ELSEVIER

Bioresource Technology **58** (1996) 285–290

0960-8524/96 $15.00

PII:S0960-8524(96)00118-6

THE POTENTIAL OF OFF-STREAM LIVESTOCK WATERING TO REDUCE WATER QUALITY IMPACTS*

Derek C. Godwin[a] & J. Ronald Miner[b]

[a]*Watershed Management Extension Agent, Oregon State University, Curry County, OR, USA*
[b]*Bioresource Engineering Department, Oregon State University, Corvallis, OR, USA*

(Received 12 December 1995; revised version received 9 August 1996; accepted 26 August 1996)

Abstract

Small commercial and non-commercial animal enterprises (SCAEs) are often located in suburban watersheds. Such operations raise a small number of animals on a few acres and have potential water quality impacts from their manure management. A typical pollution abatement practice includes fencing livestock from streams and providing an off-stream watering area. However, if there is a large stream to land area ratio, this practice becomes very costly for implementation and maintenance. An alternative is to provide off-stream watering areas without fencing to lure animals from the stream. This project demonstrated that off-stream watering areas are an effective alternative to stream fencing. They reduce the time animals spend at the stream under small acreage grazing conditions. In addition, an animal-operated pasture pump was demonstrated to be a viable off-stream watering device. The animal-operated tested pump pulled water from the creek and held the water in a small basin accessible to the animals. It is a usable alternative where conventional watering systems are inconvenient or expensive. Copyright © 1997 Elsevier Science Ltd.

Key words: Livestock grazing, riparian zones, water quality, manure.

INTRODUCTION

Small commercial and non-commercial animal enterprises (SCAEs) raise a few beef cows, horses, pigs, sheep, poultry, or other animals on a few acres. These enterprises are often located in suburban areas of watersheds and show potential for degrading water quality through increased bacterial, nitrogen and phosphorus concentrations. Many SCAEs allow animal access to streams for watering. Since animal manure is a source of bacteria, nitrogen and phosphorus that impact water quality, reducing manure deposits in the stream and riparian area is desirable.

The most common practice to limit animal access to streams is to fence the stream area and provide off-stream watering. This practice is effective in reducing animal impacts to water quality. However, the cost of implementing and maintaining the fence can be prohibitive, especially if implemented on a basin wide level.

An alternative may be to provide off-stream watering areas to lure animals away from the stream without denying access. This is obviously less expensive than fencing, but the effectiveness is undocumented as far as we are aware. This project evaluates the effectiveness of providing off-stream watering areas to reduce the time animals spend at a stream without denying access.

Providing off-stream watering areas for animals usually requires one or more watering tanks and fresh water pumped from a household water supply or stream. Given the expense of setting up and maintaining these watering systems, landowners may not change their present practices of allowing animal access to the creeks. An alternative off-stream watering system is an animal-operated diaphragm pump which does not require water tanks or an electrical connection. This type of pump, referred to as a pasture pump, allows the animal to control the amount of water pumped and holds water (1–2 pints) in a basin accessible to the animals. Two questions often raised by SCAEs are: (1) Does the pump limit animals' water consumption? (2) Since only one animal can access the pump at a time, would animals drink more water from an open trough or tub than the pasture pump? This project compares water consumption of dairy heifers from a pasture pump and from a water trough. The project also evaluated the pasture pump as an off-stream

*Technical Paper No. 10,872, Oregon Agricultural Experiment Station, Corvallis, Oregon.

watering device to lure horses from the stream to reduce water quality impacts.

BACKGROUND

Livestock manure is a potential threat to the health of other animals and humans. Manure contains enteric and possible pathogenic bacteria, nitrogen and phosphorus that may pass, via water, to animals and humans. Animal wastes from diseased or disease-carrying livestock are capable of spreading a large number of diseases, including salmonellosis and leptospirosis to other animals or humans (Moore *et al.*, 1988). Bacterial contamination of surface waters by runoff and seepage from livestock operations is possible. For example, Miner *et al.* (1967) showed beef feedlot runoff contains *Salmonella* organisms.

Nitrogen, in the form of nitrate (NO_3), is water soluble and a threat to surface and groundwater quality. The standard for nitrate in drinking water is 45 mg l^{-1} (10 mg l^{-1} as nitrogen) (USEPA, 1989). Phosphorus is a threat to water quality because it promotes algae growth. Excess nitrogen and phosphorus in surface waters can cause algal blooms that reduce dissolved oxygen and cause dramatic pH changes.

Continuous grazing systems which allow cattle to roam over a large area can cause the quantity of vegetation to differ within the area. Rotational grazing systems use fences and watering areas to manage cattle, striving for a more equal quantity of vegetation grazed in each fenced area. Rotational grazing systems vary in intensity by the size of grazing areas, seasonality, and time interval of rotation. Walker *et al.* (1985) found short-duration rotational grazing provided more uniform distribution of manure over each area than continuous grazing. This apparently was due to animals walking further and having greater variability in their travel distance compared to the continuous-grazing system.

Miner *et al.* (1992) evaluated the effectiveness of an off-stream watering area in reducing the time free-ranging cattle spent in or near the stream during the winter months. They theorized if the cattle spent less time in or near the stream, then the manure defecated in this area would also be reduced. The study was conducted over 8 days, from late January to early February, using two different pastures. The control pasture had no water tank, and the animals used the stream for watering. The second pasture had a water tank, and the animals chose between watering at the creek or from the tank. The time cattle spent in the creek with an off-stream water source available was 94% less for cattle with access to the stream as their only water source. Even when the feed source (hay) was placed equal distance between the water tank and the stream, the time cattle spent in the creek was considerably reduced.

METHODS

The following studies assume the distribution of manure in pastures is proportionate to the time the animals spend in a particular area. Therefore, if the time an animal spends in the stream or riparian area is reduced, then the amount of manure deposited in this area is also reduced. The off-stream watering area studies were conducted at two SCAEs in the Tualatin River basin near Portland, OR. The water consumption study was conducted at the Oregon State University Dairy Research Center in Corvallis.

Off-stream watering study 1

The amount of time four beef cows (averaging 283 kg) spent within 4·6 m (15 ft) of a stream, with and without an off-stream watering area available, was evaluated. The cows grazed a 3-acre pasture. A water trough was located approximately 23 m (75 ft) from the creek access area and outside of the animals' normal path to the creek. The stream and an adjacent grazing area was fenced except for a walkway, or chute, that allowed one animal to enter or leave the area at a time. The stream-side area was approximately 9·3 m^2 (100 ft^2) and allowed all four cows to loiter and have stream access at the same time. This stream-side pasture was thoroughly grazed prior to the study.

A CR10 datalogger, distributed by Campbell Scientific, Inc., and two lightbeam counters were attached to the chute. When the lightbeams were broken, the datalogger recorded the date, time and direction the cows were moving in relation to the stream. The data were processed to determine the time animals spent at the stream.

The study was conducted from 7 August to 18 September 1993. Initially, no water trough was available and the cows had water available at the creek. Nine days were allowed for the cows to adjust, then data were collected for 17 continuous days. Subsequently, a water trough was provided and the animals could water at the creek or water trough. Six days were allowed for the cows to adjust, then data were collected for 11 continuous days. Daily high and low temperatures were recorded but changed little during the data collection period.

Off-stream watering study 2

Water consumption by two mature pleasure horses was monitored under different pasture management alternatives. An animal-operated pasture pump (Utina, Model M) was placed approximately 175 ft from the point of creek access. The pasture pump pulled water from an off-site calibrated water tank which allowed water to be monitored. The horses had continuous access to the pasture pump, but

never to the water tank. The calibrated water tank was protected from wind and sun to minimize evaporation.

For the control, the horses had access to the pump and grazed both the wet pasture (1·5 acres) and the drier pasture (1·5 acres). For Alternative 2, the horses could water from either the creek or the pasture pump and grazed just the wet pasture. For Alternative 3, the horses could water from either the creek or the pasture pump and grazed just the drier pasture. The horses could always graze the area between the pasture pump and creek.

The control condition was monitored for 30 days, wet pasture for seven days, and drier pasture for 8 days. The study was conducted from 4 August to 17 September 1993. Daily maximum and minimum temperatures from the nearby area were recorded.

Pasture pump water consumption study

The water consumption of 27 Holstein dairy heifers from an open water tank and a pasture pump was monitored and compared. The pump used was a Utina Model M pasture pump distributed by Farm Trol Equipment Company of Theresa, Wisconsin. The pasture pump was attached to plywood and placed over the water tank when in use. The plywood denied animal access to the water tank, but the pump used the tank's water as the water source.

The 27 heifers averaged 386 kg (850 lb) and were 15–16 months old. The heifers had access to an approximate 2·4 hectare (6 acre) pasture. The pasture was irrigated as needed during the course of the study. The heifers were given approximately 2 weeks of alternating between the pasture pump and water tank before water consumption data were recorded. Animal behavior was observed during this period.

Daily water consumption from the water tank and pasture pump were measured by taking water depth measurements in the tank. The water tank capacity was 374·5 l (99 gallons). Water depth measurements in the tank were converted to volume. Measurements were made at approximately 0830, 1130, 1430, 1730 and 2030 h each day. The pump was placed on, or taken off the water tank, at the 1130 hour. The study was conducted for 13 days beginning 9 July 1993.

RESULTS AND DISCUSSION

Off-stream watering study 1

When the cows had access to water at the stream only, the four cows spent an average of 60 min day^{-1} at the stream with a standard deviation of 29 min (Table 1). When given the choice of watering at the tank or at the stream, the total time spent near the stream was reduced to an average of 15 min with a standard deviation of 18 min.

Since the data contained outliers suggesting a non-normal distribution, a Wilcoxon Two Sample Rank Test was performed on the data. This test is non-parametric and does not pivot on normality. The ranking of the data is shown in Table 1, while the hypothesis test and results are shown in Table 2. The mean time the four cows spent at the stream with a water trough available was significantly different than without a water trough. These results

Table 1. Data for off-stream watering study number one. Four cows drink from a stream with and without an off-stream watering area (watering trough) available

Cows access stream only			Cows access stream and trough		
Minutes at stream			Minutes at stream		
Day	Min	Rank	Day	Min	Rank
22/8/93	84	27	14/9/93	51	19
23/8/93	64	22	15/9/93	9	5·5
24/8/93	153	28	16/9/93	11	7·5
25/8/93	66	23	17/9/93	14	9
26/8/93	28	10	18/9/93	9	5·5
27/8/93	37	12	19/9/93	47	18
28/8/93	72	24	20/9/93	5	4
29/8/93	30	11	21/9/93	0	1
30/8/93	57	21	22/9/93	2	2
31/8/93	41	13	23/9/93	11	7·5
1/9/93	76	25·5	24/9/93	3	3
2/9/93	45	16			Rank sum = 82
3/9/93	56	20			
4/9/93	44	14·5			
5/9/93	76	25·5			
6/9/93	46	17			
7/9/93	44	14·5			
	Average = 60				Average = 15
	S.D. = 29				S.D. = 18
					% Reduction = 75
					Cows drink from creek (% of time) = 25

Table 2. Wilcoxon 2 Sample Rank Test analyzing if a significant difference exists between the time four cows spend at a stream with and without an off-stream watering area available

Hypothesis test	
Ho: u1 = u2	
H1: u1 < oru2	
where:	u1 is the mean minutes at stream with stream and trough access
	u2 is the mean minutes at stream with stream access only
Test analysis	
T1 = sum of ranks = 82	
T2 = n1(n1+n2+1) − T1 = 237	
where:	n1 = number of observations for minutes at stream with stream and trough access
	n2 = number of observations for minutes at stream with stream access only
Results	
At alpha = 0·01 level, T is 105 (Snedecor & Cochran, 1989); T2 is greater than T at this level. Therefore, mean minutes at the stream with trough option is significantly lower than minutes at stream without trough option at an alpha = 0·01 or 99% confidence level	

were significant at the 99% confidence level using an alpha of 0·01. No correlation was determined between daily air temperatures and time spent near the stream.

The time of day the four cows entered the stream zone was observed using the data. No cows entered or exited the stream zone from sundown to sunrise the following day. This was consistent with the observations of Miner *et al.* (1992).

As a matter of discussion, three land management options can be theoretically compared for their reduced affect on water quality. The three options are: (1) construct a fence to deny all stream access and provide a watering area, (2) provide an off-stream watering area only and (3) maintain the status quo. Godwin (1994) reviewed the literature and found that beef cows defecate approximately 12 times per day. Considering beef cows mainly graze during the day, we can estimate 12 defecations over a 12-h period or one defecation h^{-1}. Based on these assumptions, this study suggests that providing an off-stream watering area reduces the number of defecations in the stream from once daily to once every 4 days (75%) for four beef cows. Fencing the cows from the stream would eliminate direct fecal deposits in the stream.

The amount of manure kept from the stream is redistributed in the pasture. Therefore, the corresponding water quality improvement is dependent on rainfall, runoff conditions and distance to the stream. Godwin (1994) reviewed the literature on effectiveness of filter strips in reducing bacteria, nitrogen and phosphorus from runoff. Under most rainfall and runoff conditions, bacteria are filtered from 95 to 100%, nitrogen filtered from 70 to 100%, and phosphorus filtered from 70 to 100% from runoff.

Off-stream watering study 2

Daily water consumption of two mature horses from a pasture pump averaged 24·4 l (6·46 gallons) when they had no creek access, 11·6 l (3·06 gallons) for the wet pasture with creek access, and 20·3 l (5·35 gallons) for the drier pasture with creek access (Table 3). The water consumption from the pasture pump was reduced 53% for the wet pasture and 17% for the drier pasture alternatives with creek access.

Analyses of variance between the control (no creek access) and the test conditions were conducted for the water consumption data (Table 4). Water consumption from the pasture pump under the wet pasture alternative was significantly different (*P*-value = 0·0469) from the control (Table 4). There was insufficient evidence to conclude that water consumption from the pasture pump under the drier pasture study was significantly different (*P*-value = 0·4102) from the control (Table 4). No

Table 3. Average daily water consumption data for two horses drinking from a pasture pump with and without creek access

	Daily water consumption (l)
No creek access (30 days)	
Average	24·4
S.D.	13·4
Creek access and wet pasture (7 days)	
Average	11·6
S.D.	7·5
% Reduced	53
Creek access and drier pasture (8 days)	
Average	20·3
S.D.	8·4
% Reduced	17

Table 4. Results of an analysis of variance test between water consumption by two horses from a pasture pump with and without creek access

ANOVA: Single-factor						
No creek access (control) versus creek access with wet pasture						
Summary						
Groups	Count	Sum	Average	Variance		
Column 1	30	733	24.4	181		
Column 2	7	80	11.4	38.2		
Source of variation	SS	d.f.	MS	*F*	*P*-value	*F* crit
Between groups	959.892	1	959.892	6.142937	0.018162	4.121347
Within groups	5469.081	35	156.2595			
Total	6428.973	36				
ANOVA: Single-factor						
No creek access (control) versus creek access with drier pasture						
Summary						
Groups	Count	Sum	Average	Variance		
Column 1	30	733	24.4	181		
Column 2	8	162	20.3	70.2		
Source of variation	SS	d.f.	MS	*F*	*P*-value	*F* crit
Between groups	110.5281	1	110.5281	0.694312	0.410196	4.113161
Within groups	5730.867	36	159.1907			
Total	5841.395	37				

correlation was determined between daily air temperatures and water consumption.

This study indicates that providing an off-stream watering area reduces the amount of time the horses spend at the stream. The wet pasture scenario was not as effective as the drier pasture scenario. However, this may be due to the horses having water to drink in the pasture or ingesting more water with the forage.

Pasture pump water consumption study

Daily water consumption from the pump and from the water trough, average daily consumption, and standard deviation are recorded in Table 5. Due to the small number of data sets for comparison and the large variability between days suggesting non-normal distribution functions, the data were analyzed qualitatively rather than quantitatively. The average water consumed from the pasture pump was higher than the amount consumed from the water trough, indicating the pasture pump did not limit the animals' water consumption. In addition, no significant amounts of water being spilled or wasted from the pasture pump were observed.

Table 5. Daily water consumption from one pasture pump (pump on) or one open water tank (pump off) by 27 Holstein dairy heifers from 9 July to 23 July (1130 to 1130 h) 1993

Pump on/off	Consumption (l)	Pump on/off	Consumption (l)
On	491	Off	485
On	478	Off	358
On	737	Off	475
On	587	Off	600
On	707		
On	513		
On	738		
	Average = 607		Average = 480
	S.D. = 118		S.D. = 99

Data were collected during the summer of 1993 when daily maximum and minimum air temperatures ranged from 65 to 74°F (18–23°C) and from 46 to 60°F (8–16°C), respectively. No correlation between daily air temperatures and water consumption was determined. There was only 1 day of recorded rainfall (21 July) which measured 0·41 in. (1·04 cm). The amount of water consumed on that day was not affected. The pasture was irrigated on 15, 16 and 19 July. However, water consumption was not affected.

The learning period for the heifers to use the pasture pump was typically less than 1 day. A 'pecking order' among the cows was created at the pump. Less dominant heifers waited while more dominant ones drank. No heifers showed physical signs of dehydration nor were any animals injured. Two days were needed for less dominant heifers to establish a routine of when to use the pump.

CONCLUSION

These studies and Miner *et al.* (1992) confirm that providing off-stream watering areas will decrease the time livestock spend at a stream. There seems to be minimal difference in time spent at the stream between providing off-stream watering areas with fence versus no fence. One of the studies indicated that the location of the watering area may influence effectiveness in reducing time at the stream.

Assuming the distribution of manure is correlated with the time an animal spends in an area, off-stream watering can reduce water quality impacts. Since both practices redistribute defecations from the stream to the pasture, their effectiveness becomes dependent on rainfall, runoff conditions, and distance to the stream. Under no runoff condi-

tions, the off-stream watering area is nearly as effective as a fence in reducing manure inputs to surface water. Considering the results of the study and the cost of implementing and maintaining a fence, off-stream watering has a high potential to reducing water quality impacts of grazing livestock at a reduced cost.

These studies also illustrated that pasture pumps can be used in the off-stream watering area instead of a water trough and provide similar environmental benefits. In addition, pasture pumps seem to provide adequate water to maintain animal health.

REFERENCES

Godwin, D. C. (1994). Implementing best management practices in small commercial and non-commercial animal enterprises. MSc thesis, Department of Bioresource Engineering, Oregon State University, Corvallis.

Miner, J. R., Fina, L. R. & Platt, C. (1967). *Salmonella infantis* in cattle feedlot runoff. *Appl. Microbiol.*, **15**, 627–628.

Miner, J. R., Buckhouse, J. C. & Moore, J. A. (1992). Will a water trough reduce the amount of time hay-fed livestock spend in the stream (and therefore improve water quality)? *Rangelands*, **14**(1), 35–38.

Moore, J. A., Smyth, J., Baker, S. & Miner, J. R. (1988). *Evaluating Coliform Concentrations in Runoff from Various Animal Waste Management Systems*. Oregon State University Agricultural Experiment Station Special Report 817, Corvallis, Oregon.

Snedecor, G. W. & Cochran, W. G. (1989). *Statistical Methods*, 8th edn. Iowa State University Press, Ames, Iowa.

USEPA (1989). *National Primary and Secondary Drinking Water Standards; Proposed Rule*. 40 CFR Parts 141, 142 and 143. U.S. Environmental Protection Agency, Washington, DC.

Walker, J. W., Heitschmidt, R. K. & Dowhower, S. L. (1985). Evaluation of pedometers for measuring distance traveled by cattle on two grazing systems. *J. Range Mgmt*, **38**(1), 90–93.