Assessing biological effects of natural gas drilling on headwater streams in the Fayetteville Shale region.

Project Summary

There are approximately 1330 producing natural gas wells within the Fayetteville Shale region of Arkansas and new wells continue to be installed. Few studies have examined how the drilling process affects sedimentation and aquatic biota in this region. We propose to **(1)** quantify and characterize sediments in streams that drain land with a high density of permitted locations (>10) versus those that drain land with few to no gas permits (<4); **(2)** compare sediment quantity and composition and quantify and identify biota in streams that drain wells with implemented Best Management Practices (BMP) in the Gulf Mountain Wildlife Management Area (WMA) to those that do not.

Objective 1: we will pair streams by geographic location and % land cover for a total of 6 pairs across the Fayetteville Shale region. Sediment, algal biomass and primary production, invertebrates, and fishes will be measured in spring 2010 in each stream to determine the community composition and possible changes in composition occurring from activities associated with gas wells.

Objective 2: we will pair Gulf Mountain BMP drilling sites with high density of wells and no BMPs. We will sample in autumn 2009, before well construction, and in Spring 2010 after well construction and BMP implementation.

Our data will provide data on the effectiveness of drilling Best Management practices, baseline biological surveys of 15 headwater streams, the amount and composition of benthic and suspended sediment associated with drilling activities, and effects of sediment associated with drilling activities on sensitive aquatic biota, such as the speckled pocketbook mussel and Yellow cheek darter located in the Little Red River watershed.

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Budget Summary:

Total amount requested $120,993

Matching funds (UCA/UA/TNC) $120,948

Total project amount $241,941

Funding priorities addressed by proposal: Our project will assess the effects of natural gas drilling on biota in headwater streams by measuring sediments, primary production, invertebrates, and fish in headwaters with low or no permitted gas wells versus those with a high density of newly constructed active wells (>10; high/low); **and** those catchments with well construction that implement BMPs and those that did not implement BMPs (no BMP/BMP). We will address 2 priorities listed under the Arkansas Wildlife Management Plan:

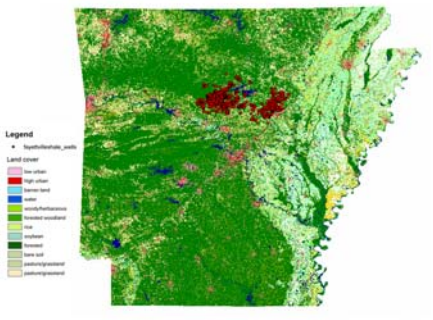
1. **Implement conservation actions and monitoring in the Fayetteville Shale area**
2. **Survey headwater aquatic biodiversity. Reduce anthropogenic impacts to headwater streams and cave recharge areas.**

Project Goals and Objectives: Our goals are two-fold: (1) We will inventory and assess the aquatic biota in 12 headwater streams, 6 with high and 6 with low densities of newly constructed active wells. (2) We will determine the efficacy of newly devised BMPs for horizontal well construction to reduce sedimentation to surrounding streams. Headwater streams comprise over 90% of the total stream miles of Arkansas's river networks, providing critical habitats for sensitive invertebrates, salamanders, and fishes. Many land uses threaten the biological health of headwaters including agriculture, logging, and drilling for natural gas. Therefore, headwater streams are listed as ecosystems of concern under the AWAP and species of concern inhabit some of these streams. The installation and implementation of gas wells has the potential to dramatically increase sedimentation to headwater streams by increasing road and ditch densities; clearing vegetation around gas pad, pipeline, and compressor sites; and more directly from impacts associated with temporary and/or permanent stream/riparian intersection and alteration from road crossing, pipeline, and reservoir construction (Fig. 1). This sediment has the potential to smother biota and alter the community structure of the headwaters.

Fig. 1. Sedimentation from installation and maintenance of natural gas wells. A) Stream trenching for laying pipe under a small stream; b) ditch and fill activities along the riparian corridor of a stream; and C) slope clearing of vegetation to lay pipe for gas distribution, D) compressor sites, roads, and E) gas wells. Photos courtesy of Lindsey Lewis, USFWS

Region & Study Site Location: Our study sites will be located in the Fayetteville-Shale region of central Arkansas in 15, 2$^{nd\ or}$ 3rd-order headwater streams (Fig.2).

Study Design and Methods: The study design is a paired stream approach that will allow for an experimental block design to increase our ability to detect biological differences due to sedimentation



from drilling and minimize differences due to geographic location, local geology, differences in hydrology, and precipitation. We will determine suitable paired stream locations by determining catchment area and calculating land cover above each sampling reach using the Arc Hydro extension

Fig. 2: 2006 Arkansas land use and land cover data with producing wells in Fayetteville Shale region (red dots).

in ArcMap (Fig. 3, Table 1). In each stream, we will ground-truth, conduct habitat assessments, and then delineate a 200 meter stream segment to sample in replicate. Our sampling will include 9 streams from the Little Red River drainage and 6 from the Cadron Creek drainage.

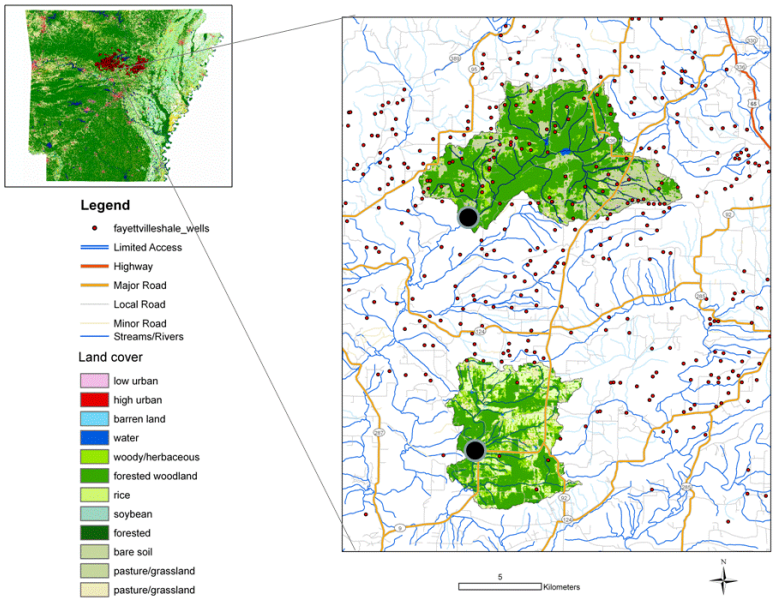


Fig. 3: Example of site selection showing paired high and low density catchments. Potential study reach locations are shown as black dots.

Table 1. Percent land cover in each of the catchments in Fig. 3 using 2006 Arkansas land use and land cover data.

Catchment	Urban	Water	Herb/woody	Woodland	grasses (warm)	grasses (cool)
Low well	2	0	20	50	23	4
High well	2	1	9	63	24	1

We will quantify the following variables in autumn 2009 and Spring 2010 in high/low catchments and no BMP/BMP catchments (**15 total catchments**):

1. Ten benthic and suspended sediment samples from each stream reach at high and low flow. Benthic sediments will be sampled using a corer, collecting a known volume of slurry subsample, and filtered in the laboratory. Suspended sediments will be sampled using portable automated sequential water samplers and filtered in the laboratory. Sediment content (organic vs. inorganic fractions) and volume will be quantified (Wallace et al. 2006).

2. Replicate sediment samples from low and high flows will be analyzed for isotopic composition of particulate organic matter (POM) and particulate inorganic matter (PIM). Stable carbon and nitrogen ratios, as well as ^{14}C measurements, will be used as identifiers or markers for sources of sedimentation (Hilton et al. 2008; Jennerjahn et al. 2008).

2. Five to 10 benthic invertebrate samples will be collected in each stream reach within each representative habitat using a 250 µm mesh Hess sampler. Invertebrates will be collected, preserved in ethanol, enumerated, identified, and biomass will be estimated. Invertebrate richness, diversity, density, life history traits, and biomass will be determined for each stream at base flows only (Entrekin et al. 2007).

3. Fish will be sampled at base flows with triple pass electro-fishing. Fish taxa richness, density, and biomass will be quantified. Fish that cannot be identified in the field will be preserved in 10% formalin and taken to the laboratory. Individual fish will be identified and weight and length measurements recorded.

4. Periphyton biomass and primary production: Five to 10 cobbles will be collected in each stream reach within each representative habitat, stored on ice, and analyzed for chlorophyll *a* and ash-free dry mass in the laboratory. Whole-system metabolism (i.e., gross primary production, community respiration, net ecosystem production) will be measured in each study stream by determining diel dissolved oxygen patterns using multi-parameter sondes equipped with temperature, conductivity, optical DO, and turbidity sensors and conservative gas and solute releases to estimate re-aeration. Photosynthetically-active radiation will be monitored using Odyssey light loggers at each stream reach during metabolism estimates. Water samples will be collected and analyzed for total nitrogen and total phosphorus on a Lachat rapid flow analyzer before and after metabolism estimates.

Monitoring: measurements that can be communicated to the public

- Quantity and type of sediments: compare the amount of sediments in high and low well density catchments and compare catchments with and without implemented well BMPs; compare the amount of organic to inorganic carbon in high and low well density catchments and those with and without implemented BMPs. Determine source of sediments and possible contamination from wells using carbon and nitrogen isotopic signatures.

- Water quality: measure the total amount of nitrogen, phosphorus, pH, and turbidity in the water column that could be indicative of contamination by agriculture, sewage, or drilling practices.

- Biological community structure and composition: quantifiy biological metrics, such as % individuals intolerant to sediments, # rare taxa, species richness and diversity, and total density, in the high/low density catchments and in the no BMP/BMP catchments.

- Ecosystem metrics: to be used as an indicator of stream "health" by measuring the amount of oxygen produced by the microbial community and available to the invertebrates as food.

Species of concern

- Speckled pocketbook mussel (*Lampsilis streckeri)*

- Yellow cheek darter (*Etheostoma moorei*)

Measurable products:

- Measure the effectiveness of BMPs for horizontal well construction to reduce sedimentation to surrounding streams.
- Baseline data on periphyton biomass, primary production, and invertebrate and fish diversity, density, and biomass in 12 headwater streams with varying levels of permit densities and landuse in understudied habitats.
- Provide management recommendations for minimizing sedimentation that may occur from drilling activities.
- Provide data to alert land managers to potential effects of sedimentation from gas drilling on species of concern.
- Submission of at least 3 peer-reviewed scientific publications addressing the effects of natural gas drilling on biota in Arkansas.
- Data will be placed in the Comprehensive Wildlife Conservation Strategy upon completion.
- Generated maps will be made available at www.ArkansasWildlife.com.
- Students and principal investigators will present data at the North American Benthological Society, American Fisheries Society: state and local chapters, American Society of Limnology and Oceanography, and Arkansas Academy of Sciences.
- Project updates will be available at the PIs websites and the Arkansas Fish and Wildlife Service webpage.

Timeline

	2009	2010		
	Autumn	Spring	Summer	Autumn
Sampling				
Pre-BMP sampling	X			
All catchment sampling		X		
Sample Processing				
Sediment quantification	X	X	X	
Periphyton and Metabolism	X	X	X	
Invertebrates	X	X	X	
Fish	X	X	X	
Data analysis		X	X	X
Report completion				X

Partnerships: University of Central Arkansas biologists and chemists will be working in collaboration with the United States Fish and Wildlife Service, The Nature Conservancy, and the University of Arkansas, Fayetteville. Collectively, the partnership will provide a diversity of knowledge relevant to the

project, equipment needed to carry out research objectives, and people located in close proximity to the study locations.

Qualifications of University of Central Arkansas to carry out this project

University of Central Arkansas has a location ideal for this multi-investigator project and has been involved in biological research in the area for many years. UCA has a strong Environmental Science Program to train undergraduate students, who will be central to this effort, as well as a graduate program in biology. In addition, the chemistry department has analytical equipment. The collaboration with the University of Arkansas Fayetteville and The Nature Conservancy will provide additional analytical support for water quality analysis, mass spectrometry, and graduate student involvement through Michelle Evans-White's laboratory, GIS analysis, spatial statistics, and additional biological experience in the Fayetteville Shale region.

Sally Entrekin has a background in aquatic ecology that has focused on food web and organic matter dynamics in headwater streams on which she has published. Her responsibilities on this project will include project organization, mentoring of an undergraduate and graduate student to investigate organic matter dynamics and invertebrate community structure.

Ginny Adams research has focused on the conservation of sensitive and endangered species in relation to anthropogenic disturbance. She is an expert in cave and spring ecology and has studied morphology, physiology, life history, genetics, and ecology of invertebrates and fishes on which she has several scientific papers. Her responsibilities on this project will include mentoring of undergraduate and graduate students in fish collection and identification.

Reid Adams research has focused on physiology and ecology of freshwater fishes and invertebrates in large river systems and has several papers relevant papers on these subjects. He will contribute his broad experience on the ecology of streams and rivers in this region. His responsibilities on this project will include mentoring of undergraduate and graduate students in fish collection and identification.

Michelle Evans-White research and scientific publications have focused on roles of animals in organic matter and nutrient dynamics in stream ecosystems and how anthropogenic factors may alter species functional roles. Her responsibilities on this project will be monitoring whole-stream metabolism, water chemistry (including storm sampling), and providing analytical support to faculty at UCA.

Lindsey Lewis is a biologist with the United States Fish and Wildlife Service. Among his many duties, he monitors the activity of well drillers in the state of Arkansas. He will act in an advisory role to help us find study locations, gain access to private lands, and help disseminate our research results.

Karen Steelman has a great deal of experience with radiocarbon dating and stable isotope analysis and will aid in the characterization of the organic and inorganic content of sediments. She will mentor undergraduate students in field, as well as with laboratory sampling and processing.

Ethan Inlander is a professional geographer and project manager with over 15 years experience applying geospatial technologies and analyses to land management and conservation issues. His emphases include watershed modeling, riparian mapping and conservation prioritization. His responsibilities on this project will be to provide input on GIS modeling and landscape characterization.

Daniel Millican is an aquatic ecologist with experience in identification of species-environment relationships using multivariate analyses. His responsibilities on this project will be to provide advice on biological and landscape sampling design, and on using statistical analyses to identify landuse influences on biological characteristics.

Literature Cited

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