Effects of Feral Swine on Water Quality in a Coastal Bottomland Stream

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Abstract: Feral swine *(Sus scrofa)* are abundant throughout the southern United States with a complex legal status and a reputation for negative interactions with wildlife and vegetation. The impacts of feral swine upon water quality are not extensively nor quantitatively documented in the published literature. We quantified the effects of feral swine on dissolved oxygen, fecal coliform bacteria, overall heterotrophic bacteria plate counts, and the presence of disease-causing bacteria. We sampled Mill Creek in western Louisiana in summer 2002 and spring 2003. Feral swine increased fecal coliform counts ($P = 0.03$ in 2002 and $P \leq 0.01$ in 2003) and heterotrophic plate counts ($P \leq 0.01$ in 2003). Fecal coliform counts ($r^2 = 0.25$, $P = 0.01$ in 2002, $r^2 = 0.30$, $P \leq 0.01$ in 2003) and heterotrophic plate counts ($r^2 = 0.44$, $P = 0.02$ in 2003) were positively related to swine presence. We also identified pathogenic bacteria, *Aeromonas* spp., *Staphylococcus aureus,* and *Shigella* spp., in swine impacted water. We quantified the increase in fecal coliform bacteria and suggest the potential for disease transfer caused by feral swine. We recommend swine management consider negative impacts of swine on water quality and the potential health hazards of high swine densities on humans and other wildlife.

Key words: Escheria coli, fecal coliform, feral swine, Louisiana, *Sus scrofa,* water quality

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Feral and free-ranging swine roam the southern, central, and western United States with negative impacts on native wildlife, vegetation, and water quality (Bratton 1975, Wood and Barrett 1979, Wood et al. 1992, Mason and Fleming 1999). Most feral swine are concentrated in the southeastern United States (Wood and Barrett 1979) with slowly expanding populations in the central and western regions (Gipson et al. 1998, Walthman et al. 1999). These swine are primarily descendents of formerly free-ranging domestic stocks (Wood and Barrett 1979). However, some swine, particularly in parts of Louisiana, are free-ranging. Feral swine exist under a number of different legal statuses including game animal, nuisance species, and domestic stock animal (Wood and Barrett 1979). Hunting, where possible, has been established as the best control measure (Caley 1993), yet hunting is often a controversial swine management technique (Wood and Barrett 1979). The complicated legal status and controversial control methods, particularly with free-ranging swine and their descendents, make population management problematic for wildlife and land managers.

Benign neglect is not a management option with feral swine. Feral swine compete with wildlife for food (Wood and Barrett 1979, Singer et al. 1984, Focardi et al. 2000) and serve as reservoirs for wildlife diseases (Wood and Barrett 1979, Wood et al. 1992, Mason and Fleming 1999). Native vegetation abundance and diversity, including timber regeneration rates, also are reduced due to feral swine activities (Bratton 1975, Howe et al. 1981, Lipscomb 1989, Mitchell and Mayer 1997, Ford and Grace 1998, Ickes et al. 2001).

Although feral swine are often found near water bodies (Wood and Brenneman 1980, Barrett 1982, Bowman and Panton 1991), the relationship between swine activity and water quality in a non-agricultural setting has only been described observationally by Belden and Pelton (1975, 1976), who described a belief by park personnel that swine were detrimental to native trout and contributed to increased bacterial loads near wallows. In large-scale agricultural operations, swine wastes cause decreased dissolved oxygen and increased levels of fecal coliforms and pathogenic bacteria (Burkholder et al. 1997, Mallin et al. 1997, Stone et al. 1998). It is very likely that high densities of feral swine may cause similar effects in streams.

Our goal was to quantify the influence of feral and free-ranging swine upon water quality in Louisiana streams. We suspected, similar to large-scale agricultural operations, that feral swine roaming the bottomland hardwoods of western Louisiana would create water quality problems by lowering dissolved oxygen, increasing bacterial loads, and introducing disease-causing pathogenic bacteria into streams.

Methods

We selected Mill Creek, a low order tributary of the Calcasieu River, in Allen Parish, Louisiana, for our study. Mill Creek lies in a low-lying, poorly drained depression encompassing approximately 161,470 ha. Typical of most southwestern Louisiana streams, Mill Creek's watershed has multiple uses with 88.7% of the land in commercial timber rotation, 8.7% in agriculture, and 1.2% urbanized. Most of the Mill Creek watershed included in this study is within the West Bay Wildlife Management Area (WBWMA) and is administered by the Louisiana Department of Wildlife and Fisheries. WBWMA has an active timber management plan, but does not have an active swine population management program.

We established five sample reaches, two tributaries (Alligator and Cottonmouth creeks) and three main channel reaches (Old Oakdale Road, Tower Road, and Scott Road) within Mill Creek, to assess the impact of swine on water quality in August 2002. Our criteria for swine activity were actual swine sightings or the presence of wallows, density of tracks, and rooting within and alongside the stream. We recorded the number of wallows, density of tracks, and presence of scat. We selected one tributary with swine activity and one without evidence of swine activity. In our main channel reaches, the location of swine activity changed with season: downstream reaches had swine activity in the fall whereas upstream reaches had swine activity in the spring.

We visited the Mill Creek watershed in August 2002, October 2002, and April 2003. Within each sample reach, we measured dissolved oxygen, specific conductance (suspended particle concentration), and temperature with a handheld YSI Model 85 probe (YSI Inc., Yellow Springs, Ohio). We also collected two water column samples for fecal coliform and heterotrophic plate counts, which are commonly used measures of assessing water quality (American Public Health Association 1998).

Our fecal coliform and heterotrophic plate count lab procedures followed the water assessment protocols outlined by the American Public Health Association (1998). Six subsamples of 1, 10, and 50 mL volume (2 of each) were filtered through a Millipore HC fecal coliform testing filter (Millipore Inc., Billerica, Massachusetts). We added Millipore fecal coliform media and incubated the samples for 24 h at 38 C in a water bath. Fecal coliform counts were made under magnification using a darkfield Quebec colony counter (Leica Microsystems, Buffalo, New York). Twelve additional subsamples of 1, 0.1, 0.01, 0.001 and 0.0001 mL were taken for heterotrophic plate counts. These subsamples were mixed with R2A media in pour plates and incubated for 48 h at 35 C. The heterotrophic plate counts also were made using the darkfield Quebec colony counter. Also, in the lab, we randomly selected 24 microbial colonies from the heterotrophic plates for gram-staining and differential media testing using Enterotube II (Beckton Dickson Microbiology Systems, Sparks, Maryland) media tubes. We used Holt (2000) to interpret the results of the gram-staining and differential media tests.

We hypothesized fecal coliform and total bacteria counts, as represented by heterotrophic plate counts, would be higher in sites with swine activity. We used a two-way ANOVA, performed separately for 2002 and 2003, with *a priori* contrasts between swine active and inactive tributary reaches and additional contrasts among swine active and inactive main stem reaches comparing heterotrophic plate counts, fecal coliform counts, water quality parameter, rooting, wallowing, and scat. We also tested relationships between swine presence/absence and water quality parameters with logistic regression. When violations of normality assumptions were detected, we used log transformations to approximate normality for fecal coliform and heterotrophic plate count data.

Results

We observed seasonal changes in swine activity in the Mill Creek watershed. In the summer and fall 2002, swine activity was concentrated in wet lowland areas in the downstream reaches of the watershed. This concentrated swine activity in our downstream reaches, were along Cottonmouth Creek (site C) and Scott Road (site E)

Table 1. Presence of swine activity, $\bar{x}$ (SE) fecal coliform counts (FC), $\bar{x}$ (SE) heterotrophic plate counts (HPC) measure at five locations in the Mill Creek watershed, southwest Louisiana, 2003–2003.

Creek	Reach	Swine activity	$\bar{x}$ FC	$\bar{x}$ HPC
	Summer and Fall 2002			
Alligator	A	No	220 (18.7)	325 (25)
Cottonmouth	C	Yes	610 (150.3)	258.5 (151.5)
Mill	B	No	91 (23.1)	194.5 (88.5)
Mill	D	No	94.5 (9.2)	1,620 (400)
Mill	E	Yes	118 (2.7)	3,810 (610)
	Spring 2003			
Alligator	A	Yes	372.5 (21.7)	138,000 (2,000)
Cottonmouth	C	No	952.5 (86.6)	67,500 (26,500)
Mill	B	Yes	872.5 (139.7)	104,000 (9,750)
Mill	D	No	85.5 (34.57)	24,750 (750)
Mill	E	No	30 (5.7)	18,500 (8,500)

accesses. By the following spring, swine activity moved upland to Alligator Creek (site E) accesses. In the summer and fall, we observed more, but not significantly greater, riparian damage, rooting, and wallows in and alongside reaches in Cottonmouth Creek (site C) and along Scott Road (site E), than in the spring in reaches in Alligator Creek (site A) and along Old Oakdale Road (site B). Swine activity was never observed at the Tower Road (site D) access.

Dissolved oxygen, temperature, and specific conductance measurements did not significantly differ among stream reaches in any season. Dissolved oxygen concentration was low (1.07–4.3 mg L^{-1}) and depressed below potential saturation (11%–36% of saturation), accounting for temperature, in all reaches. Water temperature was fairly uniform (16.3–17.9 C) throughout the watershed.

However, in each sampling trip, our microbial data reflected the presence of swine in stream reaches (Table 1). We attribute the increased fecal coliform and heterotrophic plate counts to swine in the watershed because we have been able to eliminate other potential sources, such as humans, domestic animals, or other semi-aquatic wildlife. Data from the Louisiana Department of Environmental Quality (2003) and our measurements indicated Mill Creek water near the closest settlement, Elizabeth, Louisiana, to have low fecal coliform counts. WBWMA removed domestic animals from its property several years ago. Finally, we found no evidence of river otters *(Lutra canadensis)* or muskrats *(Ondatra zibethicus)* in the study reaches, and beavers *(Castor canadensis)* were only present near Tower Road (site D), where we recorded consistently low fecal coliforms and heterotrophic plate counts. In August and October 2002, swine-impacted reaches were higher in fecal coliforms (F = 14.46, df = 1, P = 0.03), but were not higher in heterotrophic plate counts. Swine-impacted reaches in April 2003 were higher in fecal coliforms ($F = 250.94$, df = 1, $P \leq 0.01$), and heterotrophic plate counts ($F = 746.6$, df = 1, $P \leq 0.01$). In 2002, analyses of swine presence/absence indicated weak correlation between heterotrophic counts and dissolved oxygen with swine presence; however, fecal coliforms were positively related to swine presence ($r^2 = 0.25$, $P = 0.01$). In 2003, heterotrotrophic plate counts ($r^2 = 0.44$, $P = 0.02$) and fecal coliform counts ($r^2 = 0.30$, $P \leq 0.01$) were positively related to swine presence, but dissolved oxygen was not related.

Microbial identifications yielded evidence of pathogenic bacteria in swine impacted reaches with potential health impacts to wildlife, fish, and humans. Fecal coliform counts reflect the abundance of *Escheria coli,* a potential intestinal pathogen to vertebrates. Drinking water standards for fecal coliform colonies state that colony counts must not exceed 200 per 100 mg L^{-1} (American Public Health Association 1998). All of our reaches with swine activity exceeded this threshold. In sites with swine activity, we identified *Aeromonas* spp., *Staphylococcus aureus,* and *Shigella* spp., which are also potentially pathogenic to humans and wildlife. These bacteria were not present in our randomly selected samples from reaches without swine activity.

Discussion

Our data provide quantitative evidence that confirm decreases in some water quality measures and increases in potential for disease transfer with swine presence. In western Louisiana, reductions in water quality and increases in potential exposure to disease have important implications to wildlife and humans who are exposed to the waters of Mill Creek and the Calcasieu River downstream.

We did not observe decreases in dissolved oxygen, increases in temperature, or increases in specific conductance reflecting swine disturbance. Instead, dissolved oxygen was low and depressed below saturation throughout the watershed. However, we did establish correlations between swine presence and elevated levels of fecal coliform and heterotrophic plate counts in both 2002 and 2003.

Elevated levels of fecal coliforms have been reported downstream of agricultural swine production operations (Burkholder et al. 1997, Mallin et al. 1997). However, to our knowledge, no published reports exist on the impact of feral swine on fecal coliform counts. Fecal coliform counts were elevated beyond drinking water standards and were significantly higher in swine impacted reaches. *E. coli* is a known intestinal pathogen of vertebrates that also causes septicemia and meningitis (Holt 2000). The host of *E. coli* is immune to its native bacteria, but exposure to foreign *E. coli* by drinking or through open wounds may cause disease in wildlife and humans. Although we did not estimate swine density, elevated levels of fecal coliforms beyond ambient numbers one would expect from native wildlife suggest that swine concentrate their activities in streams. Swine appeared to elevate fecal coliforms beyond drinking water standards potentially causing a disease hazard to wildlife and humans.

Feral swine have been recognized as sources for wildlife disease (Wood and

Barrett 1979). Perhaps more disturbing than the fecal coliform counts were the pathogens identified in swine impacted reaches. Although some bacteria common in the environment have been described, many non- or potentially pathogenic bacteria in aquatic ecosystems have not been studied in detail (Leff and Lemke 1998). We were only able to identify 63% of the colonies we selected for gram-staining and differential media tests. However, we did find *Aeromonas* spp., *Staphylococcus aureus,* and *Shigella* spp. in swine-impacted reaches. Bacteria in the genus *Aeromonas* are pathogenic to frogs, fish, and humans, *Staphylococcus aureus* is a pathogen to humans, and bacteria in the genus *Shigella* cause bacillary dysentery in humans (Holt 2000). We suggest that feral swine not only serve as a reservoir for wildlife disease, but also may be potential sources for disease in human populations.

Management Implications

We believe the significantly higher levels of fecal coliforms exceeding drinking water standards in stream reaches utilized by swine implies management protocols should control the number of swine in a given watershed. As well, the presence of pathogenic bacteria in stream waters where swine are active suggests a potential health hazard to wildlife and humans. These data should assist wildlife biologists and land managers in developing swine management plans that consider the impacts of swine populations on stream water quality.

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