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# Stream primary producers relate positively to watershed natural gas measures in north-central Arkansas streams

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## HIGHLIGHTS

- Unconventional natural gas metrics were associated with stream primary producers.
- Gas metrics often related positively to primary producer measures.
- Algal communities in minimally impacted streams were N-limited.
- Natural gas activities may alleviate N-limitation of algal communities.

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## ABSTRACT

Construction of unconventional natural gas (UNG) infrastructure (e.g., well pads, pipelines) is an increasingly common anthropogenic stressor that increases potential sediment erosion. Increased sediment inputs into nearby streams may decrease autotrophic processes through burial and scour, or sediment bound nutrients could have a positive effect through alleviating potential nutrient limitations. Ten streams with varying catchment UNG well densities (0–3.6 wells/km$^2$) were sampled during winter and spring of 2010 and 2011 to examine relationships between landscape scale disturbances associated with UNG activity and stream periphyton [chlorophyll *a* (Chl *a*)] and gross primary production (GPP). Local scale variables including light availability and water column physicochemical variables were measured for each study site. Correlation analyses examined the relationships of autotrophic processes and local scale variables with the landscape scale variables percent pasture land use and UNG metrics (well density and well pad inverse flow path length). Both GPP and Chl *a* were primarily positively associated with the UNG activity metrics during most sample periods; however, neither landscape variables nor response variables correlated well with local scale factors. These positive correlations do not confirm causation, but they do suggest that it is possible that UNG development can alleviate one or more limiting factors on autotrophic production within these streams. A secondary manipulative study was used to examine the link between nutrient limitation and algal growth across a gradient of streams impacted by natural gas activity. Nitrogen limitation was common among minimally impacted stream reaches and was alleviated in streams with high UNG activity. These data provide evidence that UNG may stimulate the primary production of Fayetteville shale streams via alleviation of N-limitation. Restricting UNG activities from the riparian zone along with better enforcement of best management practices should help reduce these possible impacts of UNG activities on stream autotrophic processes.



## 1. Introduction

As the United States (U.S.) strives to gain energy independence and find cleaner alternatives to coal and oil, exploration and recovery of unconventional natural gas (UNG) has become more prominent. Additionally, technological advances in well installation, such as horizontal drilling and hydraulic fracturing, have made natural gas recovery from deep shale rock formations more feasible. In the U.S. there are 29

*Abbreviations:* UNG, unconventional natural gas; Chl *a*, chlorophyll *a*; GPP, gross primary production; IFPL, inverse flow path length; PAR, photosynthetically active radiation; NDS, nutrient diffusing substrates.

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shale basins that span 20 states (Entrekin et al., 2011). These shale basins have been under intense development of natural gas infrastructure in the past decade, with more than 5000 wells installed from 2005–2013 in the Fayetteville shale alone (AOGC; Fig. 1). Currently the U.S. is a world leader in UNG extraction and use, but an increase in global extraction is expected due to vast unconventional gas reserves (Malakoff, 2014). By the year 2050, NG is expected to meet 47–53% of global energy demands (Rahm and Riha, 2014; Malakoff, 2014). Combustion of natural gas is estimated to produce less carbon dioxide per unit energy gained relative to other fossil fuels (Shahidehpour et al., 2005). However, the recovery of UNG could have several negative environmental implications such as, creating unnatural low flow conditions due to excess water extraction for hydraulic fracturing (Vidic et al., 2013), surface and groundwater contamination from improper storage and disposal of fracturing fluids (Vidic et al., 2013) and increased sediment erosion from well pad construction sites (Williams et al., 2008). Unfortunately, few studies exist that assess these potential impacts of UNG production on terrestrial and aquatic ecosystems. While there are several environmental impacts associated with the development of UNG resources, the primary focus of this study was on sediment erosion and its associated potential impacts.

Construction of UNG wells and infrastructure increases potential for sediment erosion to surface waters (Entrekin et al., 2011; Williams et al., 2008). Several hectares of vegetation are cleared from the land prior to well pad construction. Additional infrastructure, such as roads and pipelines, is installed to facilitate the recovery and transport of the natural gas produced, both resulting in a decrease in forested habitat and increase in forest fragmentation (Drohan et al., 2012; Moran et al., 2015). Sediment from bare land associated with the well site and infrastructure construction can be transported in runoff to streams (Williams et al., 2008) and cause increased turbidity (Entrekin et al., 2011) and potentially sedimentation. After installation is complete, some vegetation may be allowed to grow back; however, gravel roads and the immediate vicinity of the well are usually kept cleared, which may cause a more lasting effect on sediment delivery to streams, as has been documented with logging roads (Beschta, 1978).

Sedimentation is one of the major contributors to poor stream health among wadeable U.S. streams (USEPA, 2006), having major direct negative and indirect positive effects on autotrophs. Increasing stream sediment load beyond natural levels might negatively effect biotic communities (Allan and Castillo, 2007; Owens et al., 2005). Specifically, suspended sediment attenuates light (Parkhill and Gulliver, 2002), which can shade benthic algal communities (Brown and King, 1987; Yamada and Nakamura, 2002; Young and Huryn, 1996). Additionally, suspended sediments can scour benthic algal communities from rock surfaces (Horner et al., 1990). As discharge decreases suspended sediments may be deposited, burying algal communities and reducing habitat quality for recolonizing communities (Waters, 1995) due to the instability of finer sediments during spates (Biggs et al., 1999). Conversely, sediments entering into streams may have a positive, indirect influence on algal biomass due to increased sediment bound nutrients.

Landscape disturbances such as urbanization (Vaze and Chiew, 2004) and pasture land use (Nguyen et al., 1998; Quinn and Stroud, 2002; Vaze and Chiew, 2004) can increase runoff of nutrients associated with sediments, and leaching of nutrients from soils (Lewis and Likens, 2007). Higher nutrient loads within streams that are nutrient limited can result in increased algal biomass (Tank and Dodds, 2003), and an overall eutrophication of the system. A previous study in Ozarks streams suggested that N-limitation of algal growth was dominant (Lohman et al., 1991). If landscape disturbance from UNG development mobilizes soil N, then benthic autotrophs might respond positively. Given the suite of possible direct and indirect effects of sediments on primary producers, the impact of UNG development on stream periphyton may be complex.

Sediment erosion associated with UNG activity might have both direct and indirect effects on in-stream autotrophic processes and the ability to detect these effects could vary seasonally due to spates. Spates, occurring most often during spring and autumn, scour the benthos regardless of increased sediment erosion, making it difficult to link landscape disturbances to changes in autotrophic processes. More stable flow conditions during summer and winter might allow for better detection of landscape disturbance effects on autotrophic processes.

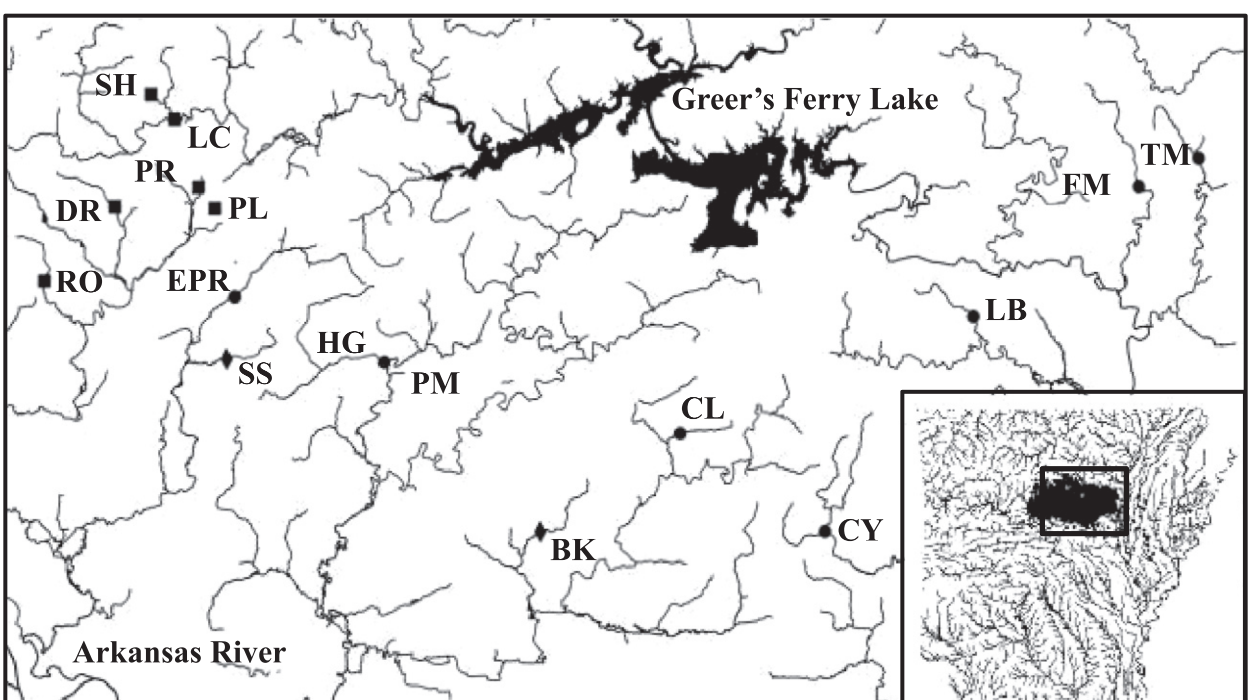


**Fig. 1.** Study reaches in north central Arkansas within the Fayetteville Shale play, abbreviations for site names are defined in Tables 1 and 6. Sites marked with (●) represent study reaches only in the gradient study. Sites marked with (■) represent study reaches used only in the nutrient limitation study and sites marked with (♦) represent study reaches used in both studies.