

COULD WILD PIGS IMPACT WATER QUALITY AND AQUATIC BIOTA IN FLOODPLAIN WETLAND AND STREAM HABITATS AT CONGAREE NATIONAL PARK, SOUTH CAROLINA?

Scott A. Zengel and William H. Conner

AUTHORS: Scott A. Zengel, PBS&J/EcoScience and Clemson University, Department of Forestry and Natural Resources, 2639 North Monroe Street, Building C, Tallahassee, Florida 32303; and William H. Conner, Clemson University, Baruch Institute of Coastal Ecology and Forest Science, Highway 17 North, PO Box 596, Georgetown, SC 29442-0596.

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Abstract. Non-native wild pig (*Sus scrofa*) disturbance was evaluated over three years (2000-2003) in fixed 1,000 m² plots at Congaree National Park in South Carolina. Hog disturbance (mainly rooting) averaged across all years was more abundant in cypress-tupelo swamp (19% total ground disturbance) compared to bottomland hardwoods (9%). In small linear cypress-tupelo sloughs and along small creeks, rooting disturbance frequently approached 80-100%, particularly during the driest months. Rooting disturbance was also abundant along Cedar Creek, the main blackwater stream running through the interior of the park. Drought and low water levels over the first two years of the study likely intensified hog activity on the floodplain and especially in cypress-tupelo swamps and along small streams. During the peak drought year, hog disturbance was even greater for cypress-tupelo swamp (29%) as compared to bottomland hardwoods (11%). In peak drought months, hog disturbance in cypress-tupelo swamps reached mean values of 38-42%. Quadrat-based (0.25 m²) percent cover values for understory vegetation and leaf litter/fine woody debris in undisturbed cypress-tupelo areas were 30% and 70%, respectively. By comparison, in recently rooted cypress-tupelo areas, these values were 14% and 40%, with 46% cover by bare exposed soils. Additional observations included concentrated rooting and wallowing along surface water areas, and greater turbidity and hog fecal material in and around recently rooted surface waters. Direct predation on native freshwater mussels was also documented. A positive association between rooting and the presence of coarse woody debris, an important microhabitat for wetland and aquatic invertebrates, amphibians, and small reptiles, was also identified. These results and observations, coupled with similar observations by other researchers within the park, and recent quantification of hog effects on water quality and aquatic invertebrate communities in similar habitats elsewhere, indicate that wild pigs could potentially affect

water quality conditions and aquatic biota at Congaree National Park.

INTRODUCTION

Congaree National Park (Congaree Swamp) is located on the upper coastal plain of South Carolina in Lower Richland County, near the City of Columbia. The park is characterized by mixed bottomland hardwood forest and cypress-tupelo swamps occurring on the Congaree River floodplain. The Congaree River is considered a major alluvial river and is part of the upper Santee River system. The park also contains smaller blackwater streams including Cedar Creek and Tom's Creek that are tributaries to the Congaree River. Non-native wild pigs (*Sus scrofa*) at Congaree Swamp are thought to be a mix of feral animals originating from domestic stock released or escaped to floodplain forests of the Congaree River and hybrids of wild boar and feral animal crosses introduced by various hunting clubs and adjacent land owners, with the hybrid wild boar – feral hog phenotype being prevalent (Mayer and Brisbin 1991). Wild pig populations and associated ecological impacts in the National Parks have been a documented or suspected problem for some time (Singer 1981). Park resource management staff, numerous researchers, and several environmental and conservation organizations have been concerned about the potential ecological impacts of wild pigs at Congaree National Park for many years, particularly in relation to substrate disturbance caused by wild pig rooting and wallowing. As a result, a research study and monitoring program was designed and implemented to investigate and quantify wild pig habitat use and disturbance levels and patterns at the park (Zengel 2008). Results and observations from the study are combined with past and emerging literature to identify possible effects of wild pigs on water quality and aquatic biota at the park.

METHODS

Wild pig habitat use and substrate disturbance were sampled using 12 fixed 50 m by 20 m rectangular floodplain plots (1,000 m²). Sampling was conducted every other month over three years (September 2000 to July 2003). During sampling, hog-related substrate disturbance was mapped within the plots using 1-m grid cells. In addition, within each forest plot, a minimum of six 0.25 m² photo-quadrats were established; at least three quadrats randomly located in areas with no signs of visible disturbance by wild pigs and at least three quadrats randomly located in areas recently disturbed by wild pig rooting (new, fresh rooting sign). Vertical photographs of the quadrats were made from a height of approximately 1.5 meters, using a 35 mm Single Lens Reflex film camera and 400-speed color film. High resolution digital images were prepared from the color film negatives for analysis. The digital photographs were analyzed using a random point-intercept method to determine cover values for vegetation, leaf litter and fine woody debris, coarse woody debris (CWD), and bare soil. Finally, over the duration of the study, roughly 20 miles of set travel routes to and from the sampling plots were walked during each sampling period and field observations made concerning the types and abundance of wild pig sign and disturbance along features such as hiking trails, small blackwater streams, linear cypress-tupelo sloughs, oxbow lakes, and seepage areas. Visual estimates of disturbance cover and turbidity observations were noted in rooted and wallowed areas. Results from the disturbance study and field observations are combined with other literature from the park, as well as past and emerging literature on hog effects on water quality and aquatic invertebrate communities in similar habitats elsewhere, to determine if wild pigs could potentially impact water quality and aquatic biota at Congaree National Park.

RESULTS

Hog disturbance (mainly rooting) in the 1,000 m² plots across all years was more abundant in cypress-tupelo swamp (19% total ground disturbance), the lowest and most wet forest type, as compared to bottomland hardwoods (9%). Based on plot data and travel route observations, rooting disturbance frequently approached 80-100% in small linear cypress-tupelo sloughs and along small blackwater streams, particularly during the driest months. Rooting disturbance was abundant along Cedar Creek, the main blackwater stream running through the interior of the park. Prolonged drought and lack of major flooding from the Congaree River over the first two years of the study likely intensified hog activity on the floodplain and especially in cypress-tupelo swamps and

along small streams. During the peak drought year, hog disturbance was even greater for cypress-tupelo swamps (29%) as compared to bottomland hardwoods (11%). In peak drought months, hog disturbance in cypress-tupelo swamps reached mean values of 38-42%. Quadrat-based percent cover values for understory vegetation and leaf litter/fine woody debris in undisturbed cypress-tupelo areas were 30% and 70%, respectively. By comparison, in recently rooted cypress-tupelo areas, these values were 14% and 40%, with 46% cover by bare exposed soils. A positive association between recently rooted areas and the presence of coarse woody debris was also identified. Recently rooted areas had greater association with coarse woody debris (29% incidence) than areas without recent rooting (8%). Additional qualitative observations included concentrated rooting and wallowing around surface water areas (including small streams, ponds, oxbow lakes, and seepage areas) and elevated turbidity and the presence of hog fecal material in and around recently rooted surface waters. Though not directly measured, localized observations of elevated turbidity related to wild pig rooting and wallowing activity were visibly above background levels when compared to areas upstream of hog-disturbed areas and similar areas without recent hog disturbance. This was particularly the case for areas of stream bank disturbance compared to the relatively low turbidity levels typical for small blackwater streams. Direct hog predation on native freshwater mussels (Florida pondhorn, *Uniomerus carolinianus*) in small blackwater streams was also documented.

DISCUSSION

Early studies of wild pigs in Great Smoky Mountains National Park described the potential water-quality related effects of wild pig rooting and wallowing including sedimentation, increased fecal contamination, nutrient mobilization, and impacts to aquatic biota such as native brook trout (*Salvelinus fontinalis*) (Belden and Pelton 1975, 1976; Lacki and Lancia 1983; Singer *et al.* 1984). Other than nutrient mobilization (Lacki and Lancia 1983; Singer *et al.* 1984), indications of other potential water quality effects were largely observational or suspected. More recently, new quantitative information concerning the influence of wild pigs on water quality and aquatic biota has begun to emerge in the literature. Wild pigs have been associated with increased fecal coliform levels, increased biological oxygen demand (BOD), presence of pathogenic bacteria, and changes in aquatic microbial and invertebrate communities in forested floodplain streams in Louisiana (Kaller and Kelso 2003, 2006; Kaller *et al.* 2007). Wild pigs have also been documented as a potential contributing factor in a recent pathogenic *Escherichia coli* outbreak associated with agricultural produce from

California (Jay *et al.* 2007). Two recent studies further describe potential negative influences of wild pig rooting on herpetofauna declines in forested wetlands and aquatic habitats in North Florida (Dodd *et al.* 2007, Means and Travis 2007).

The wild pig disturbance data and observations presented above, coupled with past and recent literature sources, indicate the potential that wild pigs could affect water quality and aquatic biota at Congaree National Park, particularly during drought and low water levels (and during subsequent flooding of rooted areas). Potential wild pig effects could include (1) increased erosion, turbidity, and sedimentation from rooting activities; (2) increased fecal contamination; (3) nutrient mobilization and associated surface water enrichment; and (4) direct and indirect effects on aquatic biota and communities.

Erosion, Turbidity, Sedimentation

Widespread wild pig disturbance on the Congaree floodplain removes vegetation and leaf litter cover, exposing and loosening soils that may become more susceptible to mobilization by surface waters and erosion, and may contribute to turbidity and potential downstream sedimentation, especially during flood periods following extensive rooting. Along small blackwater streams of Congaree Swamp, removal of vegetation and destabilization of consolidated stream bank sediments may have a similar effect, both during base flow conditions and during flooding. Williams and Benson (2004), working in the park during drought and low water conditions in 2002, observed several locations along the Congaree River and Cedar Creek (a blackwater tributary to the Congaree River) where hundreds of meters of stream bank had been rooted by hogs to 15-30 cm depths, resulting in bank destabilization and potential erosion and downstream sedimentation, possibly threatening native freshwater mussels. Maliszewski (2005) also noted wild pig rooting as a source of sediment mobilization at Congaree, and commented that rooted sediments would likely behave quite differently during flood events as compared to areas without such disturbance. Despite widespread substrate disturbance, rooting in mesic hardwood forests of Great Smoky Mountains National Park did not increase sedimentation loading to streams (based on total suspended solids), due to soil type and infiltration rates (Singer *et al.* 1984). However, there are obvious differences in landscape setting and sediment dynamics between the two study areas and regions. Additional work may be warranted in this area.

Fecal Contamination

Wild pig fecal contamination, like that documented in similar floodplain habitats in Louisiana (Kaller and Kelso 2003, 2006; Kaller *et al.* 2007), could also be a concern for Congaree Swamp, particularly given the relatively

large population size / high population density of wild pigs thought to be present on the Congaree floodplain, especially during drought conditions and low water levels (Friebel 2007, Zengel 2008). Both the Congaree River and Tom's Creek (a blackwater tributary to the Congaree that passes through the park) are on the 2008 South Carolina 303(d) list of impaired water bodies due to fecal coliforms (SCDHEC 2008). Cedar Creek was formerly on the impaired list for fecal coliforms (Maliszewski 2005), but is not currently listed. Water quality sampling that has supported these listings has occurred primarily outside and upstream of the park (downstream of the park as well for the Congaree River). In addition, sampling for *Enterococci* and *E. coli* within the park has indicated that Tom's Creek and portions of Cedar Creek did not consistently meet EPA freshwater criteria for these parameters (Montebello and Montebello 2008). Tom's Creek in particular has had chronic issues with fecal contamination, including difficulties identifying the sources of contamination (Maliszewski 2005). The most likely suspected sources are malfunctioning septic tanks, livestock (cattle), and wildlife (Maliszewski 2005). It is certainly possible that wild pigs are a contributing factor, both inside and outside of the park. The documented presence of pathogenic bacteria associated with wild pig activity in Louisiana and California raise additional concern (Kaller and Kelso 2003, 2006; Jay *et al.* 2007). The park and the University of South Carolina are currently conducting a study of fecal contamination in Tom's Creek using *E. coli* sampling that will contribute new and important information on this topic (T. Thom, pers. comm.). Using a combination of weight of evidence approaches; traditional sampling and analysis for fecal coliforms, *Enterococci*, and *E. coli*; and microbial source tracking (MST), PBS&J and partners have similarly examined waterbody and watershed-level impairments due to fecal contamination from multiple sources, including sewer systems, septic tanks, stormwater runoff, illicit discharges, livestock, and multiple wildlife species (unpublished data). Kaller *et al.* (2007) applied MST to their wild pig studies, with success. Similar methods could be used to further examine fecal contamination associated with non-native wild pigs at Congaree Swamp and in similar situations elsewhere in South Carolina.

Nutrient Mobilization and Enrichment

Wild pig rooting has been associated with increased organic matter decomposition rates in forest soils, increased soil nutrient transformation and mobilization, and increased nitrate levels in streams draining heavily rooted watersheds of Great Smoky Mountains National Park (Lacki and Lancia 1983; Singer *et al.* 1984). Based on the abundance and density of rooting at Congaree National Park, it is possible that similar affects could be occurring there as well. Studies comparable to those of

Lacki and Lancia (1983) and Singer *et al.* (1984) examining wild pig rooting and nutrient relationships in southern floodplain forests or other forested wetland systems are not known. Perhaps such studies are needed. Worth noting, forest tent caterpillar (*Malacosoma disstria*) outbreaks and canopy defoliation events in water tupelo (*Nyssa aquatica*) stands have been associated with increased nutrient levels in floodplain soils and adjacent streams in Louisiana, due to litterfall and insect frass (Effler *et al.* 2006, 2007). Similar forest tent caterpillar outbreaks and defoliation events occur in South Carolina, including Congaree National Park (USFS 2001, Zengel 2008). Investigations of nutrient dynamics in floodplain systems of Congaree National Park or elsewhere in South Carolina should consider both wild pigs and forest tent caterpillars.

Aquatic Biota and Communities

Kaller and Kelso (2006) and Kaller *et al.* (2007) quantified differences in aquatic invertebrate communities as a result of wild pig rooting in floodplain stream habitats in Louisiana. Specific changes included declines in freshwater mussels and in certain guilds of aquatic insects (collectors and scrapers). Similar to observations reported in this study, including wild pig predation on Florida pondhorn, Williams and Benson (2004) also observed wild pig predation on native freshwater mussels at Congaree, including variable spike (*Elliptio icterina*) and other species. They describe long reaches of stream bank rooted and littered with broken mussel shells, and implicated wild pigs as one of the most important threats to native mussels and stream and floodplain habitats within the park. In addition to fecal coliforms, Tom's Creek (upstream of the park) is also on the 2008 South Carolina 303(d) list due to impaired macroinvertebrate communities (SCDHEC 2008). It is possible that wild pigs could be a contributing factor. On-going water quality and stream invertebrate (Stream Condition Index) studies conducted by PBS&J and partners in forested wetland streams in North Florida have noted increasing incidence of wild pig rooting for several study sites, perhaps related to drought and low water levels (unpublished data). These studies may present additional opportunities to examine wild pig influences on aquatic invertebrate communities and biota. Similar studies at Congaree National Park and elsewhere in South Carolina could be insightful.

The positive association of wild pig rooting and the presence of coarse woody debris at Congaree Swamp confirmed prior anecdotal observations of hogs preferentially rooting around, under, and into coarse woody debris on the floodplain. Similarly, Singer *et al.* (1984) observed that 67% of downed branches and logs in intensively rooted areas had been moved by pigs, and another 10% were broken apart by pig rooting. The association of pig rooting with coarse woody debris is

likely related to food/prey resources, including invertebrates, amphibians, and small reptiles. Coarse woody debris is an important habitat for wetland and aquatic invertebrates and many other species (McMinn and Crossley 1996, Braccia and Batzer 2001). It is possible that high levels of hog disturbance and predation in coarse woody debris could affect aquatic communities and biota associated with these microhabitats, especially for taxa closely associated with or dependent on coarse woody debris. Worth noting, Kaller and Kelso (2006) focused their invertebrate community analysis on collections from woody debris.

SUMMARY

Wild pig disturbance data and other observations at Congaree National Park, coupled with past and emerging literature, indicate that wild pigs could potentially affect water quality conditions and aquatic biota at the park and perhaps elsewhere in similar settings in South Carolina, particularly during or following drought and low water levels. Potential effects could include (1) increased erosion, turbidity, and sedimentation from rooting activities; (2) increased fecal contamination; (3) nutrient mobilization and associated surface water enrichment; and (4) direct and indirect effects on aquatic biota and communities. Since much of this argument for Congaree National Park is based on observational or circumstantial information coupled with literature review, additional research in this area is needed.

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