used are from the comprehensive study. Dashed line indicates 1-h demarcation, and dotted lines identify the area of the graph influenced by the stress-free THI (62 to 72) and the stressful THI (72 to 84) environment.

**Table 5.** Odds and odds ratios for time spent by cattle in the riparian zone (RZ), riparian shade (RS), nonriparian shade (NRS), and total shade (TS) for pastures G5 and G8 as a function of water trough availability[1,2]

| Item | Odds (observations ≥1 h) Available | Odds (observations ≥1 h) Not available | Odds ratio (not available/available) | 95% CI | CHISQ | Probability |
|---|---|---|---|---|---|---|
| $THI_{62–72}$ | | | | | | |
| RZ | 0.16 | 1.43 | 8.97 | 2.75 to 29.25 | 15.83 | 0.0001 |
| RS | 0.15 | 1.07 | 6.98 | 2.15 to 22.62 | 12.21 | 0.0005 |
| NRS | 1.50 | 2.29 | 1.53 | 0.61 to 3.86 | 0.81 | 0.37 |
| TS | 1.73 | 4.09 | 2.37 | 0.88 to 6.39 | 2.97 | 0.08 |
| $THI_{72–84}$ | | | | | | |
| RZ | 1.28 | 1.53 | 1.19 | 0.73 to 1.95 | 0.47 | 0.49 |
| RS | 1.20 | 1.30 | 1.08 | 0.66 to 1.76 | 0.093 | 0.76 |
| NRS | 4.50 | 4.79 | 1.06 | 0.56 to 2.01 | 0.037 | 0.85 |
| TS | 16.29 | 10.58 | 0.65 | 0.25 to 1.71 | 0.77 | 0.38 |

[1] Odds and odds ratios are presented for 2 temperature and humidity index (THI) ranges (62–72 and 72–84). $THI_{62–72}$ is representative of a stress-free weather environment, whereas $THI_{72–84}$ is representative of a heat-stressed environment. Odds (observations ≥1 h) = number of observations ≥ 1 h/number of observations <1 h.

[2] CI = confidence interval; CHISQ = chi square.

alternative water source reduced the amount of time cattle spent near the stream.

Note that too few dates were available in the controlled study to test the effect of THI on trough availability. However, when comparing THI between the comprehensive study and the controlled study, it is interesting to note that the overall average THI was 69 in the controlled study and 75 in the comprehensive study. This could explain why water trough condition did not affect more significantly the time cattle spent in RZ in the comprehensive study. Another potential reason is that the comprehensive study evaluated the response of randomly selected cows during 17 d with or without troughs. In contrast, the controlled study evaluated the response of individual cows that were subjected to 7 d without troughs and 7 d with troughs. Thus, the controlled study reduced the variability caused by using different animals to evaluate the impact of water troughs.

An additional factor that may have increased variability is shade because both the amount and distribution varied between pastures (Table 2). The current body of literature on shade effects on cattle behavior is very limited, though researchers have theorized that shade distribution could affect pasture utilization (Parsons et al., 2003). In our pastures, the majority of the shade available to cattle was in nonriparian areas, though the amounts varied greatly between pastures (Table 2, Figure 1). Further research is needed to better understand the role of location and amount of shade on time spent by cattle in riparian zones as well as the economic impacts of fencing out streams or adding water troughs. Economic optimization should include water quality and quantity, cattle productivity, and pasture utilization especially in light of current and forecasted droughts in the southeastern United States.

## *Conclusions*

Our results indicate that providing cattle with water troughs away from riparian zones tended to reduced the amount of time cattle spent in riparian zones by 63% (52 $\text{min}\cdot\text{d}^{-1}$) when environmental conditions were not stressful (THI <72). When environmental conditions became stressful (THI >72), our data indicate that cattle spent similar amounts of time in riparian zones whether or not troughs were available. Cattle grazing endophyte-infected tall fescue under stressful environmental conditions have difficulty dissipating heat and consequently get in the stream water to help control their body temperature. In the Georgia Piedmont in the United States, $THI_{62–72}$ periods most commonly oc-

**Table 6.** Time spent by cattle ($\text{min}\cdot\text{d}^{-1}$) in riparian zones (RZ), riparian shade (RS), nonriparian shade (NRS), and total shade (TS) as a function of water trough availability[1]

| Item | RZ | RS | NRS | TS | THI Average | THI Min | THI Max | THI SD |
|---|---|---|---|---|---|---|---|---|
| Trough availability | | | | | | | | |
| Not available | 83 (6) | 74 (7) | 290 (254) | 363 (248) | 69 | 46 | 83 | 11 |
| Available | 36 (9) | 26 (9) | 320 (255) | 346 (249) | 68 | 53 | 82 | 10 |
| *P*-value | 0.05 | 0.05 | 0.94 | 0.96 | | | | |

[1] Time is presented as daily minutes with SE in parentheses. Data are averaged from collection periods in which trough availability was changed within 17-d measurement periods and is referred to in the text as the controlled study. Temperature and humidity indices (THI) presented are average, minimum (min), maximum (max), and SD.

cur during the cooler periods and are also often the wetter periods. A management strategy that results in cattle loafing or congregating in uphill locations away from streams during the wetter periods may result in less compaction near streams and retention of beneficial vegetation. Such a management strategy would be beneficial to stream water quality especially in the cooler wetter periods. It is important to note that these results apply to continuously grazed pastures with a diverse mix of warm- and cool-season grass species.

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