Portable Cold-weather Goat Shelter Development and Testing

By Cherrie Nolden
2015 Annual Progress Report

SUMMARY:

Portable goat shelter designs with goat preference data for shelter components and density levels are not available in the current published literature. Tested shelters would enable goats to be used for brush control purposes during the winter at remote sites, which could generate income for the goat producer, restore brush-invaded ecosystems, and provide diet diversity and natural behavior expression for the goats. I used the significant goat preferences that I collected from my 2014 research (Nolden, 2015) to construct more double deck portable shelters with opaque covers, then tested the densities at which goats would willingly use the shelters. I set up the experiment to test goat densities at 1.5x, 2x and 2.5x the Animal Welfare Approved (AWA) certification requirements of 16 square feet per adult goat (20, 26 and 33 goats per shelter with 210 sq ft per shelter, respectively). This was calculated based on the goats using both decks of the double deck shelters. The goats rarely chose to use the second deck, which effectively doubled the density of goats in each of the portable shelter treatments (112 sq feet used by 20, 26 or 33 goats per shelter). Goats seeking shelter under the portable shelter was a good indicator of exclusion from the preferred location inside the shelter. I collected count data of the number of goats that were excluded from the shelter from photographs taken every 30 minutes at night for 6 nights in late December, 2015. I used a repeated measures ANOVA to assess significant differences in number of excluded goats at the three density levels. All three levels were significantly different ($p<0.0001$), with the lowest density (5.6 sq ft/goat) excluding 0.5 goats each night, the medium density (4.3 sq ft/goat) excluding 2.3 goats, and the high density (3.4 sq ft/goat) excluding 5.8 goats. Temperature and time of night were also significantly influential in goat use of the portable shelters, but they both varied by density treatment ($P<0.0001$ and $P=0.0386$, respectively). This research indicates that portable goat shelters providing around 6 square feet of bedded space per goat could be sufficient for sheltering goats at remote brush control sites in winter weather for around $645 of infrastructure.

OBJECTIVES:

My goal for 2015 was to apply the preferences that the goats displayed in 2014 to further refine the shelters for goat preferences and for goat producers that want to browse goats during cold and wet weather. In 2014, the goats strongly indicated that they preferred dark shelters (opaque covers) and displayed a trend for double deck shelters when they sought shelter at night (Nolden, 2015). There is very little research supporting goat density recommendations, so the objective for 2015 was to test goat shelter densities. Animal Welfare Approved (AWA) recommends 16 square feet per goat in a shelter (AWA, 2015), but my observations of my goats indicated that the goats preferred to sleep together and didn't use all of the available space. This made me think that the goats could be willing to use less space than 16 square feet per goat, but I didn't know at what density the goats would feel overly crowded and not use the shelter space. The only published density data that I could find was a study by Anderson and Boe (2007), where they tested low, medium and high goat densities, elevated platforms and agonistic behavior. I designed the 2015 experimental goat densities to be 1.5 times, 2 times and 2.5 times the AWA-recommended density (Low, Medium and High density, respectively), which corresponded to Anderson and Boe's (2007) density levels as low, medium and medium-high goat densities, respectively. I assessed goat use of portable shelters at these densities with Moultrie game cameras set to take photographs every 30 minutes at night, for 6 nights in late December, 2015. This was a randomized complete block design for the whole plot effect, with each night being a block (the experiment was repeated for 6 nights), with three treatments (Low, Medium and High) and with repeated measures of counts from photographs of each shelter taken simultaneously every 30 minutes (28 pictures per night, per shelter). Counts were the number of goats that were not using the inside part of the shelter, but were seeking shelter underneath the bed of the trailer. This reflected the number of goats that were excluded from the preferred shelter. If a shelter could house all goats when they wanted shelter, this would be the desirable density for that shelter type.

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ACCOMPLISHMENTS:

I modified the shelters from 2014 (covered with black plastic, widened ramps, increased the hatch opening size and removed the trailer skirt), set three identical shelters up for density testing, randomly placed 3 groups of goats (20, 26 and 33 goats per shelter) in each shelter, photographed each shelter every 30 minutes for 6 nights in late December when the weather was not suitable for goats to be outside without shelter, entered the data from each photograph and analyzed it with proc mixed in SAS. Goats selected for each group were based on individuals that naturally hung out together in the large barn that normally provides winter shelter (Anderson and Boe, 2007). Water was provided to each group by an automatic heated Ritchie waterer. Outdoor space exceeded the AWA requirement of 27 square feet per goat (AWA, 2015). Food was provided ad libitum outside the shelter, with sufficient space for all goats to eat simultaneously (personal experience). Mineral was provided ad libitum inside the shelters. Goats were inspected twice daily for health and managed according to approved animal care protocols by UW-Madison and University of Minnesota.

The below pictures show the portable shelter layout for the 2015 research. The hoop house is fully open on the south end, and sealed/capped on the north end. The south end is elevated for natural passive ventilation (Harmon and Hoff, 1994). Ramps with lath slats for traction lead into the south end of the shelter, providing access to both decks. Straw bedding was provided as needed to ensure dry and clean sleeping quarters for every group. The High density group needed to be re-bedded daily, whereas the Low density group needed new bedding every 3rd day.

RESULTS:

The number of goats that sought shelter under the deck of the hoop house was significantly influenced by goat density ($P<0.0001$), outdoor temperature ($P<0.0001$), the time of night that the picture was taken ($P=0.0035$), and the interactions between density and time of night ($P=0.0386$) and density and temperature ($P<0.0001$). The Type 3

Tests of Fixed Effects table shows this result of the analysis. In a model that includes these effects, the average number of goats that are not using the desirable part of the shelter are 5.8508 for the High density shelter, 2.3340 for the Medium density shelter, and 0.5820 for the Low density shelter. So, on average, half a goat is excluded from this portable shelter at the lowest goat density in this study, and around 6 goats are excluded in the highest density shelters in this study.

The tables below show the SAS code, plus the class level information for the study design and the covariance estimates with the error structure that best handles the evenly-spaced repetitive count data from the photographs. There were 6 nights (Night) in the study, where the temperature (Temp) varied from 22-68F. Three goat density treatments (Trt) were photographed with 3 game cameras at the same time every half hour for 28 pictures per night and they were given a sequential picture number (PicNum) for the repeated measure. Counts of goats under the shelter at night (time when goats seek shelter) were made from each photograph, for a total of 504 data lines in this analysis. The game cameras recorded temperature, date, moon phase and group number on each picture, and took photos with an infrared flash at night (see example picture below). Night was a random effect and the fixed effects were modeled as Count = Temp Trt PicNum PicNum*Trt Temp*Trt.

Class Level Information		
Class	Levels	Values
Night	6	1 2 3 4 5 6
Temp	16	22 23 25 27 29 31 32 33 35 41 46 50 51 53 57 68
Trt	3	High Low Medium
PicNum	28	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28

Covariance Parameter Estimates		
Cov Parm	Subject	Estimate
Night		0.05599
Night*Trt		0.08596
AR(1)	Night*Trt	0.5879
Residual		0.8169

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Temp	15	360	7.61	<.0001
Trt	2	10	63.23	<.0001
PicNum	27	360	1.96	0.0035
Trt*PicNum	54	360	1.41	0.0386
Temp*Trt	30	360	3.83	<.0001

```
proc mixed; class night temp trt picnum;
 model count = temp trt picnum picnum*trt temp*trt;
 random night night*trt;
 repeated / subject=night*trt type=ar(1);
 lsmeans  trt picnum picnum*trt temp*trt / diff;
  ods output diffs=ppp lsmeans=mmm;
  ods listing exclude diffs lsmeans;
run;
```

Example picture from game camera during a snow storm; some goats under portable shelter, others eating (L)

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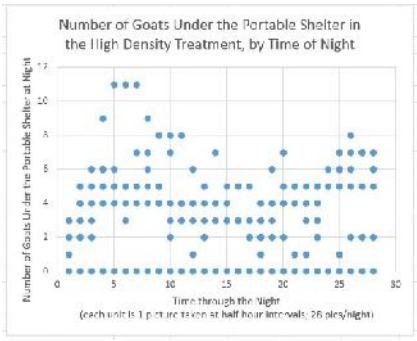
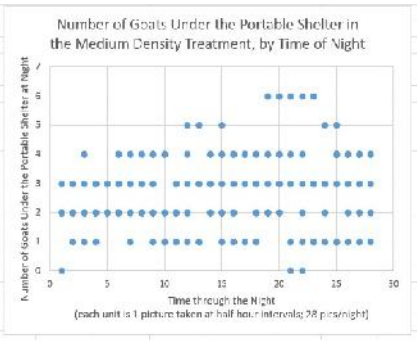
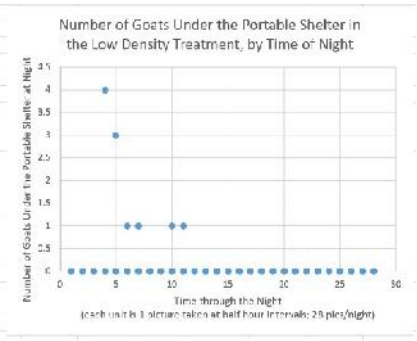
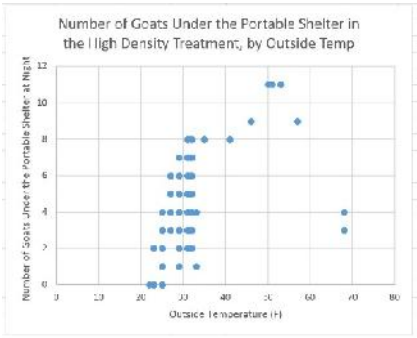
The charts below show interactions of goat density with time of night, and goat density with temperature. Goats in the High density treatments showed a bimodal pattern of number of individuals under the shelter as the night progressed (16:54 to 06:24 was defined as night, with counts every half hour for 28 repeated measures per night). The Medium density treatments increased slowly through the night, and the Low density treatments tended to have a few goats under the shelter early in the night but none there by the end of the night.

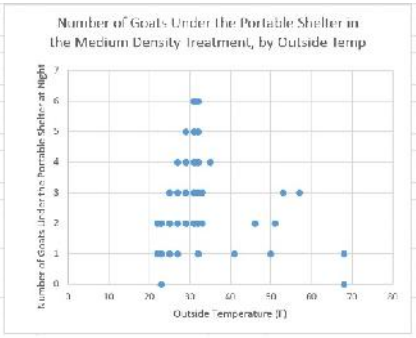


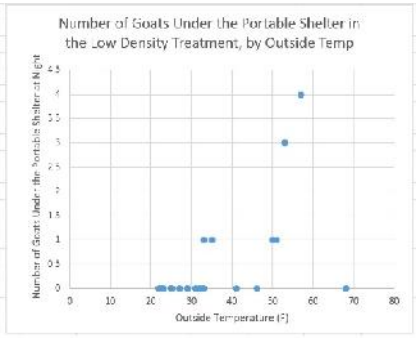




The High density treatment group had more individuals under the shelter than the Medium or Low density treatments. Goats in the Medium and High density treatments showed a similar pattern of a sharp decline of individuals sleeping under the shelters as temperatures dropped from 30F to 20F, but showed different patterns at higher temperatures.







DISCUSSION:

The High density shelter was intended to represent a 2.5-fold density increase relative to the AWA recommendations of 16 square feet per goat (AWA, 2015), but the way the goats used the shelters increased this number. The portable shelters consisted of 2 decks, with the upper deck being smaller due to the passage hatch with the ramp that allowed goats to enter or exit the upper deck from inside the shelter. The lower deck provided 112 square feet of space (7' x 16') and the upper deck provided 98 square feet (7' x 14'). This would be enough space for 13 goats, according to AWA standards, 32.8 goats at 2.5x density (High), 26.3 goats at 2.0x density (Medium), and 19.7 goats at 1.5x density (Low). The shelters were built on boat trailers with 2.5 feet of clearance between the ground and the lower deck of each shelter. There was no skirt preventing goats from going under the shelters, so this was effectively additional shelter space that wasn't part of the experimental design. Arguably, goats using the underside of the shelter were there because they couldn't enter the desirable part of the shelter. The underside of the shelters would provide protection from rain and snow but would provide very little protection from wind. There is no insulation from the ground under the shelters, so this would be a colder place to sleep. The two decks inside the shelters provided full wind and rain/snow protection, dry straw bedding, and natural passive ventilation, so this was the desirable shelter space. I only recorded 6 instances of goats using the upper deck of these shelters in 2015. This was not expected. It resulted in 33 goats packing themselves into the lower deck of the High density shelter when the weather was nasty, effectively providing only 3.39 square feet of space for each goat. They accomplished this, but only when the weather was really miserable (31F, 20-40 mph blown snow and sleet). When the weather was moderate, quite a few goats ended up sleeping under the High density shelters at night (6 on average, according to the analysis, but highly variable according to the charts showing temp*treatment and treatment*time of night

interactions). The Medium density shelter provided 4.31 square feet per goat when they chose to not use the upper deck, and the Low density shelter provided 5.6 square feet per goat without the upper deck. These two densities were significantly different from each other and from the High density shelter, in terms of number of goats sleeping under the shelter at night, which provides a better approximation of the space that goats actually need in a shelter. Most of the time, the Low density shelter, which effectively provided 5.6 square feet of sleeping space, easily housed all of the goats in that treatment and its replicates.

I was surprised that the goats rarely chose to use the upper deck of the shelters and didn't use the upper decks for sleeping. This is consistent with what they did in 2014, but I assumed that it was due to the ramps being too narrow and the hatch in the shelter allowing passage between decks being too small in 2014. Anderson and Boe (2007) indicated that goats readily use elevated structures. I doubled the ramp width and doubled the hatch size before this 2015 experiment. I also hung a 25 lumen LED camping lantern in the peak of each shelter to provide a light that might attract them to the upper deck. None of these modifications seem to have made a difference in increasing goat use of the upper decks.

The groups of goats used in this research contain a mix of meat type and dairy type goats. I only have record of 2 of the meat goats venturing to the upper deck in 2015; only dairy goats were seen up there in 2014 and the dairy goats were the primary double deck users in 2015. The goats were using the double deck during the day and not for sleeping. I have approximately 10 Myotonic goats and 20 regular meat goats that have residual hind leg paralysis from previous meningeal worm infections. Neither of these type of goats can climb as well as goats that don't have these conditions, so it is not surprising that those individuals didn't make it to the upper decks of the shelters. There was no difference in use of the lower level of the shelter by the less agile vs. more agile goats, and I didn't see the less agile goats excluded from the portable shelters more than the more agile goats. Exclusion was based on social structure with subordinate individuals more likely to be excluded (Ross and Scott, 1949). I expected the agile goats to eagerly climb to the upper decks and use this space for sleeping shelter.

It is possible that the upper deck ramps are too steep. I find this surprising since these same goats seem able to climb vertical hay bale panel feeders that are designed to reduce hay wastage. Regardless, lengthening the upper deck ramps would be a way to test if this steepness is an issue for the goats.

Feeding the goats inside the portable shelter with an outside-placed small square bale holder would recycle the refused forage as bedding and reduce the need to re-bed the shelter frequently when goats are using the shelter at high densities. Alternatively, the air quality may be better outside, and feeding the goats outside of the shelters could improve their lung health by removing them from the potential for stale air, mold spores, ammonia and close proximity to other goats.

Goat using the upper deck for play during the day

Lantern in the upper deck for 25 lumens of light

Hatch opening and ramp; perspective from the lower deck (L), and upper deck (R), North end of each shelter

CONCLUSIONS:

This study suggests that providing a socially stable group of goats with a little bit more than 5.6 square feet of bedded shelter per goat could be sufficient for housing goats in this type of portable shelter in these winter weather conditions. This represents 15-20 goats in a portable hoop house shelter with floor dimensions of 7 feet by 16 feet. Higher densities of goats resulted in more goats not using the desirable portion of the shelter during weather that would cause distress to the excluded goats.

IMPLICATIONS:

Since the goats chose to not use the upper decks of the shelters for sleeping, these extra decks could be considered an unnecessary expense, weight, and construction challenge. The single deck shelters are much easier to build and clean out since a human can stand inside them, rather than be forced to crawl. If the portable shelters were constructed with adjustable flashing, a single deck shelter could quickly be converted to a double deck with bedding tossed under the shelter and the flashing secured to the ground to exclude wind and precipitation. This would effectively double the shelter space that the goats have demonstrated that they are willing to use. Thus, a single deck portable shelter of 7'x16' could house 30-40 goats, using the deck and the protected underside of the shelter. It is possible that elevated structures, visual barriers and additional wall space inside a single deck shelter could also

increase available space and thus increase acceptable goat densities inside the shelters, as was shown by Aschwanden et al. (2009).

30-40 goats is a reasonable sized group of goats for brush control purposes, and constructing one portable shelter of this type would only cost around $645. That is a very small infrastructure cost for placing goats at a winter site that is full of invasive woody vegetation that the goats would girdle over winter while using the shelter when needed. These portable shelters are easy to build on used heavy duty boat trailers, and are easy to transport down the road since the tongue end of the shelter is sealed. These shelters could be used for transporting goats if an end was affixed.

This was a small study, so a larger study with more replicates, over a longer period of time in more weather conditions, with the collection of video-based behavioral data (agonistic behaviors) would produce even stronger results and develop a better defined goat shelter density recommendation. Testing the flashing idea and lengthening the upper deck ramps would be informative also.

Materials	Count	Per Unit	Total
Black Silage Plastic	20'x28'	$ 30.00	$ 30.00
Used Heavy Duty Boat Trailer	1	$ 300.00	$ 300.00
2x4s, 8' each	20	$ 3.00	$ 60.00
Deck Screws	1	$ 40.00	$ 40.00
Stock panels (16'x50")	5	$ 25.00	$ 125.00
Lathe bundle	1	$ 11.00	$ 11.00
Plywood, treated	4	$ 15.00	$ 60.00
Pipe insulation, 16'/shelter	3	$ 2.00	$ 6.00
Fencing staples, box	1	$ 12.00	$ 12.00
			$ 644.00

OUTREACH:

I created a poster and handouts of the 2014 research, which I presented at:

- 2015 MOSES conference
- 2015 GrassWorks Grazing Conference
- 3 goat production workshops in Minnesota in 2015
- 2015 Aldo Leopold Foundation Family Day
- 2015 Wisconsin DNR Endangered Resources Tour of BAAP Restoration
- 2015 Wisconsin Dairy Goat Association Meeting
- 2015 Whole Farm Planning Workshop
- 2015 Wisconsin School for Beginning Dairy Farmers
- 2015 Wisconsin Farm Technology Days
- 2015 National Grazing Conference
- 2015 Animal Behavior and Welfare, Animal Sciences 375, UW-Madison

I created a powerpoint presentation of the 2014 research, which was presented at UW-Madison in 2015.
I will submit this research summary to the MOSES conference as a poster abstract to share the results of the 2015 study, and will put together handouts and a powerpoint of the study results.
I plan to submit these studies to a peer-reviewed journal for publication and to the popular goat production and ecological restoration magazines.

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