Assessment of High Value Ecological Areas in Pennsylvania's Shale Region






Assessment and Baseline of High Value Ecological Areas in the Shale Region

Establishing Baselines for Long-term Monitoring

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Western Pennsylvania Conservancy

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Executive Summary

Background

While concerns over impacts to drinking water and public health from development of "unconventional" natural gas resources from deep shale formations have dominated the conversation, the potential impact to rare and important plant and wildlife species and critical ecological resources from the development of shale gas is of great concern to the conservation community in Pennsylvania and throughout the Appalachian Region.

It is unclear to what degree shale gas development will impact Pennsylvania's native biological diversity, and more specifically the state's critical habitats and rare plant and animal populations. However, these areas are potentially threatened by fragmentation, introduction and invasion of exotic species, habitat loss, use of chemicals in the extraction process, erosion and sedimentation, changes to surface water flow, and treatment of wastewater.

As part of the broader monitoring trend across Pennsylvania, the Western Pennsylvania Conservancy initiated an ecological assessment of areas of high ecological value that may be under threat from development activities associated with shale natural gas development. Our assessment focused on obtaining baseline species and habitat data from specific locations that support rare and important wildlife species. Obtaining baseline data is critical to assess the extent of impacts, if any, and to inform policies and regulations to avoid impacts to other areas and minimize them through adaptive management.

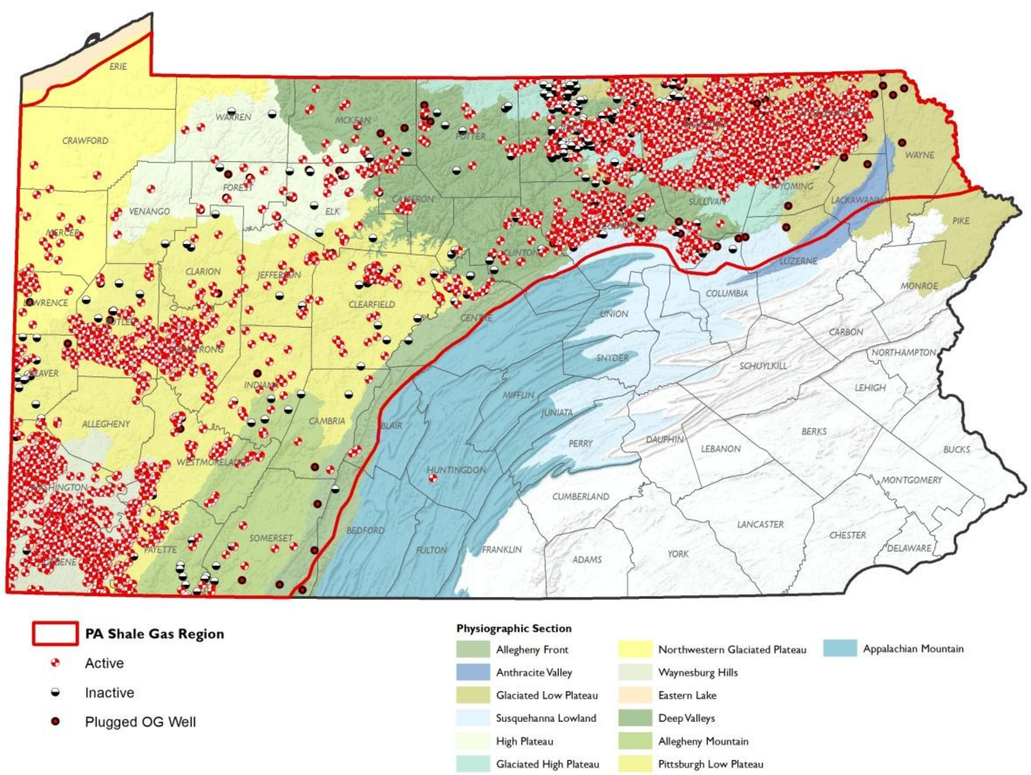

Figure i. Active, inactive and plugged shale gas wells in Pennsylvania by physiographic region.

There are just over 9,000 shale gas wells in Pennsylvania, which employ horizontal drilling technology and hydraulic fracturing to extract the tightly-held natural gas from deep shale formations. These "unconventional" resources are thought to provide considerable economic benefit to the region; however the scale of the development, water resources needed, and the amount of waste produced pose substantial challenges to our ecosystem. Despite a recent slowdown in development in 2014, we expect development to continue into the future.

Shale gas well pad in the Lick Run Focal Area

Shale gas development may impact both aquatic and terrestrial (landscape) ecosystems. Landscape impacts are probably most apparent with the size of the well pads and extent of pipeline infrastructure that must be developed to transport the natural gas to market. Several sources have determined the average size of well pads to be approximately 1.3 – 2.7 hectares (3-7 acres) and have been documented as being as large as 8 hectares (20 acres). In 2010, The Nature Conservancy (TNC) published projections of natural gas development and the potential impacts on Pennsylvania's forests in its Pennsylvania Energy Impacts Assessment, which projected 60,000 wells by 2030 on 7,000-16,000 well pads in the Marcellus Shale region of Pennsylvania. Based on their calculations of lands cleared for development of well pads and supporting infrastructure, Pennsylvania stands to lose between 15,700 and 33,500 hectares (38,800 and 83,000 acres) of forested habitat by 2030. They estimated between 33,000 to 81,000 hectares (81,500 to 200,300 acres) of interior forest habitat could be indirectly affected. Additionally, in a follow up study, TNC estimated that 8,050 to 20,000 kilometers (5,000 to 12,500 miles) of new pipelines would be needed to support the 60,000 wells. This natural gas pipeline development could impact up to 60,000 hectares (150,000 acres) of land, potentially impacting over 360,000 hectares (900,000 acres) of forest and affecting interior forest specialists as new edge habitats are created by new pipeline right-of-ways.

Aquatic ecosystems are also threatened by shale gas development. Aquatic ecosystems are potentially threatened by water withdrawal, erosion and sedimentation, and potential inputs of salts, heavy metals, and chemicals associated with the hydraulic fracturing process and flowback and produced waters from deep in the shale formation. Just over 60 percent of the 137,767 km (85,623 miles) of streams in Pennsylvania are within the shale gas region. Nearly 63 percent of streams designated as High Quality and 64 percent of streams designated as Exceptional Value are found within the shale gas region. Most striking of these statistics, nearly 90 percent of streams classified by the Pennsylvania Fish and Boat Commission (PFBC) as "wilderness trout streams" in Pennsylvania are found within the shale region. Water quality has been the focus of citizen science research and monitoring activities across the shale region. Many of these efforts have brought conservation organizations and university researchers together with citizen groups to monitor the conditions of local aquatic ecosystems and possibly provide information that can be used to protect valuable ecological resources.

Despite this concern over potential impacts of habitat fragmentation, degradation, and loss on our species of concern, we have little information on habitat quality from the areas supporting these species. Even more concerning is our lack of data on the impact of new infrastructure associated with natural gas extraction on habitat quality and the species associated with specific (and high quality) habitats.

The Pennsylvania Natural Heritage Program (PNHP) calculated that over 45 percent of the areas identified as Core Natural Heritage Areas in County Natural Heritage Inventories are found within the region of Pennsylvania underlain by the Utica and Marcellus Shale formations, the primary targets for deep gas extraction in Pennsylvania. Further analysis of PNHP's rare species data indicates that 724 species tracked by PNHP and approximately 62 percent of all species occurrences in the state are found within the combined Marcellus and Utica regions; 346 of these species have more than 70 percent of their occurrences in the shale gas region. While determining shale gas impacts on a specific species or group of species is more complicated than just overlaying site locations, core habitats, and threats, these numbers suggest that a substantial proportion of rare plant and animal species could be affected by the development of shale gas in Pennsylvania. Species of isolated habitats and those requiring specific habitat resources may be most threatened.


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Pipeline right-of-way crossing Spring Creek, Jefferson County.

Many scientists and conservation professionals have called for more baseline data collection to assess the current quality of high value biological diversity areas. These data are needed to accurately project potential risks to wildlife species and habitats and are useful to land conservation initiatives. Better data will help inform management planning to avoid and minimize impacts through implementation of best management practices and craft policies that maintain critical ecological resources, such as high quality aquatic habitats and contiguous interior forest.

This loud call for more baseline survey resulted in the initiation of a number of studies across the shale region, primarily university researchers and non-profit groups with topics ranging from water quality to assessment and monitoring of invasive plant species and interior forest birds. The Pennsylvania Department of Conservation and Natural Resources (DCNR) initiated a baseline assessment of shale gas impact on state forest land in 2010. This effort will provide critical information to guide management of their lands to reduce potential impacts of shale development on our state forests.

The following sections describe our site selection process and the monitoring targets we selected, along with a summary of our approach and findings.

Monitoring Sites and Threats

We conducted a two-year baseline assessment of target sites within 35 high value ecological areas, referred to as "focal areas," situated across the shale region of Pennsylvania. We selected these 35 focal areas because of their ecological value, the quality of aquatic and terrestrial resources within, and potential threat from development of shale gas resources.

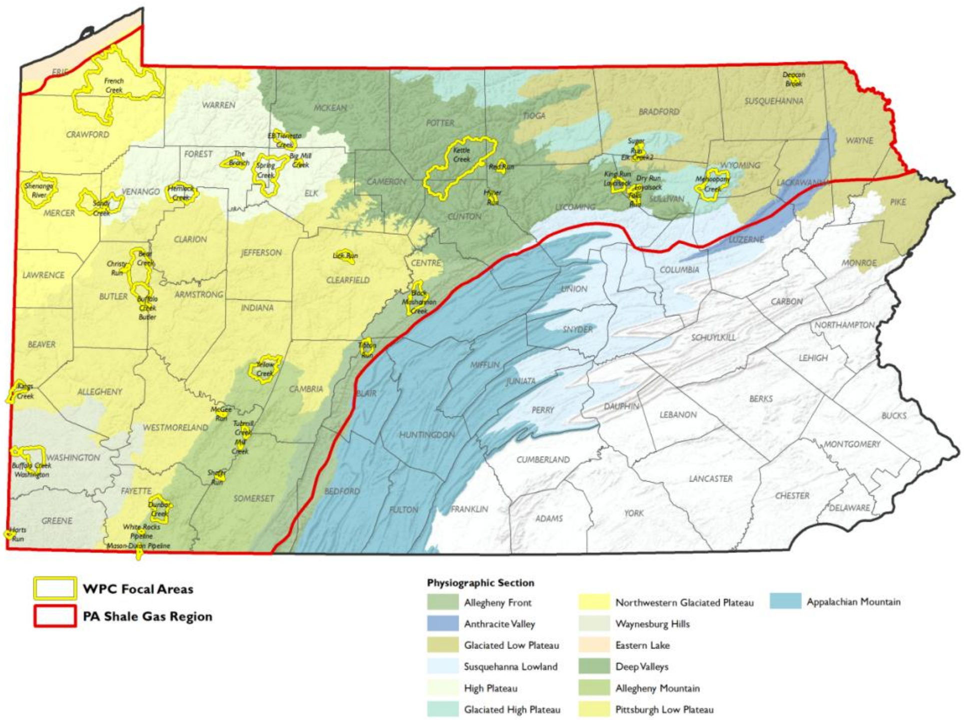


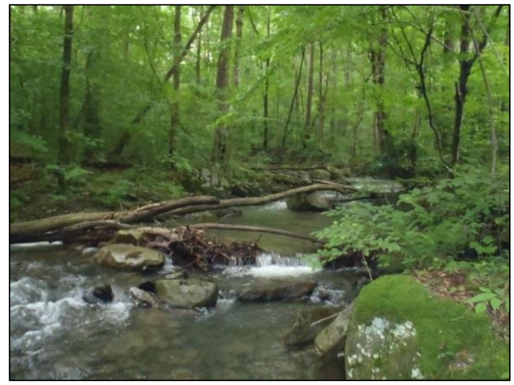
Figure ii. Focal areas (n = 35) containing aquatic and terrestrial assessment sites and targeted ecological inventories.

Our approach and findings are as follows:

- We identified areas of high ecological value through a process called Ecological Value Analysis (EVA) in GIS using a combination of data layers representing critical habitat and ecologically sensitive areas, along with information on location of rare species from the PNHP.
- The 35 focal areas were situated in 26 counties and support rare and important wildlife and plant species in critical stream and forest habitats and are also areas of particular conservation interest to our organization and, in many cases, other conservation organizations.
- We evaluated shale gas development potential in GIS using specific modeling methods to determine the shale gas resources of an area. The GIS model used projected development of well pads, but eventual site selection also took road and pipeline potential into account, especially in regions that were not experiencing high pressure from well drilling.
- Some focal areas were located in areas with substantial shale gas development; others are in regions with little or no development. Many of the focal areas experienced past development from extractive industries (i.e., there are no pristine ecosystems without human impacts).

Monitoring Targets

While shale gas development poses a challenge to management of a significant number of species and their habitats, we do not have the baseline information needed to determine the extent of these impacts; this information is critical to determine best management practices for avoidance, mitigation, and adaptive management.



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Limestone Run, a tributary to Dunbar Creek, Fayette County.

The primary targets of our monitoring effort were streams and forest patches, made up of some of our most ecologically important aquatic and terrestrial ecosystems in Pennsylvania. We also conducted specific surveys for rare and important species that are indicators of ecological quality and that may be negatively impacted by shale gas extraction and associated impacts from infrastructure development. The assessment targets that we chose are widely considered to be ecological indicators of quality and, outside of regionally specific plant and animal species, are also among the monitoring values assessed by other researchers in the various shale regions across the country.

In all, we conducted field assessment and monitoring activities at over 405 discrete sites within the 35 focal areas in 2013-2014 to obtain baseline information in areas where we projected shale gas development to be probable. We visited many of the sites multiple times each year, particularly the 51 aquatic monitoring sites and the 30 forest and outcrop sites. We also used up-to-date aerial imagery and recent land cover data in GIS to determine the level of fragmentation and its possible effects on the rare and important wildlife species within each focal area.

The primary targets of our assessment and monitoring efforts were

- *Landscape and Fragmentation*
- *Water*
- *Forests*
- *Rock Outcrops*
- *Rare and Important Species*

Landscape and Fragmentation

Fragmentation of contiguous forested landscapes into smaller, isolated tracts has an effect on plant and animal distribution and community composition. When a large piece of forest tract is fragmented, or split into pieces, the resulting forest islands may lack some of the habitats that existed in the original tract, or may be smaller than the minimum area required by a given species. For example, the Louisiana waterthrush (*Seiurus motacilla*) is rarely found in small woodlots because they require upland forests with streams within their territory and most small woodlots lack this necessary component. Area-sensitive species such as the northern goshawk (*Accipiter gentilis*), barred owl (*Strix varia*), bobcat (*Lynx rufus*), and timber rattlesnake (*Crotalus horridus*) require interior forest areas in excess of 6,000 acres to accommodate breeding and foraging territories. The development of infrastructure needed to extract natural gas from the Marcellus and Utica Shales is expected to greatly impact the forests and streams of Pennsylvania. Fragmentation impacts are very specific and have different effects in different landscapes. Different species react to fragmentation in different ways. It is important to understand the current conditions of the landscape in order to assess change and for siting and landscape planning. Landscape and fragmentation analyses provide valuable information to guide management activities that work to reduce the overall impacts of large-scale development activities.


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Shale gas well pad near The Branch, Forest County.

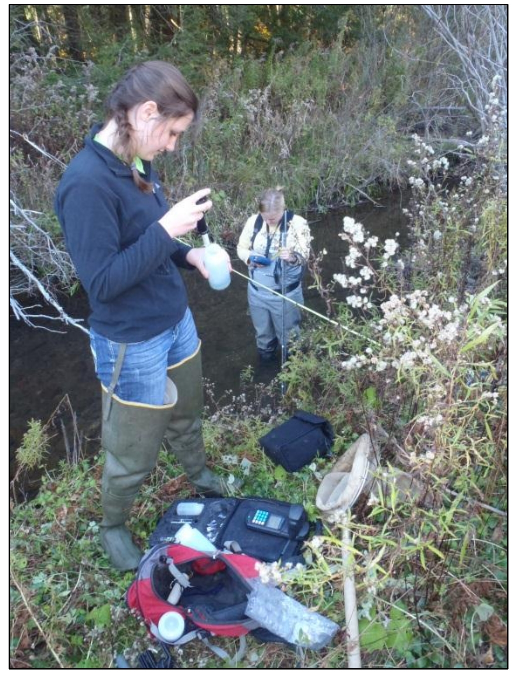
Our approach and findings are as follows:

- We assessed the forest cover and fragmenting features that existed in 2013 for each focal area in GIS based on the existing land cover data (2011 National Land Cover Dataset) and available aerial imagery from 2013. We used several landscape and fragmentation statistics to establish the baseline of forest cover and fragmentation.
- We also classified the mapped forest patches of each focal area into patch, edge, "perforated" forests (forests with canopy breaks within interior portions of mapped forests), and core forest (these patches were further classified into the following groups: 100, 100-200, and greater than 200 hectares).
- Focal areas differed considerably in the amount of forest cover and other land cover/land use depending on the physiographic section in which they occurred. The 35 focal areas ranged in size from 4.1 to 829.2 square kilometers and ran from 44.8 percent forest cover to 98.5 percent (mean of 85.0 percent).
- In all, there were 169 drilled shale gas wells in the 35 focal areas as of January 1, 2015. These wells were found on 59 well pads of which 36 (61 percent) fell within forest land cover types; the remaining 23 pads (39 percent) were situated in agricultural, developed, and disturbed land.
- Road density (kilometer road/square kilometer) tended to be higher in the northwestern glaciated plateau and Pittsburgh Low Plateau sections and lower in other, more remote, sections of the shale gas region. Mean road density was 0.45 – 2.44 within the focal areas. Pipeline density (kilometer pipelines/square kilometer) was 0.0 to 1.94. Focal areas within the northwestern portion of Pennsylvania had the highest density of both roads and pipelines due to their history of agriculture and shallow gas development.
- Anecdotally, the extent of the landscape impacts from infrastructure construction where drilling occurred differed considerably from one focal area to another. For example, in the Lick Run and

Hyner Run focal areas, both with high percent forest cover, the development of well pads and associated roads and pipelines comprised the majority of the non-forest land cover. In contrast, in the Buffalo Creek (Washington County) and Yellow Creek focal areas, shale gas infrastructure looked to have little direct impacted on forests, as the infrastructure was sited primarily in open agricultural areas and did not appear to greatly impact the configuration of forests within the focal area. There were forest patches that had been bisected by new pipeline infrastructure. More work needs to be done to assess the extent of habitat alteration of specific areas due to shale gas development.

Water

There many threats to the streams of Pennsylvania from the development of shale gas. Many of these threats are also associated with other forms of development, such as road building and construction; however the extraction of shale gas requires significant amounts of water, uses a host of chemicals in the extraction process and produces significant waste, and disturbs a substantial amount of soil and vegetation. We used multiple methods to assess the current ecological conditions and obtain baseline aquatic assessment of surface water within the target focal areas.



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Streamside chemical analysis and flow measurements being taken along the East Branch Tionesta, McKean County.

Our approach and findings are as follows:

- We assessed water quality at 51 sites quarterly using chemical and biological indicators of site condition and visual assessments for habitat quality. The majority of sites were located on headwater and second order streams.
- In addition to shale gas development, issues that can affect water quality include faulty septic systems, poorly maintained dirt and gravel roads, improper agricultural practices (leading to sedimentation and nitrification of streams), and historic activities such as coal mining, shallow gas extraction, and industrial activity.
- Average reach scores for the habitat assessments completed at each of the water quality monitoring sites indicated that the riparian and aquatic habitats were somewhat already impacted across all sites; scores ranged between "optimal" and "sub-optimal" for all sites indicating that even the best sites in Pennsylvania are less than pristine.
- Analysis of macroinvertebrate data indicates that organic pollution is generally low across monitoring sites with few exceptions. Most sites ranked "very good" or "good" and two sites ranked "excellent." Five sites were ranked "fair." The sites that ranked "fair" with regards to macroinvertebrate communities also had habitat assessment scores in the sub-optimal range.
- Water quality analysis activities provide a baseline to assess future impacts. Analysis of the baseline data suggests that there are minimal impacts to surface water quality that can be attributed to shale gas development at most sites. We expected this as water quality was assessed prior to development in most focal areas. The pH of streams in this survey ranged from 4.3 to 9.4, conductivity was between 16.7 to 772.9 µS/cm, and water temperature varied from 0.0 and 26.2 degrees Celsius.
- Conductivity levels varied across all sites; this was expected due to the variation in the physiographic sections and possible changes in underlying geologic formations.
- We obtained baseline information and assessed potential pollution from shale gas by looking at specific chemicals associated with development impacts. Barium and strontium are two of these elements that are often associated with pollution events from unconventional gas development. These elements occur naturally at higher concentrations in the Marcellus and Utica Shale formations, but at lower levels in surficial geology and surface waters (the "standard natural occurrence" is 0.043 mg/L for barium (ranging from 0.0 to .34 mg/L) and 0.06 mg/L for strontium (ranging from 0.0 to 0.36 mg/L, respectively), thus are considered potential indicators

of pollution. While these elements are associated with shale gas development, pollution effects from other heavy industries and coal mining could also contribute to higher levels in surface waters of the Commonwealth of Pennsylvania.

- Barium concentrations within the focal areas ranged between 0.01 and 0.12 mg/L and strontium ranged from 0.01 and 0.30 mg/L.
- Several focal area monitoring sites, both with and without unconventional gas wells upstream, contained barium and strontium levels that exceeded "natural occurrence" averages for Pennsylvania of 0.043 mg/L.
    - Hemlock Creek, Porcupine Creek, Limestone Creek, Bear Cave Hollow, The Branch, East Branch Tionesta Creek, and Spring Creek all had consistently higher levels of barium compared to the standard natural occurrence at points throughout the monitoring period.
    - Kings Creek, Sandy Creek, French Creek and Shenango River all had consistently higher strontium levels than the standard natural occurrence throughout the monitoring period.
    - Buffalo Creek (Washington County), Yellow Creek, Little Yellow Creek, Christy Run, Bear Creek, East Branch Tionesta Creek, and Buffalo Creek (Butler County) were all consistently higher than the standard natural occurrence for both barium and strontium throughout the monitoring period.
- We found that focal areas with shale gas development had significantly higher concentration of barium than in focal area without shale gas development. Strontium was also higher, on average, in focal areas with shale gas development; however results were not statistically significant.
- None of the monitoring sites, however, had barium or strontium levels over the human health standards, set by the DEP, during any point of quarterly monitoring sampling.
- It is difficult to determine if the higher barium and strontium levels are due to the shale gas development in the area, or from other sources, or this is just an example of natural variation in the concentrations of these two elements across our study sites without further analysis and comparison to background data. We will compare these values with data from other sources and we recommend analysis of barium and strontium isotopes of surface waters in these specific areas to determine if the higher than expected levels of these elements are due to shale gas development.

Forests


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Interior bird survey within the Spring Creek Focal Area, Forest County.

Breeding birds are particularly good indicators of anthropogenic impacts due to their dependence on specific habitat types and characteristics. Forest interior dwelling species (FIDS), which include many Neotropical migrant species, require core forest to breed successfully and maintain healthy populations. Development of well pads, roads, pipelines, and compressor stations fragment critical core forest habitat and create a suite of edge effects. Edge effects result from the interactions of species and physical habitats where non-forested habitat abuts intact forest. Such impacts include increased nest predation from avian and mammalian predators, temperature and humidity fluctuations, increased pollution (e.g., noise and trash), increased invasive species, and increased brood parasitism. Understanding the current condition of forest habitat and the species within is a key component to assessing the potential for impacts of shale gas development on a particular area. For our baseline assessment and monitoring of forest ecosystems, we selected 25 sites for bird monitoring from the WPC Focal Areas.

Our approach and findings are as follows:

- Across all 25 bird and forest monitoring sites, we detected 102 species of breeding birds during 2013 and 2014. The most diverse assemblage we documented was an area with a FIDS habitat guild of 37 species. Forest interior birds comprised more than 50 percent of total bird abundance at all but one site, Lick Run, and more than 70 percent of total bird abundance at more than half of all sites. In contrast, disturbance adapted birds made up more than 25 percent of total bird abundance at just four sites: Black Moshannon Creek, Spring Creek, Lick Run, and Slate Run – all of which showed higher disturbance levels, significant disturbance throughout the site, or very recent disturbance.
- Despite the fact that all sites were located in core forest, the presence and prevalence of disturbance across sites indicates that even interior forests which support high percentages of FIDS are in less-than-pristine condition. Current disturbance likely plays a role in the density of certain forest interior birds. For species like ovenbird, black-throated blue warbler, or hermit thrush, the cumulative influences of resource development, invasive plants, deer herbivory, and small-scale fragmentation like trails may impact their ability to maintain higher densities.
- Forest bird and habitat monitoring in 2013 and 2014 served to establish baseline conditions for bird abundance, forest structure, and disturbance at sites of high ecological value. We also established relationships between forest bird communities and current disturbance levels which should function as a way to measure the effects of accumulating disturbance over time.
- Based on our evaluation of current habitat conditions, higher disturbance levels seem to contribute to the homogenization of bird communities across forest types - meaning an overall loss of bird community diversity or uniqueness.
- Shale gas development activities (pads, pipelines, seismic testing transects) were recorded at 17 out of the 25 forest assessment sites. Thirteen of our 25 forest monitoring sites had at least one well pad within 5 kilometers, and all but six sites had a well pad within 10 kilometers.
- These conditions should be monitored into the future for changes as a result of varying disturbance levels as a result of shale gas or other development.

Rock Outcrops

Rock outcrop habitats support a unique set of species requiring the rocks for protection from predators and the shaded crevices for temperature and moisture requirements. The green salamander (*Aneides aeneus)* is one of these species. Found only in southwestern Pennsylvania, quarrying, mining, and oil and gas infrastructure installation have damaged and eliminated rock outcrop habitats for this species along Chestnut Ridge in Fayette County, Pennsylvania. Protection of these rock habitats and the forest surrounding them is critical to the persistence of the species in the state. Expansion of pipelines and further removal of vegetation as part of routine maintenance may further impact existing rock outcrop ecosystems; it is thought that these habitats may decline in quality due to increased light, decreased moisture, and invasive plants as a result of new pipeline development and expansion (widening) of existing pipelines.

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Rock outcrop on Chestnut Ridge, Fayette County, Pennsylvania

Our approach and findings are as follows:

- We selected five rock outcrops with known populations of green salamanders to investigate the forest habitat quality and characteristics of the existing natural gas-related infrastructure nearby.
- All five rock outcrop assessment sites were situated near existing pipeline right of ways.
- Green salamander populations appear to have been greatly impacted by large fragmenting features; however smaller pipelines (less than 10 meters wide) with natural vegetation and intact canopies do not seem to affect dispersal and movement.

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Green salamander (*Aneides aeneus)*

- Pipelines that are at least 150 meters from the rock outcrops do not appear to impact green salamander populations.
- The results of this investigation suggested that proper siting of pipeline infrastructure and implementation of management strategies that establish and maintain forest canopy cover across right-of-ways at critical locations may positively impact green salamander populations where past development activities occurred.

Rare and Important Species

In addition to species inventories used to assess the quality of aquatic ecosystems, forests, and rock outcrop habitats, we conducted targeted inventories for rare and important wildlife and plant species within identified EVAs in areas of high potential for shale gas development. In particular, efforts were focused in and near sites where stream and forest assessments occurred. These data serve as valuable baseline information to assess future impacts from development. Additionally, we obtained information on rare plants, animals, and natural communities from the PNHP database. Many of these species are subject to environmental review via the PNDI tool.


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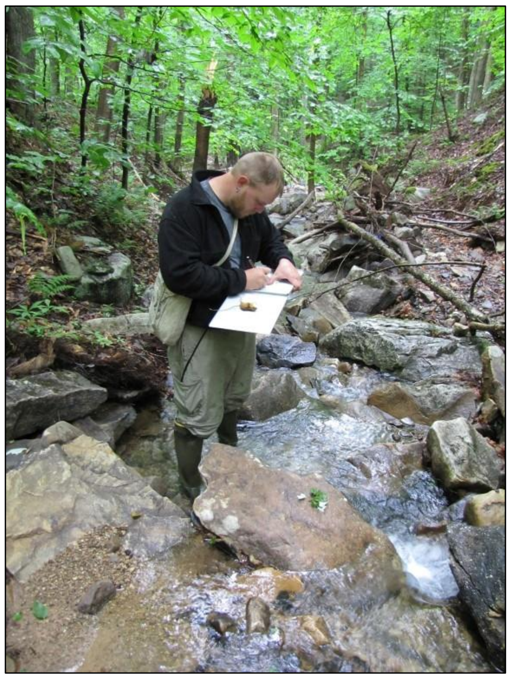
Riparian survey work along Little Yellow Creek, Indiana County, Pennsylvania.

Our approach and findings are as follows:

- We accessed the PNHP database to obtain information on rare plants, animals, and natural communities included in the PNDI tool. A total of 284 species are found in our 35 focal areas. Only Big Mill Creek, an intact forest patch in the Allegheny National Forest in Elk County, Pennsylvania did not have any occurrences of rare species.
- We conducted targeted surveys for species of special concern and species considered indicators of ecosystem quality or potentially threatened by shale gas (or pipeline) development. These included stream salamanders, American water shrew (*Sorex palustris*) and other small mammals of riparian habitats, brook trout (*Salvelinus fontinalis*), freshwater mussels, and a large aquatic salamander, the Eastern hellbender (*Cryptobranchus alleganiensis alleganiensis*). Further, because of their sensitivity to pollution and their reliance on high quality riparian/aquatic habitats, these species are good indicators of environmental quality of the streams within areas that may see impacts from shale gas and other human development activities.
- We used standard assessment protocols for each species group.
    - We conducted surveys to characterize the vegetation at 45 sites along the riparian zones of streams, near water quality monitoring points in the focal areas. In many focal areas, invasive species, like reed canary-grass (*Phalaris arundinacea*), Japanese stilt-grass (*Microstegium vimineum*), bush honey suckle (*Lonicera* spp.), and mile-a-minute (*Persicaria perfoliata*) threaten to further impair the ecological value of riparian areas.
    - Our fish surveys using PFBC "Unassessed Waters" protocols were combined with data from stream surveys from PFBC for a total of 178 fish surveys for our focal areas. We shared all fish data with the PFBC and DEP for use in listing the streams as special protections waters (Exceptional Value, High Quality, Class A Wild Trout Streams).
    - We conducted specific protocols to assess the quality of streamside habitats by assessing the composition of the streamside salamanders' community along 62 sites.
    - We conducted 17 site surveys for eastern hellbenders.
    - We assessed freshwater mussel populations at 6 sites.
    - We assessed small mammals, particularly the rare American water shrew along headwater streams in the focal areas at 24 locations.
- With the level of attention given to particular sites, many new occurrences of special concern species were documented. Survey activities resulted in new occurrences of freshwater mussels, mountain chorus frog (*Pseudacris brachyphona*), American water shrew, great spurred violet

(*Viola selkirkii*), creeping snowberry (*Gaultheria hispidula*), large toothwort (*Cardamine maxima*), and other plants identified as "watch list" species by botanists in the state.
- We submitted all records to the PNHP for use in the PNDI tool; PA threatened and endangered species will be a part of the Pennsylvania environmental review process (PNDI) and other species of concern will be utilized for review of various projects, including oil and gas projects.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Small mammal survey within the Forbes Sate Forest, Fayette County, Pennsylvania.

Conclusion

First and foremost this work represents a baseline of ecological conditions of select high ecological value areas threatened by future shale gas development activities. For many of our focal areas, shale gas development has not yet occurred or sites have just begun to be touched by development activities. Our assessment of landscape condition provides a baseline which can be used to measure land use change over time as sites are developed to produce shale gas, as well as for other development purposes.

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Fall colors starting on The Branch, Forest County.

Analysis of landscape data suggested that our areas differed markedly from one region of Pennsylvania to another, with the northwestern and southwestern portions of the state much less forested and exhibiting a higher road and pipeline density. Fifteen of our 35 focal areas contain shale gas wells, and many others have experienced impacts from the construction of road and transmission infrastructure. Shale gas development was the primary cause of forest loss and fragmentation at some sites, particularly predominantly forested focal areas; for others, the extent of landscape impact associated with shale gas pales in comparison to other human development activities, such as agriculture or residential development. It remains to be seen how fragmentation from shale gas development will impact wildlife species in these areas and more needs to be done to categorize development types, characterize potential impacts, and assess direct and indirect impacts of fragmentation.

Our water quality analyses indicated that most of our sites were of high ecological quality, as most have yet to be impacted by effects of shale gas development. While the intent of the project was to obtain baseline data prior to intense shale gas development, some sites were impacted leading up to and over the course of our study. We found correlations between shale gas drilling activities and certain chemicals associated with shale gas development pollution in surface waters. We must continue to look for historic water quality data for our focal areas to determine if current levels of salts and elements associated with shale gas development have changed since drilling took place. Pre-drilling baselines for chemicals such as barium, strontium, and chloride would be very valuable in assessing impacts from current drilling activities. Coal mining and other industrial activities were common to many watersheds of Western Pennsylvania and this may have influenced the amount of barium and strontium detected in the water. Winter road maintenance and agriculture often contribute to high chloride levels and total dissolved solids (TDS).

The results of the targeted inventories for rare and important species indicated that our focal areas were indeed areas of high ecological value. This reinforces the need for continued inventory and conservation measures to protect and maintain high ecological value areas as these places often support multiple species of concern.

Conservation Recommendations:

We expect shale gas development to continue in Pennsylvania and that a large majority of the focal areas, identified in GIS and studied in this field study, will experience some form of development in the form of well pads, pipelines, and other infrastructure. While we could not draw definite conclusions on impacts from shale gas development, we believe that there is an ongoing need to conduct status assessments and monitor areas of high ecological quality in the face of landscape fragmentation from all types of anthropogenic development and climate change. We recommend, however, that along with continued baseline monitoring, we engage in more hypothesis-driven studies, which look to directly assess the impacts of specific development activities on wildlife species and critical habitats.

In conclusion, we suggest that the following efforts can positively affect conservation of high ecological value areas through providing information for management and policy decisions that minimize impacts from shale gas development:

- *Continue assessment and monitoring activities in areas where shale gas development is imminent and develop effective mechanisms to use data in management of areas of high ecological value.*
- *Develop more hypothesis-driven studies which look to directly assess the impacts of specific development activities on wildlife species and critical habitats and seek solutions for the impacts.*
- *Evaluate the benefits of particular management practices on specific wildlife species.*
- *Continue to systematically assess stream and forest habitats for rare and important species that serve as indicator of short- and long-term water quality change.*
- *Support policies and incentives to encourage development and implementation of best management practices to limit impact of development activities on high quality ecological areas and critical habitats.*
- *Support establishment of a river basin commission for the Upper Ohio Basin an equivalent entity of jurisdiction to regulate water quantity or quality. .*
- *Support the establishment of adequate setbacks from streams and springs through existing statutes such as the Pennsylvania Clean Streams Law.*
- *Provide support to land management agencies in monitoring efforts and provide information for adaptive management activities to avoid and minimize impacts from development of shale gas on state land.*
- *Seek opportunities to protect high value ecological areas through acquisition.*

1. Introduction

Background

While concerns over impacts to drinking water and public health from development of "unconventional" natural gas resources from deep shale formations have dominated the conversation (e.g., Colborn et al. 2011), the potential impact to rare and important plant and wildlife species and critical ecological resources from the development of shale gas is of great concern to the conservation community in Pennsylvania and throughout the Appalachian Region. In addition to impacts to drinking water, human health, and rural communities of the state, it is thought that forests and streams of the Appalachian Region will see substantial impacts from the development of infrastructure needed to extract and transport natural gas from the Marcellus and Utica Shale formations, which cover nearly 150,000 square miles across five states (Johnson et al. 2010, Johnson et al. 2011, Drohan et al. 2012, Slonecker et al. 2013 DCNR 2014, Evans and Kiesecker 2014). Well pads, pipelines, compressor stations, and roads are projected to directly impact thousands of hectares of wildlife habitat, primarily forests, and even more impacts associated with edge effects and loss of wild character (Johnson et al. 2010). The extraction process itself, referred to as hydraulic fracturing, which uses millions of gallons of water, plus chemicals to extract the tightly held natural gas from the shale, presents considerable ecological challenges to the quality of streams and rivers in the region and their ability to support wildlife species.

WPC

Entrance gate to shale gas well near East Branch Tionesta, McKean County.

According to the Pennsylvania Department of Environmental Protection (DEP), there are just over 9,000 "unconventional" wells in Pennsylvania as of April 2015 (Figure 1.1). The term "unconventional well" refers to a natural gas well that is drilled into a rock formation (in Pennsylvania, these are entirely shale rock formations) below the Elk Sandstone geologic layer where natural gas cannot be extracted without the use of horizontal drilling and hydraulic fracturing (PA DEP 2015). Unconventional gas wells, or shale gas wells, which are costlier to drill, but are more productive than shallow, or "conventional," natural gas wells, have increased greatly in number since the first shale gas well was drilled in 2004 (Brantley et al. 2014). The well pads needed to support shale wells average 1.3 – 2.7 hectares (3-7 acres) in size and can be as large as 8 hectares (20.5 acres) (Johnson et al. 2010, Drohan and Brittingham 2012). They often contain multiple well bores, with laterals extending up to a mile in multiple directions, enabling a drilling company to access large areas of underground natural gas from one drilling location (Johnson et al. 2010). The large well pads are needed to support the drilling rig and equipment associated with drilling and fracturing the well. Well pads also sometimes contain storage areas, waste pits, and reservoirs to store the water needed for the hydraulic fracturing process that is used to free the tightly held gas from the shale.

Shale gas development causes direct forest loss and impacts surface waters and aquatic habitats through forest clearing, increased impervious surface, and erosion and sedimentation activities associated with well pad, road, and pipeline construction (Johnson et al. 2010, Johnson et al. 2011, Entrekin et al. 2011, Drohan et al. 2012, Weltman-Fahs and Taylor 2013). While Pennsylvania has a long tradition of resource extraction, such as coal mining and natural gas and oil development, the location of the most productive "sweet spots" in the shale places the industrial activities associated with shale gas development within primarily rural and forested landscapes that have not experienced this type of development. Early

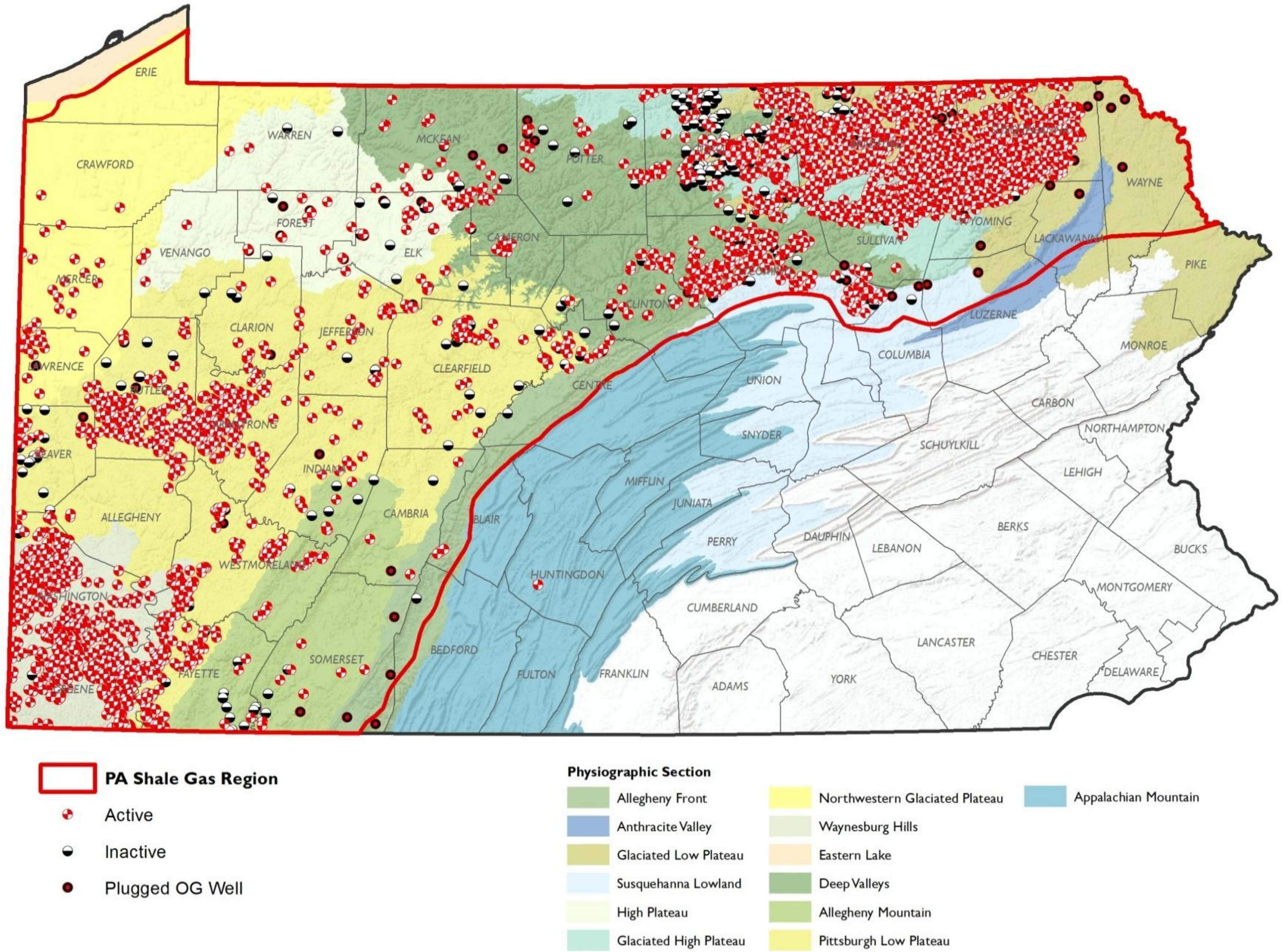


Figure 1.1. Map of shale region in Pennsylvania and drilled "unconventional" shale gas wells as of April 2015.

studies investigating land use and landscape impacts of shale resources indicated that a majority of development has taken place in forested landscapes (Johnson et al. 2010, Drohan et al. 2012).

Water

There are 137,767 km (85,623 miles) of streams within Pennsylvania, of which just over 85,000 km (52, 831 miles) are within the shale gas region, or 61.7 percent of streams in the state. The extraction of shale gas requires significant amounts of water, uses a host of chemicals in the extraction process and produces waste, and disturbs soils and vegetation as infrastructure is constructed. Aquatic ecosystems are potentially threatened by water withdrawal, erosion and sedimentation, and potential inputs of salts, heavy metals, and chemicals associated with the hydraulic fracturing process and flowback and produced waters from deep in the shale formation (Weltman-Fahs and Taylor 2013).

Nearly 63 percent of streams designated as High Quality (HQ) and 64 percent of streams designated as Exceptional Value (EV) are found within the shale gas region. Nearly 90 percent of streams classified by the Pennsylvania Fish and Boat Commission (PFBC) as "wilderness trout streams" in Pennsylvania are found within the shale region.

Forests

There are nearly 7,000,000 hectares (17,000 acres) of forest in Pennsylvania; approximately 70 percent is within the shale region. In Pennsylvania, about 59 percent of all shale gas well pads have been developed in forested habitat with even more, 68 percent, sited in forests within the north central regions (Brittingham et al. 2014a). In addition to the effects of land clearing on forested habitats, development results in increased impervious surface (Drohan and Brittingham 2012).

Projecting into the future, TNC, with contributions from Western Pennsylvania Conservancy (WPC) and Pennsylvania Audubon scientists, estimated that by 2030 Pennsylvania would see up to 60,000 drilled unconventional wells on between 7,000 and 16,000 well pads, translating to between 13,760 and 33,185 hectares (38,000 to 90,000 acres) of forest loss. Evans and Kiesecker (2014) expanded this analysis to the entire Appalachian Region estimating that there were 4,151 well pads as of 2014 and projecting an estimated 26,501more wells over the next 25 years. TNC further speculated that development of pipeline infrastructure, needed to transport the natural gas to market, would result in an additional 8,050 to 20,000 kilometers (5,000 to 12,500 miles) of new pipelines to support the 60,000 wells. This natural gas pipeline development could impact up to 60,000 hectares (150,000 acres) of land, potentially impacting over 360,000 hectares (900,000 acres) of forest and affecting interior forest specialists as new edge habitats are created by new pipeline right of ways (Johnson et al. 2011).

Species and natural communities most vulnerable to these impacts are those with high sensitivity to disturbance and habitat specialists, such as forest interior birds, terrestrial salamanders, and vernal pool communities (Gillen and Kiviat 2012, Brand et al. 2014, Brittingham et al. 2014a). Pipeline development further threatens wildlife through direct impacts to habitat and indirectly through a suite of edge effects, which function to decrease specific aspects of quality for a specific species. (Johnson et al 2011). In particular are forest interior-dwelling species of birds (FIDS) which tend to require large tracts of unfragmented and undeveloped mature forest at least 100 meters from hard edges like roads, housing developments, well pads, or pipelines.

Rare and Important Species

The Pennsylvania Natural Heritage Program (PNHP) calculated that over 45 percent of the areas identified as Core Natural Heritage Areas in County Natural Heritage Inventories (http://www.gis.dcnr.state.pa.us/maps/index.html?nha=true) are found within the region of Pennsylvania underlain by the Utica and Marcellus Shale formations. Further analysis of PNHP's rare species data indicates that 724 species tracked by PNHP and approximately 62 percent of all species occurrences in the state are found within this landscape. Three hundred forty-six of these species have more than 70 percent of their occurrences in the shale gas region (Yeany et al. 2012, PNHP 2015). Many scientists and conservationists in the region have proposed that species with limited distributions in the region may also be disproportionally impacted by shale gas development activities (Johnson et al. 2010, Gillen and Kiviat 2012, Weltman-Fahs and Taylor 2013, Brand et al. 2014).

Despite this concern over potential impacts of habitat fragmentation, degradation, and loss of our species of concern, we still have limited information on habitat quality from areas of high ecological value that support species of special concern. Even more concerning is our lack of data on the impact of new infrastructure associated with natural gas extraction on habitat quality and the species within.

Many conservation professionals have called for more baseline data collection (Johnson et al. 2010, Gillen and Kiviat 2012, Brand et al. 2014) to assess the current quality of high value biological diversity areas and assessment and monitoring activities to determine the extent of shale gas development impacts and to inform conservation and management activities (Benner 2012, Larkin, Stoleson, and Gover 2012).

This loud call for more baseline survey resulted in the initiation of a number of studies across the shale region, primarily university researchers and non-profit organizations with studies ranging from establishing water quality baselines and monitoring for shale gas pollution, to paired watershed studies to assessment of invasive plant species (PA DCNR 2014) and impacts to interior forest birds from the construction of shale gas infrastructure (Brittingham and Goodrich 2010, Brittingham et al. 2014, Thomas et al. 2014). Water quality has been the focus of citizen science research and monitoring activities across the shale region (FracTracker 2014). Many of these efforts have brought conservation organizations and university researchers together with citizen groups to monitor the conditions of local aquatic ecosystems and possibly provide information that can be used to protect valuable ecological resources. The Pennsylvania Department of Conservation and Natural Resources (DCNR) initiated a baseline assessment of shale gas impact on state forest land in 2010 (DCNR 2014). This effort will provide critical information to guide management of their lands to reduce potential impacts of shale development on Pennsylvania's state forests and will contribute to establishment of best management practices for shale gas development activities on forest lands in the region.

Assessment of High Value Ecological Areas in the Shale Region

As part of the broader monitoring trend across Pennsylvania, Western Pennsylvania Conservancy (WPC) initiated an ecological assessment of areas of high ecological value that may be under threat from development activities associated with shale natural gas development. Our assessment focused on obtaining baseline species and habitat data from specific locations that support rare and important wildlife species. Obtaining baseline data is critical to assess the extent of impacts, if any, and to inform policies and regulations to avoid impacts to other areas and minimize them through adaptive management.

Through this project, we established an ecological baseline of conditions prior to development within specific areas where future development is probable, and in some cases, early in the development process. For these areas, we sought to identify the current status of conservation values and existing impacts to critical habitat resources that support species of special concern. While sites were not specifically chosen to assess specific impacts of shale development, development has begun in some of our sites, and in these sites, analysis of data allowed us to evaluate associated impacts. Also, in addition to our baseline data collection, a goal of this work was to identify and select several species in Pennsylvania that may be particularly sensitive to effects of anthropogenic development in order to make inferences as to what may happen when effects of shale gas development occur.

The following report describes our site selection process and the monitoring targets we selected, and a summary of our approach and findings. Detailed information and data from inventory and assessment activities within our study areas will be made available through our website.

2. Site Selection and Threats

We conducted a two-year baseline assessment of target sites within 35 high value ecological areas, referred to as "focal areas," spread across 26 of Pennsylvania's 62 counties (Figure 2.1). The focal areas were situated across the Shale Region of Pennsylvania and were selected because of their ecological value, the quality of aquatic and terrestrial resources, and potential threat from development of shale gas resources.

The following provides a general overview of the process we used to evaluate the landscape, select sites, and determine the potential threat from shale gas development, and describes our monitoring targets, the methods used to assess the current condition of the targets, and the primary findings of the work to date.

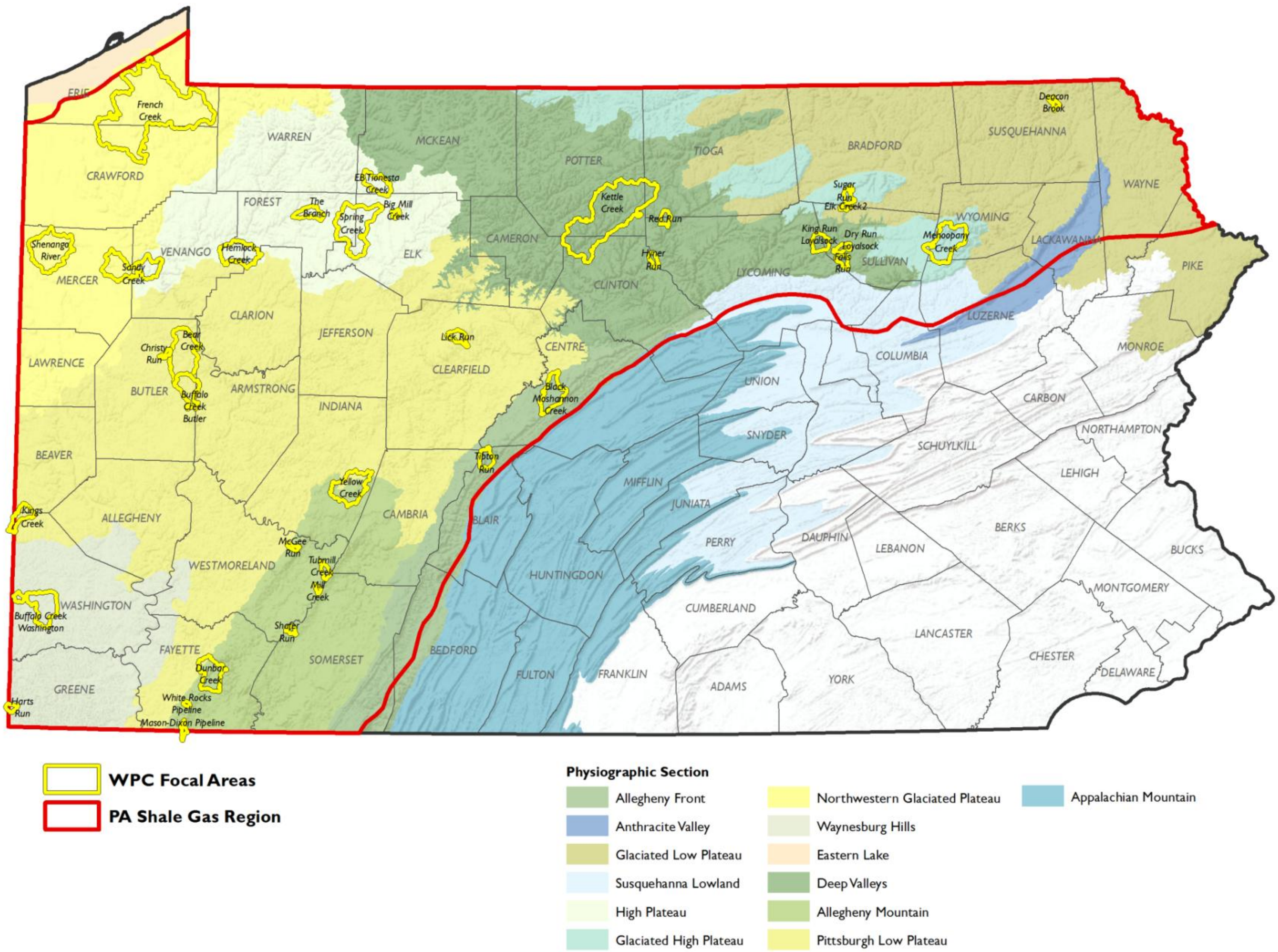


Figure 2.1. Western Pennsylvania Conservancy Focal Areas studied 2013-2015 by physiographic section.

Ecological Value

We determined high value areas for biological diversity conservation using a process called Ecological Value Analysis (EVA). The EVA is a GIS analysis technique that synthesizes important natural resource information in a single geospatial layer for natural resource management, land use management, and awareness. These types of analyses are often used to guide conservation planning efforts. Our EVA was constructed using aquatic and terrestrial habitat information, available environmental quality data, and rare plant and animal species occurrence data. The analysis produced a statewide, continuous raster surface that represents the combined value of all data sets used; a 30mx30m grid cell (pixel) was used as the unit of analysis (Figure 2.2). To identify areas of conservation value, we combined adjacent high ranking pixels, resulting in defined "focal areas," which were then ranked by the average EVA score of all 30mx30m pixels within. We selected focal areas with EVA scores ranking in the top 10 percent of all areas in each physiographic section.

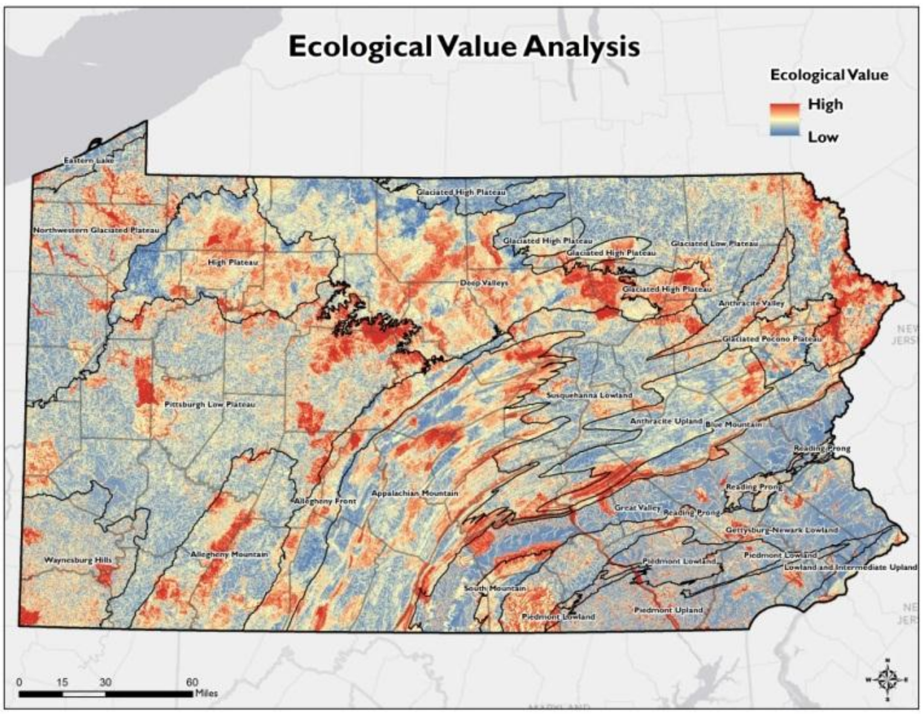


Figure 2.2. Ecological Value Analysis results by physiographic section

Forest Resources

Forest patches were scored for size, for proximity to other large forest patches, and for the amount of interior forest that they support. Data for forests were derived from the 2006 National Land Cover Dataset (NLCD) and further refined to remove non-forested land cover by an analysis protocol developed by the Western Pennsylvania Conservancy and The Nature Conservancy.

Forest Patch Size

Larger forest patches are assumed to contribute more to the state's ecological value than smaller ones. Weighting reflects value of larger patches to landscape functions:

Area of Forest Patch	Score
Non-forest	0
< 100 acres	0.25
Between 100 and 1000 acres	0.75
> 1000 acres	1.00

Interior Forest

Interior forest is defined as forest that is more than 100 meters from a forest edge. Interior portions of forest patches were mapped by removing the outer 100 meters of each forest block, and the resulting interior patches were buffered by 100 meters. This process removed the 'fringe' at the outer edge of patches which did not contribute to the interior forest (Figure 2.3). These patches were scored by the percentage of interior forest within each forest patch. This percentage was converted to a 0-1 scale, with higher values indicating patches that were close together.

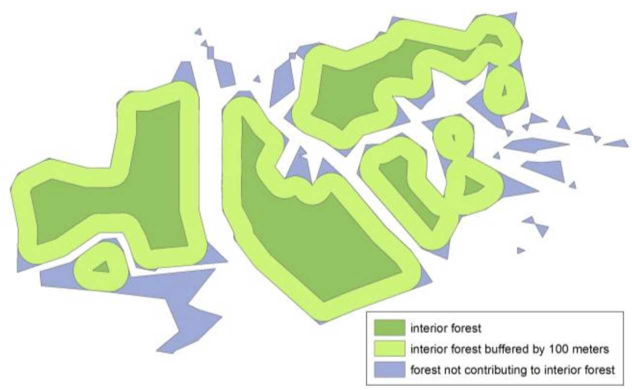


Figure 2.3. Example of the mapping of forest that contributes to interior forest.

Forest Patch Proximity

Proximity is a unitless measurement calculated by Fragstats 3.4, a program which computes metrics related to landscape fragmentation. Proximity measures the isolation of a focal patch of forest and the degree of forest fragmentation in the vicinity of the focal patch. Proximity is calculated as the sum, across all patches within 2000 meters from the center of the focal patch, of the area of each patch divided by the square of the distance to the focal patch (McGarigal et al. 2002). Thus, a forest patch will score highly for this metric if nearby forest patches are close, large, and numerous. Proximity measures were scaled from 0-1, with higher values indicating patches that were close together.

Aquatic Resources

Active River Area

The Active River Area is a holistic conservation framework for rivers and streams that integrates both physical and ecological processes that form, change, and maintain a wide array of habitat types and conditions in and along rivers and streams (Smith et al. 2008). The framework is intended to inform efforts to protect and restore the ecological integrity of rivers and streams by providing a means for explicitly considering the spatial area necessary for natural processes and disturbance regimes to occur. Equally importantly, the active river area provides a range of important benefits to society, including the reduction of flood and erosion hazards, water quality protection, providing recreational and scenic amenities, and providing for important habitat for terrestrial and other non-aquatic species. Land within the active river area is scored as 1, while non-active river area is scored as 0.

Wetlands

The National Wetland Inventory was used to identify wetlands to include in the analysis. Impoundments were excluded, and all other wetland types were given a score of 1.

Eastern Brook Trout Joint Venture

HUC12 watersheds are scored for the predicted condition of their native brook trout populations, as predicted by Thieling (2006).

Native Brook Trout Status	Score
Brook trout absent	0
Present, greatly reduced	.25
Present, reduced	0.70
Present, intact	1.00

DEP Chapter 93 Streams

Section 93.4b of the Pennsylvania Code allows DEP to designate streams as High Quality and Exceptional Quality (Commonwealth of Pennsylvania 2013). Streams were converted to 30 meter raster format and scored as follows:

DEP Chapter 93 Stream Status	Score
Exceptional Value streams	1.00
High Quality streams	.25
other streams	0

Aquatic Community Classification

The Aquatic Community Classification (ACC) rates HUC 12 watersheds for conservation value based on high quality biological communities, fish and macroinvertebrate metrics, and least disturbed streams. (Walsh et al. 2007) These ratings were combined and scored as follows:

ACC Scores for (1) Biological Communities, (2) Fish and Macroinvertebrates, and (3) Least Disturbed Streams	Score
Below 80th percentile for all three scores	0
A mix of 80th and 90th percentile for all 3 scores	0.50
Above 90th percentile for all three scores	1.00

Critical Habitat

Rare Species

For each species or natural community of conservation concern, a Core Habitat polygon was drawn, based on specifications developed by PNHP. Each polygon was scored by the combination of its global conservation rank (G-rank) and state conservation rank (S-rank), using the same scoring system used in the determination of significance rankings of NHAs. Please refer to the PNHP website (http://www.naturalheritage.state.pa.us/RankStatusDef.aspx) for an explanation of conservation ranks. Values range from 0 (the lowest biodiversity value) to 1 (the highest biodiversity value).

Forest Interior Bird Species (FIDS) Habitat

FIDS habitat is a key component of ecological value in Pennsylvania. An index of the quality of FIDS habitat was created from bird abundance data for the Second Atlas of Pennsylvania Breeding Birds (Wilson et al., 2012). The values of this index are categorized as percentiles in 5 percent increments, and are scored to the four categories listed below.

FIDS Habitat Score	Score
Below 80th percentile	0
80-90th percentile	0.25
90-95th percentile	0.75
95th percentile and above	1.00

Important Bird Areas (IBA)

IBAs (Audubon, 2011) represent the best habitats for birds using all habitats and accounts for important landscape functions such as migratory corridors. Land within IBAs is scored as 1.0, while other areas are scored as 0.

Landform Variety

The Nature Conservancy produced a measure of landform diversity based on 11 landform types from a model. Variety is the number of landform types within a 100 acre circle centered on each 30 meter grid cell. Scores ranged from 1 to 11, and for this analysis they were scaled to a range of 0 to 1.

Combining Layers

We constructed three Model Builder scripts in ArcGIS 10.0 for each of the sub-categories described above. These model builder scripts allow for each section to be updated as new data becomes available. The results of these three sub-models were also combined using a model builder script. The result was a 30m resolution raster with values ranging from 0 to 0.56 statewide (Figure 2.1). Results are best interpreted within a regional context due to large amounts of variation in ecological resources across the state.

Threat and Monitoring Feasibility

Our assessment of threat from shale gas development used a method similar to the method TNC used in its Pennsylvania Energy Impacts Assessment (Johnson et al. 2010). We determined shale gas development potential using a machine-based learning modeling approach known as maximum entropy (Maxent 3.3.3a, Princeton University, Phillips et al. 2006), which was used to find relationships between existing and permitted well pad locations and variables that might be relevant to a company's decision to drill a well.

Such variables were chosen based on data availability and included Marcellus and Utica Shale depth, thickness, thermal maturity, magnetic anomaly as well as percent slope, distance to water, and distance to roads. The model produced a raster surface that represents the probability of an area to potentially support future gas well development (Figure 2.4). However, this modeling did not include lease and ownership data, which is likely one of the significant drivers of shale gas development.

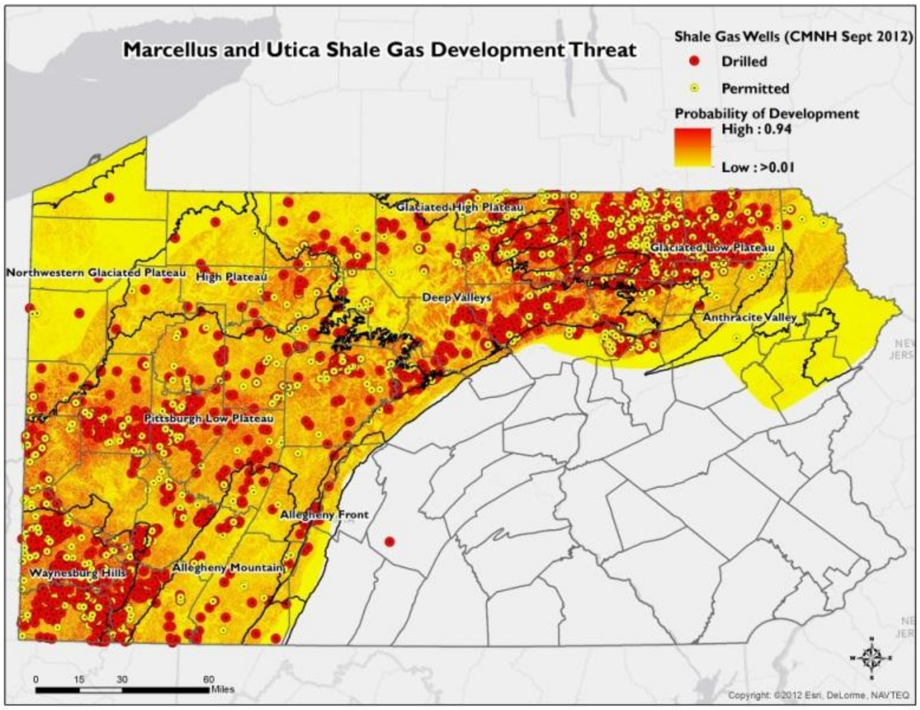


Figure 2.4. Map showing areas of high probability for development

We then determined the monitoring feasibility by variables such as distance to roads and other access information. We used this information, along with the probability of sites to be developed, to rank the focal areas and select those that were of high ecological value and under a relatively high degree of threat from shale gas development within each Physiographic Section (Figure 2.5).

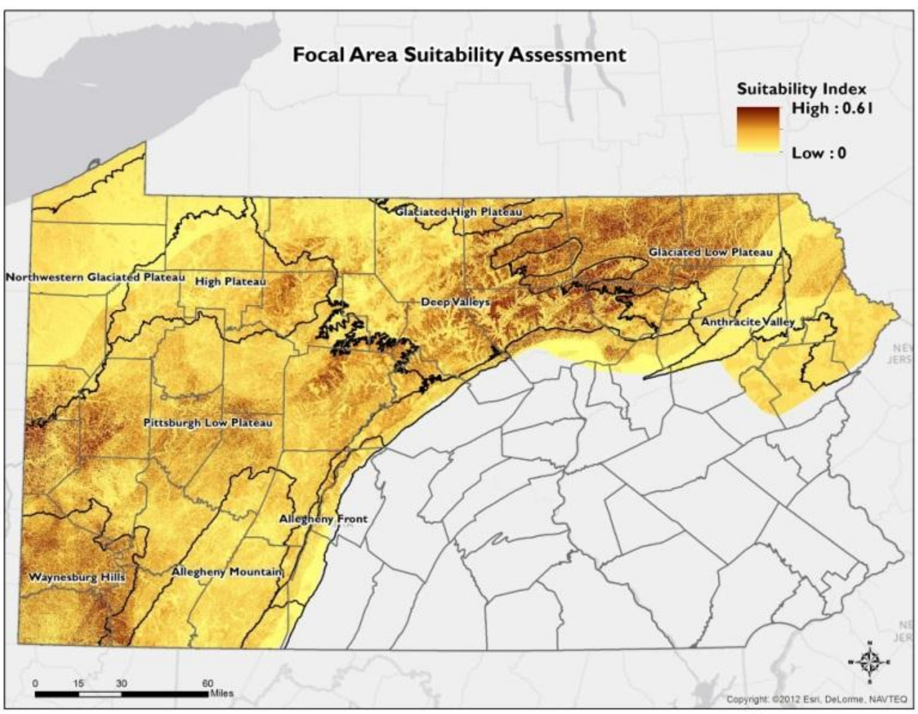


Figure 2.5. Map combining shale development probability with other factors to determine priority monitoring areas.

3. Monitoring Targets

Landscape and Fragmentation

Prior to European settlement, forest covered more than 90 percent of the area that became Pennsylvania (Goodrich et al. 2003). Today 62 percent of the state is forested, comprising an area of over 17 million acres (Goodrich et al. 2003; Myers et al. 2000).

Fragmentation of contiguous forested landscapes into smaller, isolated tracts has an effect on plant and animal distribution and community composition. When a large piece of forest tract is fragmented, or split into pieces, the resulting forest islands may lack some of the habitats that existed in the original tract, or may be smaller than the minimum area required by a given species (Lynch and Whigham 1984). For example, the Louisiana waterthrush (*Parkesia motacilla*) is rarely found in small woodlots because they require upland forest streams within their territory and most small woodlots lack this necessary component (Robbins, 1980; Robinson, et al. 1995). Area sensitive species such as the northern goshawk (*Accipiter gentilis*), barred owl (*Strix varia*), bobcat (*Lynx rufus*), and timber rattlesnake (*Crotalus horridus*) require interior forest areas in excess of 2,400 hectares (6,000 acres) to accommodate breeding and foraging territories (Ciszek 2002; Mazur and James 2000; Squires and Reynolds 1997).

Edge forest is composed of a zone of altered microclimate and contrasting community structure distinct from the interior or core forest (Matlack 1993). Along with a reduction in total forested area, forest fragmentation creates a suite of edge effects which can extend 300 meters (1,000 feet) into the remaining fragment (Forman and Deblinger 2000). Edge effects include increased light intensity, reduced depth of the leaf-litter layer, and altered plant and insect abundance (Haskell, 2000; Watkins et al. 2003; Yahner, 2000). Additionally, a number of studies have shown that the nesting success of forest-interior songbirds is lower near forest edges than in the interior due to increased densities of nest predators and brood parasites.

Development of well pads, pipelines, compressor stations, and roads in Pennsylvania has resulted in thousands of hectares of disturbance to natural habitats, about half on forest land and even more impacts associated with edge effects and loss of wild character (Johnson et al. 2010, Slonecker et al. 2012, Drohan et al. 2012). Increased shale gas development is expected to further impact the forests and streams of the Appalachian Region from development of the infrastructure needed to extract and transport natural gas (Johnson et al. 2010, Johnson et al. 2011, Drohan et al 2012, Drohan and Brittingham 2012, DCNR 2014, Evans and Kiesecker 2014).

In order to determine a baseline for landscape condition and fragmentation of our high value ecological areas in this study, we assessed the land cover of each of the 35 focal areas in GIS. We determined the forest cover that existed in 2013 for each focal area in GIS based on the existing land cover data (2011 National Land Cover Dataset) and available aerial imagery (2013 NAIP data). We then applied special analysis techniques to calculate several landscape and fragmentation statistics to establish the baseline of forest cover and fragmentation during the time of the study. We expect to continue to analyze landscape variables in relation to rare and important species and water quality parameters for each one of the focal areas in the future; especially in relation to development of infrastructure associated with shale gas extraction and transmission.

Monitoring Methods

Land Cover

We used the 2011 National Land Cover Dataset (NLCD) (Jin et. al. 2013) in ArcGIS 10.3 (ESRI 2014) as the base land cover for the project. However, we made several modifications to the dataset in order to account for the potential classification errors, as well as update it to more closely match current conditions, in particular, development of shale gas extraction and transmission infrastructure, which increased substantially in recent years. First NLCD classes were grouped into four broad categories including natural cover, water, agriculture, and development. A breakdown of the cover classes within each category is presented in Table 3.1. Based on previous work; we expect that errors in classification probably average out across the focal area.

Table 3.1. Grouping of land cover classes into four main categories.

Category	NLCD Cover Type	
Natural cover	41	Deciduous Forest
	42	Evergreen forest
	43	Mixed Forest
	52	Shrub/Scrub
	90	Woody Wetlands
	95	Emergent Herbaceous Wetlands
Water	11	Open Water
Agriculture	71	Grassland/Herbaceous
	81	Pasture/Hay
	82	Cultivated Crops
Development	21	Developed, Open Space
	22	Developed, Low Intensity
	23	Developed, Medium Intensity
	24	Developed, High Intensity
	31	Barren Land

We converted the 30 meter reclassified dataset into a 10 meter grid. Three additional layers representing linear fragmenting features (e.g., local roads, railroads, highways, pipelines) were "burned in" to the reclassified layer. Roads were represented by the finest scale data available in the 2013 ESRI StreetMap dataset within ArcGIS (ESRI 2014). No buffer was applied. Similarly, we extracted active railroads from the 2013 StreetMap dataset. No buffer was applied. A pipeline dataset (Hart Energy 2015) was also used to get a representation of pipelines. To account for potential land clearing created for the pipeline right-of-ways, transmission pipelines were given a 45 meter buffer, and all other pipeline datasets were buffered by 15 meters, following average pipeline widths described in Johnson et al. (2011). Compared to the street and railroad data, natural gas (as well as other energy types) transmission data suffers from issues of incompleteness and accuracy. Therefore, we made efforts to remove pipelines that were planned and not constructed yet, or were inaccurately mapped. All three of these datasets were classified as "developed" and added into the land cover map.

To account for shale gas drilling pads, we created a 50 meter buffer around the center point of the group of wells to represent the area of a pad and then "burned" these estimated pads into the modified land cover dataset and classified the converted pixels as developed. An example of this process is presented in Figure 3.1. We then summarized the percentage of each type of land cover within each focal area and also in each physiographic section.

(a) Land cover without shale gas burned in. Red circles indicate ~77m buffers on drilled wells.

(b) Resultant land cover after the addition of shale gas pads. Access roads and gathering lines were later digitized.

Figure 3.1. Example of the process to add in shale gas well pad into the land cover dataset.

Determining Patterns of Existing Gas Development in Focal Areas

While gas wells are tracked by the Pennsylvania DEP, the well pads, and associated infrastructure are not. In GIS, we identified the number of gas well pads in each focal area as of December 31, 2014 through a process described in Drohan et al. (2012), which, following identification of wells associated with each pad creates a 50 meter buffer, dissolves the overlapping buffers, and determines the calculated center point. We excluded all wells in the DEP dataset prior to 2004. With this, we created a snapshot of the number of well pads in each focal area existing during this study. To determine if the well pad was developed in forest/natural habitat or developed land cover, we determined the dominant land cover in which each of the pads was constructed by overlaying the pad center points on 2005 aerial imagery (PAMAP 2005 data, PASDA 2015), again following methods used by Drohan et al. (2012). To determine patterns in land ownership of well pads within our focal areas, we overlaid the derived well pad layer on a layer representing the combined lands owned and managed by state and federal land management agencies and private conservation organizations (data accessible through PASDA 2015).

Forest Fragmentation

Using the base natural cover dataset as prepared above as a starting point, we corrected mapping and classification errors. First, the natural cover grid was converted to a polygon feature class. Next, ecology staff compared the mapped patches to the aerial images (2013 NAIP) and adjusted boundaries to match the edges of the natural cover as seen in the imagery. All digitizing was done at a scale of 1:5000. This produced a map of natural cover at a scale appropriate for the focal area.

We assessed forest fragmentation by using the Landscape Fragmentation Tool (LFT v2.0) developed by the University of Connecticut (Vogt et al. 2007). This tool was used to map the types of fragmentation present across the natural cover of each focal area. For the purposes of this analysis, we used natural cover as defined above to represent habitat and water; agricultural and developed classes were considered fragmenting land covers. We assumed that the edge width was 100 meters. Although the width of 'edge effects' varies with the species or issue being studied, we assumed an edge width of 100 meters, a distance that is often used for general purpose analyses. This fragmentation was classified into four main categories:

- Core pixels are any natural cover pixels that are more than 100 meters from the nearest fragmenting pixel. Core pixels were further classified into three patch sizes, based on summaries of the relevant scientific literature:

- Small core patches have an area of less than 250 acres
    - Medium core patches have an area between 250 and 500 acres
    - Large core patches have an area greater than 500 acres
- Patch pixels are within a small natural cover fragment that does not contain any core forest pixels, and are, most likely, completely degraded by the edge effect.
- Perforated and edge natural cover are with 100 meters of fragmenting pixels but are part of a patch containing core pixels:
    - Edge pixels are along the outside edge of the natural cover patch
    - Perforated pixels are along the edge of small natural cover gaps

An example of the classified natural cover is presented in Figure 3.2. Results of the fragmentation analyses were summarized by each of the 35 focal areas.

Figure 3.2. Example output from the Landscape Fragmentation Tool. Natural cover is classified into one of six types.

Road and Pipeline Density

The amount of linear features such as roads and pipelines within a given area can have impacts on the ecology of a region. In addition to the fragmentation statistics presented above, we calculated road density (kilometers/ kilometer^2) and pipeline density (kilometers/ kilometer^2) within each focal area using the Line Density tool in ArcGIS. The mean density for both roads and pipelines was summarized for each focal area as well as each physiographic section.

Monitoring Efforts and Results

The 35 focal areas ranged in size from 4.1 to 829.2 square kilometers. Figure 3.3 presents the percentage of each land cover type across the focal areas. Focal areas ranged from 44.8 percent to 98.5 percent natural cover with a mean of 85.0 percent. Water covered the smallest percentage of each focal area, with development and agricultural making up a larger percentage of each focal area. Focal areas differed considerably in the amount of forest cover and other land cover/land use depending on which physiographic section they occurred in. For example, focal areas in the Northwestern Glaciated Plateau, Pittsburgh Low Plateau, and the Waynesburg Hills typically had higher percentages of agriculture and development, probably reflecting on the development history of the region.

Shale gas wells occur in 15 of the 35 focal areas, several of which were drilled over the course of the study. In all, there were 169 drilled shale gas wells as of January 1, 2015 in the 35 focal areas. These wells were found on 59 well pads totaling approximately 74 hectares (183 acres) of land within the combined focal areas based on spatial footprint estimates from Johnson et al. (2010). We found that 36 of the 59 well pads (61 percent) in the 35 focal areas fell within forested cover; the remaining 23 pads (39 percent) were situated in agricultural land and disturbed land (developed, scrub-shrub, herbaceous). These land cover patterns differ, somewhat, to the study by Drohan et al. (2012), which found 54 percent of shale gas wells developed before June of 2011 to be situated in forest land cover statewide and the rest in the other land cover types listed above. This difference was due in part to our selection of focal areas, which were highly forested, as compared with development sites within the region overall; but also reflects a trend presented in Drohan et al. (2012) towards increased shale well pad development in forested areas based on location of permitted wells.

Analysis of well pad location and land ownership in the WPC focal areas revealed that a total of 21 of the 59 well pads were located on public land (36 percent); all other well pads were located on private land. Within public lands, 12 of the 59 well pads were on state forest land (Hyner Run focal area in the Sproul State Forest and Lick Run focal area in the Moshannon State Forest); 7 well pads were on PGC lands (Lick Run focal area in SGL 90, Spring Creek focal area in SGL 28, Buffalo Creek (Washington County) in SGL 232); 2 pads were located in the Allegheny National Forest (Spring Creek and Tionesta Creek focal areas). Drohan et al. (2012) calculated that wells on public land comprised just 10 percent of the total number of well pads developed before June 2011. A large proportion of the land within our focal areas was publicly owned, especially in the areas of greatest concentration of well pads, which accounts for the difference from findings in Drohan et al. (2012). It is interesting to note, however, that out of the 96 wells developed within the WPC focal areas since June 2011, 55 wells (57 percent) were drilled on pads located on public lands. This may suggest an increase in development activities on public lands in recent years or may just reflect an increase in drilling throughout the region, as we did not assess drilling activity across the entire region. Trends and patterns in shale development, especially as related to high ecological value areas, state lands, and other environmentally sensitive or important areas need further investigation.

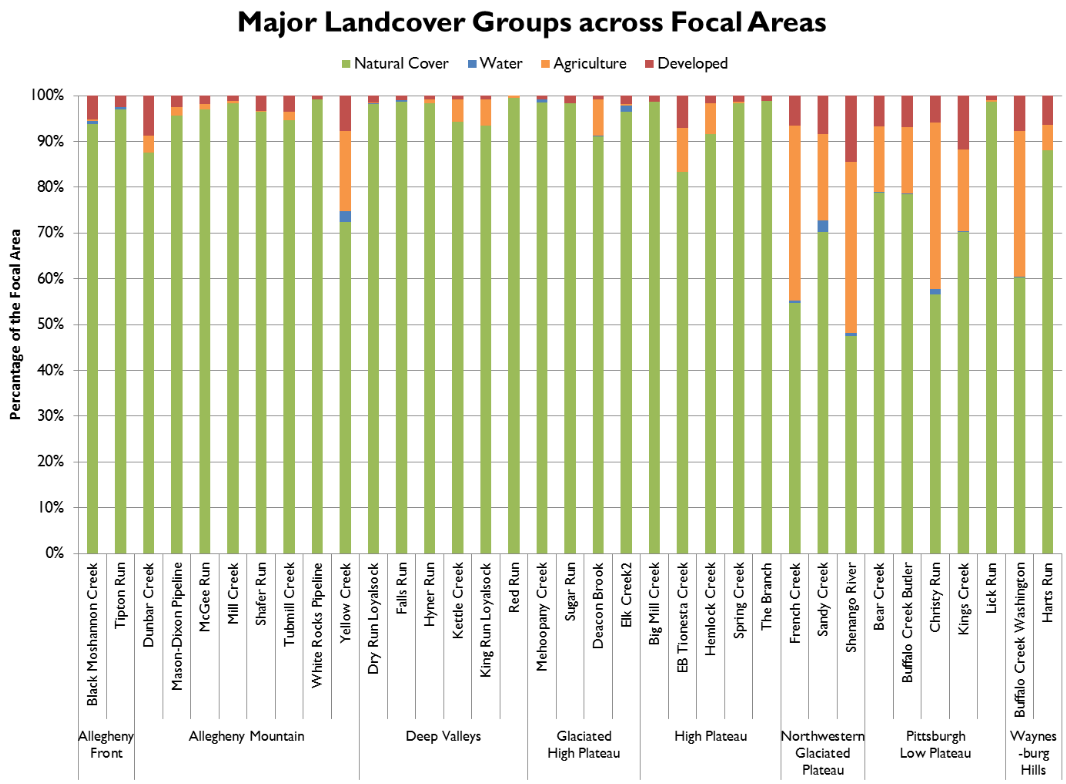


Figure 3.3. Land cover distribution within each of 35 Focal Areas.

Forest Fragmentation

Forest fragmentation values ranged considerably by physiographic section with focal areas in the Allegheny Front, Allegheny Mountains, Deep Valleys, Glaciated High Plateau, and High Plateau consistently exhibiting a higher percent of core forest (> 200 hectares) and lower percent core Edge, whereas focal areas in the Northwestern Glaciated Plateau, Pittsburgh Low Plateau, and Waynesburg Hills had relatively low scores for core forest and higher scores for Edge (Figure 3.4). Focal areas on the edge of the physiographic sections sometimes exhibited fragmentation characteristics similar to adjacent regions, such as Yellow Creek, which resembled sites in the Pittsburgh Low Plateau more so than other sites in the Allegheny Mountains. Likewise, Lick Run, on the edge of the Pittsburgh Low Plateau seemed to be more like its neighbors in the Allegheny Front, and less like other sites on the Low Plateau to the west.

Anecdotally, the extent of the landscape fragmentation attributable to shale gas infrastructure (where it occurred) differed considerably from one focal area to another. Forest fragmentation from shale gas infrastructure was most evident in focal areas that were predominantly forested. For example, in the Lick Run and Hyner Run focal areas, both with a high percent forest cover, the well pads and associated roads and pipelines comprised the majority of the non-forest land cover, which amounted to approximately one percent of the total area in each of these two focal areas. While pipeline density was

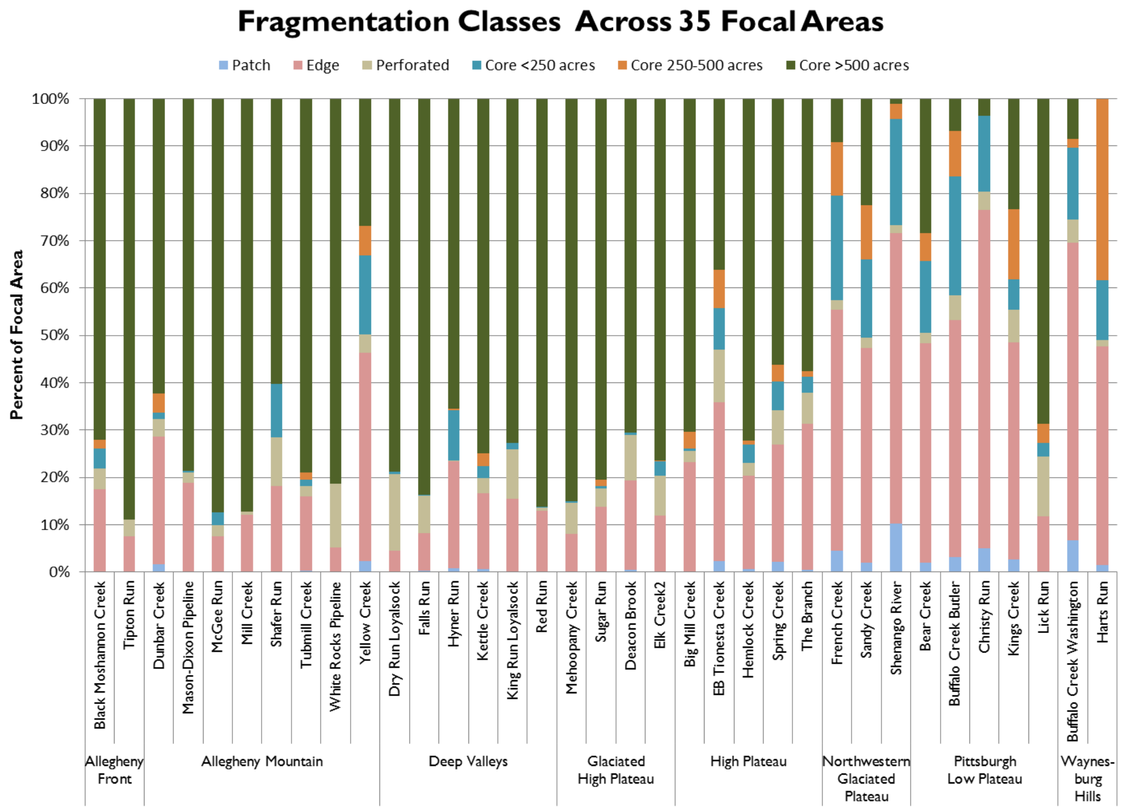


Figure 3.4. Percentage of fragmentation types across 35 focal areas.

low for both of these sites, in the field we observed that many of the gathering lines have been co-located with existing roads. In contrast to predominantly forested focal areas, it was more difficult to tell if road and pipeline infrastructure was associated with shale gas development in focal areas with more open agriculture and developed land cover.

Mean road density within the focal areas ranged from 0.45 to 2.44 (Figure 3.5). Road density tended to be higher in the Northwestern Glaciated Plateau and Pittsburgh Low Plateau sections and lower in other, more remote, sections of the shale gas region. It was not possible to determine the proportion of roads created for the sole purpose of supporting shale gas development. Many roads existing prior to development of shale gas appeared to have been widened and improved for the purposes of supporting natural gas drilling activities; but are not solely associated with shale gas development.

Mean pipeline density within the focal areas ranged from 0.00 to 1.94 (Figure 3.6). The average pipeline density varied across the 35 focal areas, with sites in the High Plateau and Northwestern Glaciated Plateau tending to have higher densities. As with roads, it was not possible to determine the proportion of pipelines associated with shale gas, as considerable infrastructure for shallow gas and natural gas transmission already exists. More work must be done to assess the extent of habitat alteration of specific areas due to shale gas development. Additionally, in examination of the pipeline dataset, we noticed many "false" pipelines were present in the dataset, as well as different mapping intensities in different regions which may have impacted the statistics. "False" pipelines were the result of permitted or proposed pipelines in the available datasets that never were developed, or have yet to be developed. This highlights the need for a high quality dataset of shale infrastructure. For statewide and regional landscape assessments to be relevant at the local level, pipeline and road data need to be more accurate.

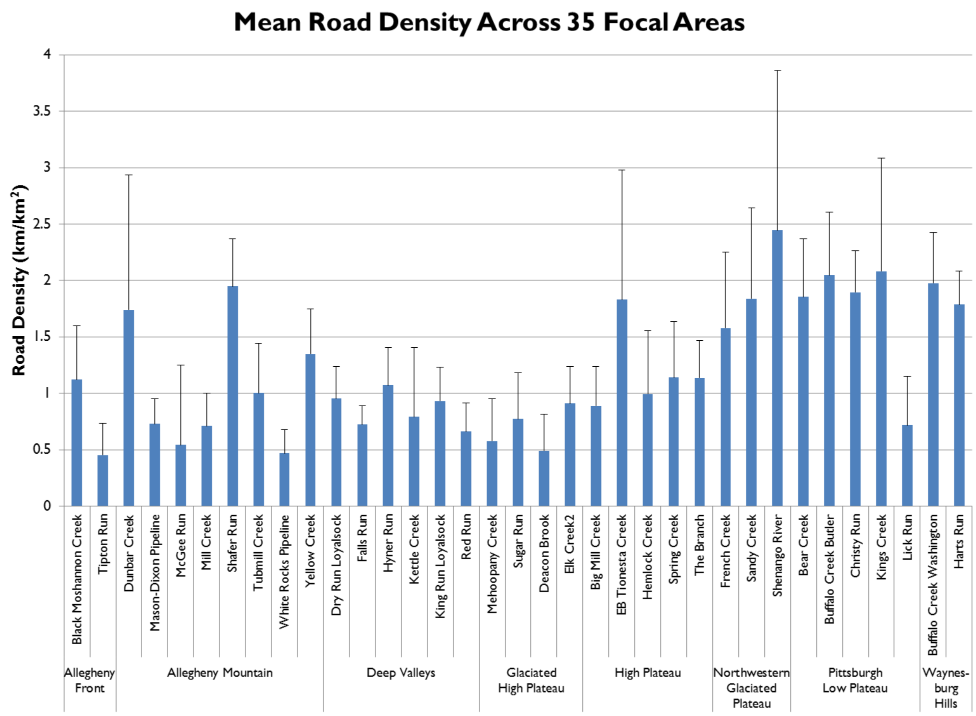


Figure 3.5. Mean road density across 35 focal areas. Error bars indicate one standard deviation.

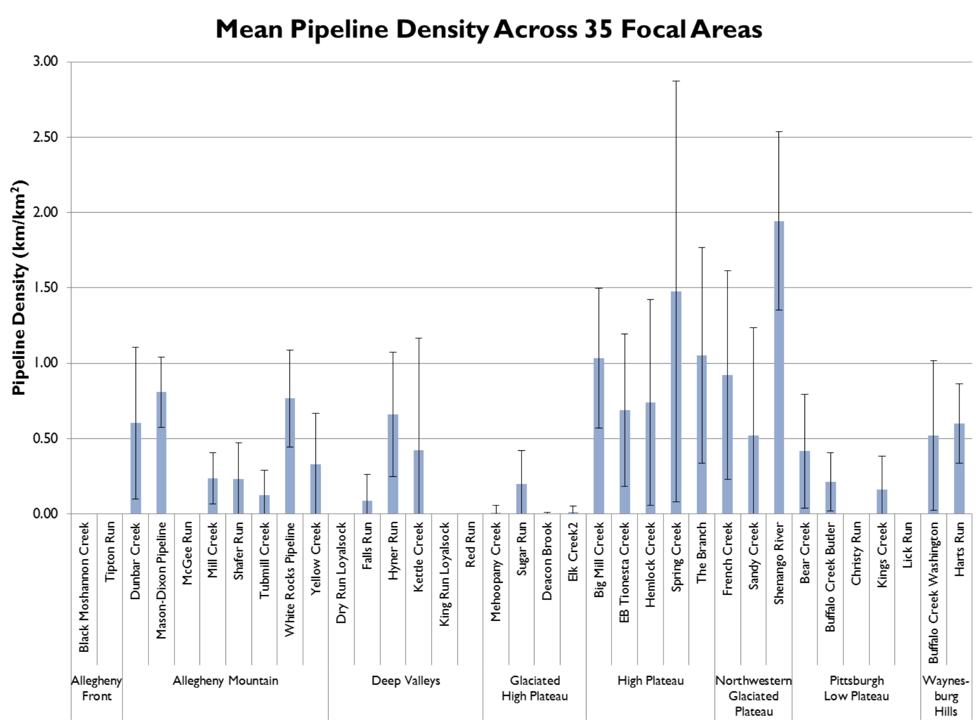


Figure 3.6. Mean pipeline density across 35 focal areas. Error bars indicate one standard deviation.

Conservation Implications and Future Work

Our land cover and fragmentation assessment will serve as a baseline to measure landscape change over time in each of the 35 focal areas. We expect forest fragmentation to increase within the focal areas with construction of shale gas infrastructure. As the expected development arrives, we will compare the amount and rate of forest loss and fragmentation within and among focal areas, and compare changes in the focal areas to regional and statewide fragmentation values. In future assessments, we will look for correlations between land cover and fragmentation statistics attributable to shale gas, and the results from field assessments at specific monitoring sites within the focal areas.

Early analysis of shale gas development patterns found that shale gas development was more prevalent on private land in Pennsylvania (90 percent) than on state owned lands (DCNR and PGC) (Drohan et al. 2012). This suggests that there is an importance of state land in protection of habitat for wildlife species, especially species that depend on interior forest conditions and high quality, cold water aquatic ecosystems. However, we showed that development is occurring on state lands, as indicated by development patterns within the high ecological value areas identified in our study. Both the DCNR and PGC manage shale development activities on their lands through leases; there are thousands of additional areas owned by the DCNR and PGC where they do not control oil and gas rights. Data from this study and others that identify areas of high ecological value can be useful in planning conservation actions to avoid and minimize impacts from development of shale resources.

Attributing Fragmentation due to Shale Gas Development

Where drilling occurred in our focal areas, we found it difficult to determine the proportion of non-forest land cover that could be attributed to shale gas development across all sites. In the most forested focal areas, fragmentation from shale gas infrastructure was noticeable and it was easy to associate fragmentation and land cover with shale gas development. In these primarily forested focal areas, such as Lick Run and Hyner Run, well pads, pipelines, and roads comprised a majority of the non-forested cover, making up approximately one percent of the total land cover of each of these focal areas. It must be noted that shale gas development often takes advantage of existing roads for well pad construction, transporting equipment and materials, and supporting the drilling and hydraulic fracturing process.

In contrast with highly forested focal areas, landscape fragmentation due to shale gas development was harder to evaluate for focal areas with a lower percent of natural cover and a greater proportion of residential development and agricultural land. In these focal areas, such as the Buffalo Creek (Washington County) or Yellow Creek focal areas, shale gas infrastructure appeared to be a minimal component of the overall amount of landscape fragmentation, and comprised little in terms of direct impacts to forest cover overall, as a great majority of the infrastructure was developed primarily in open agricultural land. There were several instances, though, where new pipelines bisected forest patches within these focal areas. This undoubtedly reduced the already low value for core forest area in the focal areas, but it was difficult to attribute these features to shale gas, as data on ownership and use of pipelines are not readily available. Analysis of the Hart Energy pipeline data and aerial imagery indicated that pipelines were also a major fragmenting feature in areas where drilling had not yet occurred, such as Dunbar Creek and French Creek. In these landscapes, it was impossible to determine if these pipelines were associated with shale gas development.

The effect of fragmentation on forest ecosystems is an area of debate and is often influenced by preference for one species or group of species over another. It is clear, though, that shale gas development in forested areas increases the amount of edge habitat. Application of best management practices to reduce overall forest fragmentation, such as colocation of access roads and gathering pipelines should benefit species requiring interior forest conditions. We present the specific fragmentation impacts on forest habitats, specifically on bird species of interior forest habitats, later in this report.

We will continue to analyze landscape variables in relation to rare and important species and water quality parameters for each one of the focal areas in the future. An up-to-date understanding of forest fragmentation and its potential impacts to specific high profile areas will enable state agencies, large landowners, and communities to implement conservation measures to avoid and minimize impacts to critical habitat resources.

Land Conservation Considerations

Protecting large intact forest habitats and minimizing fragmentation should continue to be the primary goal for land conservation in forested areas of Pennsylvania. Site planning tools to identify routes for pipelines and roads that minimize landscape fragmentation, such as TNC's InSitu planning tool (Gagnolet et al. 2014), may help to avoid impacting large patches of interior forest. However, private land ownership issues and the fragmented nature of oil, gas, and mineral rights often dictate the location of shale gas infrastructure.

In more fragmented landscapes, avoidance of remaining high value forest patches may be more attainable, and should be prioritized to save what remains of our intact forest ecosystems. Landscape planning and conservation efforts should focus on avoiding the remaining patches of forest, especially patches of high quality unique habitat or sites possessing unique geological characteristics, like rock outcrops, barrens, and limestone-derived soils. These are considered ecologically significant because their high biological diversity value. In addition, there is a greater need for habitat management and restoration in more developed landscapes. Management and restoration activities to minimize the indirect impacts of forest fragmentation will minimize cumulative impacts of shale gas and other human development.

Water

There are 137,767 kilometers (85,623 miles) of streams within Pennsylvania, of which 85,005 kilometers (52, 831 miles) are within the shale gas region or 61.7 percent of the total stream miles in the state.

Certain streams are given special protection status under Chapter 93 of DEP regulations and have additional protections afforded to them in the permitting process to help protect their significant biological resources from excessive impacts.

WPC

Bear Creek water quality monitoring location, Armstrong County

A stream can qualify as special protection status if it meets the following criteria:

> *Exceptional Value (EV)*: Water quality (chemistry), based on at least one year of data, exceeds levels necessary to support the propagation of fish, shellfish, and wildlife etc., at least 99 percent of the time for [specific chemical parameters]. Incorporates a macroinvertebrate index of biological integrity (IBI) score of 92 percent and above with regards to a reference stream.
>
> *High Quality (HQ)*: Water quality (chemistry), based on at least one year of data, exceeds levels necessary to support the propagation of fish, shellfish, and wildlife, etc. at least 99 percent of the time for [specific chemical parameters]. Incorporates a macroinvertebrate index of biological integrity (IBI) score of 83 percent and above with regards to a reference stream.

In Pennsylvania, 62.8 percent of streams designated as HQ, or 22,598 km (14,045 miles), and 63.7 percent of all designated EV streams, or 3,981 kilometers (2,474 miles), are found within the Shale Gas Region. Special designations (EV or HQ) protect a stream from new discharges or other development activities and there are additional regulations for permitting of specific development activities to ensure that the water quality is not diminished for the exceptional biological communities. EV status affords a greater protection. Streams with special protection status under Chapter 93 are thought to have high quality and greater ecological value.

Additionally, the PFBC classifies certain streams, rivers, and lakes according to the fish species these water bodies support. Roughly 33,285 kilometers (20,687 miles) or 24 percent of all streams in Pennsylvania are able to support coldwater species such as native, wild, or stocked trout. The PFBC classifies specific streams that support trout species in a number of categories including trout-stocked fisheries, naturally reproducing trout streams, Class A wild trout streams, and wilderness streams. Each of these fisheries provides a different experience for anglers and all are important from a recreational as well as biodiversity standpoint. Of the 8,179 kilometers (5,083 miles) of trout-stocked streams in Pennsylvania, 60 percent or 4,887 kilometers (3,037 miles) are found in the state's shale gas region. A stream that contains "young of the year" trout (brook, brown, or rainbow) that are not of hatchery origin, are classified as natural reproduction waters; currently there are 14,827 kilometers (9,215 miles) of streams with documented natural reproduction of wild trout species in the shale gas region, which is approximately 70 percent of stocked streams statewide. Class A trout stream is a designation for streams that produce a minimum of 25 pounds/acre of native and wild trout. There are 2,647 kilometers (1,645 miles) of designated Class A streams in Pennsylvania, with over 55 percent or 1,456 km (905 miles) found in the shale gas region. Streams designated as "Wilderness Streams" are the smallest set of trout streams in the state with special protections, and are protected by regulations similarly to EV streams with regards to development. Only 990 kilometers (615 miles) are currently designated as wilderness streams. However, 830 kilometers (516 miles) or 84 percent, of the wilderness streams are found in the shale gas region.

There many threats to the streams of Pennsylvania from the development of shale gas. Many of these threats are commonly associated with other forms of development; however the extraction of shale gas requires significant amounts of water, uses a host of chemicals in the extraction process and produces waste, and disturbs soils and vegetation as infrastructure is constructed. Water withdrawal, waste (in the form of flowback and produced water and drill cuttings), and erosion and sedimentation from well pad and pipeline development activities are the primary impacts to wildlife and habitats from unconventional gas extraction to aquatic ecosystems. Methane migration and unintended discharges of chemicals used in the hydrofracturing process into groundwater are also of concern, especially in populated areas (Brantley et al. 2014). In a recent publication, Weltman-Fahs and others (2013) identified three key pathways of the influence of shale gas development on aquatic ecosystems, particularly through the lens of impacts to eastern brook trout (*Salvelinus fontinalis*). These primary pathways, which are applicable to all aquatic organisms, focus on water withdrawal, physical habitat impacts (e.g., sedimentation), and chemical pollution (waste). The following describe these pathways in greater detail, with regionally specific references.

Water Withdrawal

Estimates of the amount of water required for hydraulic fracturing of a Marcellus or Utica Shale well vary considerably; a majority of accounts state that the process requires between 7.5 – 26 liters (2-7 million gallons (Kargbo et al. 2010, Vidic et al. 2013). Much of the time, especially in rural and forested landscapes, the water is withdrawn from surface streams and impoundments; surface waters are the primary source of water used in the hydraulic fracturing process in the Susquehanna River Watershed (SRBC) and while the amount needed for the fracturing process is low in relation to surface flows of most streams in Pennsylvania, reduction of the amount of water is thought to be problematic at times of drought and low flow (Entrekin et al. 2011). Shale gas drilling has increased the demand from headwater streams in remote areas of the Susquehanna River Watershed, particularly the West Branch and Upper Susquehanna sub-basins (DePhillip and Moberg 2010). This activity reduces the amount of water available to aquatic organisms; water withdrawals also reduce the velocity and flow, and streams that experience significant water withdrawals at times of low natural flows may see warmer temperatures and have a higher concentration of salts and other pollutants (Entrekin et al. 2011), both important to species such as eastern brook trout.

Erosion and Sedimentation

Shale gas well installation typically requires between 1.3 – 2.7 hectares (3-7 acres) of land clearing per pad, depending on the total number of wells in each pad and whether or not other infrastructure (like containment pits) is located on the pad (Johnson et al. 2010, Drohan and Brittingham 2012). This along with the installation of supporting infrastructure such as roads, pipelines, and stream crossings results in removing natural vegetation and decreasing the permeability of surfaces, leading to increased sedimentation in surface waters (Entrekin et al. 011, Drohan and Brittingham 2012). In 2010, there was approximately 3,218 kilometers (2,000 miles) of gathering pipeline which is projected to increase to 19,308 – 43,443 kilometers (12,000 – 27,000 miles) by 2030. Although pipelines are buried, a right of way width of 9.1 – 45.7 meters (30 – 150 feet) is cleared and extensive soil disturbance occurs during construction, resulting in increased erosion and sedimentation. Stream crossings create a direct pathway for sediment to enter the stream, remove riparian vegetation, and pose a risk of stream bank collapse

(Johnson et al. 2011). Sediment enters local surface waters as a component of storm water runoff, with sediment loading rates of nearly 54 metric tons per hectare per year possible for sites where vegetation was removed and with slopes greater than 6 percent (Williams et al. 2008).

Excess sediment levels are considered one of the primary stressors of surface waters nationwide because of the extent and severity of its effects on biological integrity (US EPA, 2006). Continual, elevated sediment levels may permanently alter community structure, diversity, density, biomass, growth, fitness, and rates of mortality. The impact of increased sedimentation on lotic communities begins at primary trophic levels by limiting light penetration and reducing the production of photosynthesizing organisms. Reduced primary production results in cascading effects to higher trophic levels by reducing food sources for herbivorous insects and fishes and consequently carnivorous organisms as well. Additionally, increased sediment is associated with reduced dissolved oxygen. Consequently, increased sedimentation leads to shifts in macroinvertebrate and fish populations to species that are tolerant of low oxygen levels (Henley et al, 2010).

<u>Flowback, Produced Water, and Waste</u>

Between 10 to 30 percent of the water used in the hydraulic fracturing process returns to the surface (Flowback) (Maloney and Yoxtheimer 2012, DCNR 2014). The water contains chemicals used in the hydraulic fracturing process including surfactants, antibacterial agents and lubricants, along with salts (bromide, chloride) and elements (barium, strontium) found in the shale formation, including naturally occurring radioactive materials (Kargbo et al. 2010, Rowan et al., 2011, Maloney and Yoxtheimer 2012). During gas production – additional water from deep in the shale and some of the injected water that remains longer in the shale will return to the surface with the gas and other hydrocarbons. This "produced water" often has higher levels of elements naturally occurring deep in the shale formations but less abundant in surface geology and surface waters.

The presence of levels of these chemicals and elements above naturally occurring levels may indicate the influence of pollution from hydraulic fracturing in surface waters. Some studies have shown elevated levels of barium and strontium in specific watersheds where heavy development is taken place (FracTracker 2014). Higher than normal levels of barium and strontium have also been found in the feathers of birds that eat aquatic macro invertebrates, suggesting that these elements accumulate at higher levels on the food chain (e.g. Latta et al. 2014). Flowback and/or produced water have been shown to negatively impact vegetation when applied, experimentally in a controlled study at the Fernow Experimental Forest, directly to a forest stand in West Virginia (Adams 2011).

Monitoring for these chemical constituents of flowback and production water and habitat assessments have been the focus of water quality monitoring efforts across the region (FracTracker 2014). These chemicals can be toxic at high levels to aquatic life and the wildlife species that depend on them for food. EPA has set toxicity standards for drinking and surface waters; additionally, researchers have determined average standards for most of these elements.

Many authors have suggested the need for paired watershed studies, or before-and-after control-impact designs (Weltman-Fahs and Taylor 2013); however variability from one site to another in the Appalachian Region makes the former a very difficult task to undertake. Before-and-after control-impact designs are difficult because it is hard to gather enough data over a long enough time to establish a robust baseline. However, gathering baseline data is necessary to assess change.

Because much of the concern over ecological impacts associated with unconventional gas extraction is related to impacts on aquatic resources, WPC staff have chosen to gather water quality related information throughout the shale gas region. Most of this data will be considered baseline, because limited survey data exists at any of these locations. The goal of this large data collection effort is to not only analyze the data for current conditions, but to set the stage for future water quality analysis.

Monitoring Methods

Beginning in April 2013, WPC conducted water quality assessments at 51 selected sites in 22 focal areas, distributed across the Shale Region of Pennsylvania (Figure 1. Western Pennsylvania Conservancy focal areas studied 2013-2015 by physiographic section). WPC's aquatic sampling methods included visual assessment of habitat condition and threats, field water quality assessment, and laboratory analysis for water quality parameters specifically related to impacts associated with shale gas development.

WPC

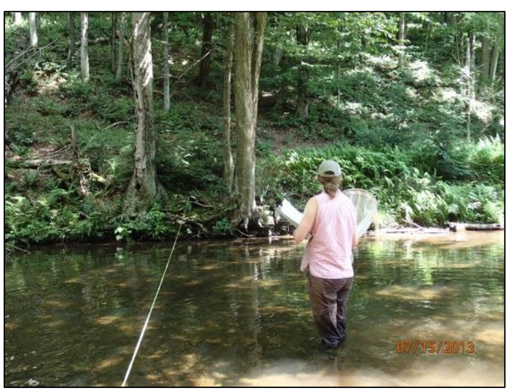
Water quality data being collected on Buffalo Creek, Washington County

Habitat Assessment and Threats

WPC performed a habitat assessment at each water quality monitoring site during the summer sampling season of each year (2013 and 2014) and evaluated threats to the site from human activity. A more detailed riparian vegetation evaluation was also conducted at select sites to identify current riparian community condition/type. The data was collected using a modified version of the United States Environmental Protection Agency's (USEPA's) Rapid Bioassessment Protocol for Streams and Wadeable Rivers. The EPA protocol assigns a numeric value to ten different stream characteristics, or "assessment elements," equating to overall stream quality (Table 3.2). The assigned assessment scores range from zero to twenty, with twenty being the highest in quality, and are based on specific conditions associated with each assessment element. The ten parameters assessed include epifaunal substrate and available cover, embeddedness, velocity/depth regimes, sediment deposition, channel flow status, channel alteration, frequency of riffles (or bends), bank stability, vegetative protection, and riparian vegetative zone width. The ten individual assessment scores for each site were totaled and averaged to yield an overall habitat assessment score. This average score was then broken into four categories: optimal, with an average score ranging between 16-20, suboptimal, with an average score ranging between 11-15, marginal, with an average score ranging between 6-10, and poor, with an average score ranging between 0-5. Graphs depicting the results from the habitat assessment and the average ranking can be found with each focal area.

Table 3.2 Rapid Bioassessment ranking scale.

Habitat Assessment Ranking	
Optimal	*average score ranges between 16-20*
Suboptimal	*average score ranges between 11-15*
Marginal	*average score ranges between 6-10*
Poor	*average score ranges between 0-5*



WPC

Habitat assessment on Crossfork, Potter County

Present and historic threats to water quality, habitats, and species were also described. Issues that currently are affecting water quality include faulty septic systems, poor condition of dirt and gravel roads, improper agricultural practices (both leading to sedimentation and nitrification/ organic enrichment of streams). Historic threats, which typically include coal mining, shallow gas extraction, and development resulted in several Total Maximum Daily Loads (TMDLs) being created by Pennsylvania Department of Environmental Protection being created. Invasive plant species, as well as potential threats from unconventional gas development, were also noted.

WPC

Heavy truck traffic sign in the Allegheny National Forest.

Water Quality

WPC staff conducted chemical and biological assessments of water quality through in-field and laboratory assessments (Table 3.3). Water quality data was collected quarterly during the months of April, July, October, and January; macroinvertebrates were collected twice a year during spring and fall visits. While winter monitoring was attempted each year, extreme weather and ice build-up during the winter months prevented access to the streams at some sites. Field sampling time averaged 45 minutes per site utilizing at least two trained field staff.

WPC

Water quality in-field analysis on Buffalo Creek, Washington County.

Data results from both in-field collections and laboratory analysis are housed locally at WPC and can be made available upon request. Some results returned from the laboratory were listed as non-detect values. The method described by Croghan and Egeghey to compute values below the limit of detection (LOD) was used to analyze non-detect values by replacing the non-detect value with a number determined by dividing the LOD by the square root of two (2003).

Table 3.3. Water quality monitoring parameters, sampling seasons, and equipment used.

	In-Field Data	Lab Grab Sample	Macroinvertebrates
Monitoring Schedule	Quarterly	Quarterly	Spring and Fall Quarter
Equipment			
Multi-Parameter	pH	pH	Collected according to DEP ICE protocol.
	TDS (Total Dissolved Solids)	TDS (Total Dissolved Solids)	
	Conductivity	Conductivity	
Dissolved Oxygen Meter	Temperature	TSS (Total Suspended Solids)	
	DO (Dissolved Oxygen)	Bromide	
Titration Kit	Alkalinity	Chloride	
Colorimeter	Phosphates	Barium (Ba)	
	Nitrates	Strontium (Sr)	
	Turbidity	Manganese (Mn)	
Flow Meter	Flow		

In-field Chemical Analysis

In-field water quality monitoring was carried out with several different pieces of equipment; all of which were calibrated in accordance to the manufacturer's recommendations. The following are descriptions of the water quality parameters that were recorded in the field:

Flow

- *Stream Flow* is the measurement, reported in gallons per minute (gpm), of the amount of water traveling through the stream channel at any one specific moment. Flow measurements taken at the time of water sample collections are used to support water quality monitoring efforts. Multiple readings over time will allow for the seasonal flow levels to be tracked. The information also allows for loading rates to be calculated for some of the parameters. Natural seasonal variations are expected when monitoring flow. Other factors such as storms, snowmelt, ice, and an overabundance of aquatic plants can affect flow rates during each season. Flow rates often experience dramatic fluctuations based on the aforementioned conditions and can vary greatly over the course of a single season, and from year to year.
- *Turbidity* is an observation of the measure of the relative clarity of water. Turbidity increases as a result of suspended solids in the water that reduce the transmission of light. Soil erosion, waste discharge, urban runoff, or algal growth may cause high turbidity. Water becomes warmer as suspended particles absorb heat from sunlight, resulting in depleted oxygen levels and an environment that is difficult for some species to survive.

Dissolved Oxygen and Water Temperature

- *Water Temperature* influences dissolved oxygen levels, rate of photosynthesis by aquatic plants, metabolic rates of aquatic organisms, and sensitivity of organisms to toxins, parasites, and diseases. Water temperature can be influenced by the amount of vegetative cover along stream banks, sediment levels, and waste distribution into a stream.

- *Dissolved oxygen* concentration in a stream is the mass of the oxygen gas present, in milligrams per liter of water (mg/L). A healthy stream is considered to be 90-100 percent saturated with oxygen and have readings that average around 9.00 mg/L.

pH and Alkalinity

- *pH* is a measurement of how acidic or basic water is. Acidic water (less than 7.0) or basic water (greater than 7.0) has the ability to impair aquatic life. Most aquatic organisms are able to tolerate small fluctuations in this parameter but as a general rule of thumb, a pH of less than 6.0 or greater than 8.0 will affect aquatic communities.
- *Alkalinity* measures the buffering capacity of a stream, referring to how well it can neutralize acidic pollution and resist abrupt changes in pH.

Conductivity and Total Dissolved Solids

- *Conductivity* is a measure of the ability of water to pass an electrical current. Conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows.
- *Total dissolved solids (TDS)* in stream water may consist of calcium, chlorides, nitrate, phosphorus, iron, sulfur, and other particles. If a stream is high in dissolved solids, stream communities may be negatively impacted (high values for this parameter depend on a variety of factors but will typically be over 500 ppm). Elevated levels of these parameters can be an indication of impacts from shale gas drilling. Produced water levels from shale gas drilling have salinity levels that are much higher than surface waters, often exceeding 1,000 mg/L (1,001 ppm) of TDS (Vengosh et al. 2014).

Phosphates and Nitrates

- *Phosphate* is the form of phosphorous that is typically present in natural waters. Organic phosphate is present in living organisms, their waste products, and their remains, as well as human disturbance of the land and its vegetation. Excess phosphate produces algal blooms, which can often lead to eutrophication.
- *Nitrates* are a natural nitrogen compound needed by all living plants and animals to build proteins, but in excess they can cause significant water quality problems. Sewage is the main source of nitrates added by humans to streams; however, fertilizers and agricultural runoff are also significant sources of nitrate pollution. Excess nitrates can cause low levels of dissolved oxygen, and concentrations as high as 10 mg/L can become toxic to warm blooded animals.

Laboratory Chemical Analysis

WPC staff also collected water samples for laboratory analysis. The specific parameters analyzed were those associated with pollution from shale gas development (e.g., barium and strontium) and were analyzed by Environmental Service Laboratories, Inc., a DEP certified lab located in Indiana, Pennsylvania.

WPC

Each site needed three different water samples collected for laboratory analysis.

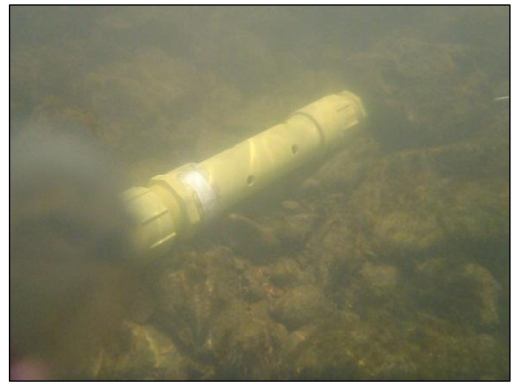
Metals such as barium, strontium and manganese exist naturally in the environment, and therefore, it is not unexpected to have low levels reported in surface waters of Pennsylvania. However, the Marcellus and Utica Shales contain much higher amounts of these metals, particularly barium and strontium, than are found in surface rock – high levels in surface and groundwater are potentially due to the influence of produced water, a byproduct of the drilling and hydraulic fracturing process (Vidic et al. 2013).

- *Barium* may be found in levels averaging 0.043 mg/L in just over 99.4 percent of surface waters (U.S. EPA, 2013). This is a very low level and will be used as a baseline guide when evaluating the results. Barium is one of the metals associated with flowback and produced waters when found in extremely high levels (Vidic et al, 2013).
- *Strontium* may be found in levels averaging 0.06 mg/L in just over 98.6 percent of surfaces waters (Seiler et al, 1994; ATSDR, 2004). Total elemental strontium was quantified by a DEP certified laboratory; analysis of isotopic strontium was not completed.
- *Total Suspended Solids (TSS)* are the visible particles of solid material, organic and inorganic, floating in the water and include, soil, metals, algae, and industrial waste. Too much TSS can affect water quality by absorbing light, consequently warming water and depleting necessary oxygen. These materials can also clog the gills of macroinvertebrates and fish, causing death or limiting the available habitat.

Total elemental barium and strontium were analyzed quarterly at all of the 51 sites that were monitored from 2013-2015. Elevated levels of barium and strontium detected through total elemental analysis cannot be directly associated with unconventional drilling without question but if results show unexpected levels, it is then possible that future sampling could be done to test for isotopic levels for comparison to wastewater geochemical fingerprints, which are associated with unconventional drilling (Capo et al. 2014). The isotopic results can aid in a stronger correlation between stream contamination and unconventional drilling.

Continuous Monitoring

In conjunction with the instantaneous water quality monitoring efforts, we installed continuous data loggers at several aquatic sites during the monitoring period (Table 3.4). Two types of continuous loggers were used; one was a Hobo brand logger that tracks conductivity over a high and low range in addition to water temperature. Partnering with Carnegie Mellon University's CreateLab, we installed a second type of data logger, called the "Flamingo," due to the bright pink reading unit. This field test of the Flamingo was done to aid with the analysis of the continuous data, but more importantly verify reliability of the data collected from the less expensive Flamingo. We analyzed the continuous data results in conjunction with instantaneous field data as well as with other partner logger data when available.



Hobo data logger, newly installed.

Table 3.4. Continuous data logger locations

Site Name	Site ID	Hobo ID	Flamingo ID	Latitude	Longitude	County
McGee Run Trib	MGR1	WPC 3	4	40.38056	-79.25106	Westmoreland
Little Yellow Creek	LYC	WPC 6	6	40.5681	-79.01905	Indiana
Limestone Run	Dunbar-Lime	WPC 1	N/A	39.92812	-79.58669	Fayette
Aunt Clara's Fork	Kings-Low	WPC 5	N/A	40.4278	-8051186	Washington
Buffalo Creek	Buff-Wash-Low	WPC 4	N/A	40.19232	-80.44749	Washington
French Creek	FCRimp	WPC 2	N/A	41.89921	-79.87081	Erie
Buffalo Creek	BuffCk-But-Up	WPC 7	N/A	40.90423	-79.72106	Butler

Macroinvertebrates

Buffalo Creek, Washington County

To assess biological indicators of water quality of streams within our focal areas, we assessed aquatic macroinvertebrates communities at all sites following the DEP In-stream Comprehensive Evaluation (ICE) protocol (PA DEP 2009). Sites selected were wadeable, freestone, riffle-run streams. Sampling consisted of six, one minute kicks from riffle areas throughout a 100-meter reach, using a 500-micron mesh D-frame net, and with each kick disturbing approximately one square meter directly upstream of net. We stored the samples in 70 percent ethanol in the field and transported them back to laboratory for processing. Invertebrate specimens of interest have been preserved in 70 percent ethanol and stored and will be deposited in a professional repository (i.e., Carnegie Museum of Natural History). We sorted, subsampled, and identified all specimens according to ICE protocol. At minimum, we identified all organisms to the family level, with select samples taken to genus or the lowest taxonomic level possible for identification. We identified most specimens in-house; however, we sent a portion of the samples to Clarion University for identification to genus. All results will be made available to partners upon request.

We evaluated the macroinvertebrate communities of each site using a variety of statistical indices. These indices allow for a general assessment of the health of a stream based on the results of the evaluation. When historic data was available from stream sites in the focal areas, we compared these data to evaluate conditions over longer time periods.

The following analyses were used to indicate the quality of aquatic ecosystems.

Shannon-Weiner Diversity Index

The Shannon-Weiner Index measures diversity by evaluating richness (the total number of taxa present) and evenness (distribution of total individuals among taxa). The index considers the abundance of each taxon as a proportion of the population. Summing the proportions of taxa across the population results in a value of diversity (between zero and three for the present study). A higher value indicates a more diverse community. Benthic macroinvertebrate communities are predicted to be more diverse in spring compared to fall.

EPT:D Ratio percent Chironomids

Ephemeroptera, Plecoptera and Tricoptera (EPT), commonly known as mayflies, stoneflies and caddisflies respectively are important indicators for water quality studies (Chessman et al 2007; Gerth and Herlihy 2006; Hewlett 2000). EPT larvae are completely aquatic and sensitive to disturbance and pollution which can impact streams (Hilsenhoff 1988; Barbour et al 1999; McIver and McInnis 2007). Diptera (D), specifically Chironomids, are more commonly known as midge flies and their aquatic larvae are able to withstand varying levels of pollution. The relative amounts of these two groups of insects in a sample can help determine the health or biological integrity of a stream.

Hilsenhoff Biotic Index (B)

The Hilsenhoff Index measures likelihood of organic pollution by assigning a pollution tolerance value to a particular organism or group of organisms (Table 3.5). Tolerance values range from one to ten, with one indicating a low amount of organic pollution. Depending on the abundance of tolerant verses intolerant organisms in a sample (B) will either be driven up or down. Scores can be assessed as follows:

Table 3.5. Hilsenhoff Organic Enrichment Values.

HBI Value	Water Quality	Degree or Organic Pollution
0.00-3.50	Excellent	No apparent organic pollution
3.51-4.50	Very Good	Slight organic pollution
4.51-5.50	Good	Some organic pollution
5.51-6.50	Fair	Fairly significant organic pollution
6.51-7.50	Fairly Poor	Significant organic pollution
7.51-8.50	Poor	Very significant organic pollution
8.51-10.00	Very Poor	Severe organic pollution

Monitoring Efforts and Results

As a result of the studies on monitoring site habitat, chemical and physical water quality, and biotic life including macroinvertebrates, the habitat average reach scores, chemical analysis (barium and strontium), and macroinvertebrate diversity indices provided the most useful descriptors of overall ecological conditions.

The average reach scores resulting from the rapid bioassessments performed annually at each water quality monitoring location ranged between 11.6 and 18.2, falling within optimal and sub-optimal categories (Figure 3.7). The best sites for habitat based on the EPA rapid bioassessment protocol included the Black Moshannon (18.2), Tipton Run (18.0) and sites in the Kettle Creekwatershed and Allegheny National Forest sites (17.8). The assessment categories that had the best scores included channel alteration, most of these sites had very little to none which allowed for a high ranking. Channel flow status also scored well, and this could be related to the high levels of rain in 2013 and 2014 helping to keep the streams full. Most sites that had a lower average reach score had weak riparian buffer and vegetative zones. This is not unexpected because site accessibility factored into the selection of the monitoring locations and accessible sites often included a paralleling road as well as other nearby anthropogenic features such as utility lines, bridges and rail lines which impacted zone widths and conditions. For example the French Creek site FC-SGL144 was not only affected by a township road, it also had a transecting utility line with a right-of-way that was regularly maintained. The monitoring sites are split into sites with no well noted upstream and sites with wells upstream. There appears to be no correlation between average reach habitat scores and presence or absence of unconventional wells (Figure 3.7).

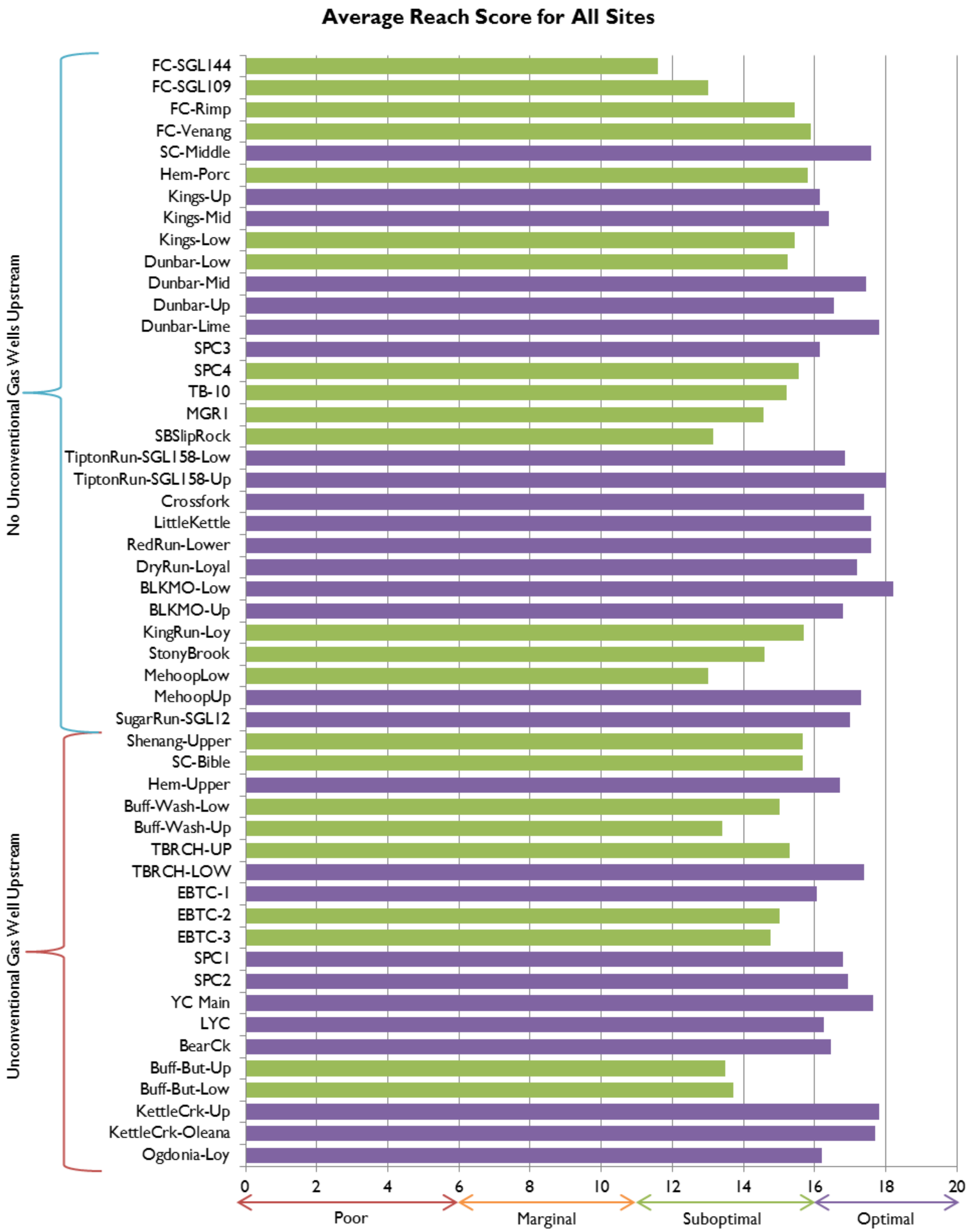


Figure 3.7 Average Reach Scores for water quality monitoring sites.

The information in Table 3.6 lists all water quality monitoring sites and indicates if there are unconventional gas wells upstream from the monitoring site. If the site did have an unconventional gas well upstream the approximate distance was listed. Also listed is whether or not the average results for strontium and barium fell above or below the expected natural occurrence average. The results show that 20 of the 51 sites had at least one unconventional gas well up-stream of the water quality monitoring site (some focal areas contained multiple water quality monitoring sites). Of these 20 there were nine sites that have an above average level of strontium and barium, seven with one or the other of the element levels above natural occurrence, and four with both strontium and barium below the natural occurrence levels. There were 31 sites that had no wells upstream of the monitoring sites. Of these 31 there was one that had above average results for strontium and barium, eight with one or the other of the element levels above natural occurrence, and 22 with both below natural occurrence.

Barium and strontium levels were found to be well below the levels identified in the EPA's safe drinking water standards, as identified in Chapter 93 of the Pennsylvania Code (Commonwealth of Pennsylvania 2013) and none are greater than the upper limits of the range of natural occurrence. Figures 3.8 and 3.9 show the averaged results for barium and strontium respectively over the monitoring period; the sites are grouped into two groups based on presence or absence of upstream shale gas wells. However, in analyzing focal areas with shale gas development versus those without in a test for equal means, we found there to be a significant correlation between mean barium level over the course of the study and presence of shale gas development higher in the watershed ($\bar{x}$ = 0.057 mg/L for focal areas with shale gas drilling, and $\bar{x}$ = 0.0341 mg/L for focal areas without shale gas drilling, p = 0.003). Focal areas with higher average levels of strontium were also those that had shale gas development upstream; however, the results were not significant ($\bar{x}$ = 0.093 mg/L for focal areas with shale gas drilling and $\bar{x}$ = 0.055 for focal areas without shale gas drilling, p = .096).

The implications of these results are unknown. We need to compare the results of our analysis to existing data from the region on barium and strontium and their base level prior to development and to determine whether or not these current levels are within the range of barium and strontium concentrations within the specific watersheds where our higher levels were detected.

Even though there is a correlation between shale gas development activities, the actual source or cause of these levels cannot be determined. There are many reasons for elevated levels of barium and strontium in surface waters, and we cannot conclude that there is pollution from drilling waste or produced water in these focal areas, and not due to some other pollution source, such as historic coal mining or heavy industry; however, this elevates our level of concern over the possibility of a potential pathway for shale gas development waste inputs into high quality aquatic ecosystems.

Table 3.6. List of water quality monitoring sites indicating if unconventional gas wells were up-stream from sampling point and details about average barium and strontium levels at these sites.

Water Monitoring Site ID	Unconventional Gas Well Up-Stream (Yes or No)	Distance if present (miles)	Average Ba concentration (0.043 mg/L)	Average Ba concentration compared to natural occurance	Average Sr concentration (0.06 mg/L)	Average Sr concentration compared to natural occurance
FCSGL144	No	N/A	0.026	Below	0.044	Below
FCSGL109	No	N/A	0.036	Below	0.065	Above
FCRIMP	No	N/A	0.036	Below	0.070	Above
FCVenang	No	N/A	0.030	Below	0.066	Above
SCMiddle	No	N/A	0.027	Below	0.063	Above
HemPorc	No	N/A	0.049	Above	0.032	Below
KINGS-UP	No	N/A	0.035	Below	0.233	Above
KINGS-MID	No	N/A	0.034	Below	0.213	Above
KINGS-LOW	No	N/A	0.034	Below	0.204	Above
DUNBAR-LOWER	No	N/A	0.043	Below	0.055	Below
DUNBAR-MIDDLE	No	N/A	0.040	Below	0.027	Below
DUNBAR-UPPER	No	N/A	0.040	Below	0.024	Below
DUNBAR-LIME-1	No	N/A	0.051	Above	0.020	Below
SPC3	No	N/A	0.037	Below	0.021	Below
SPC4	No	N/A	0.039	Below	0.010	Below
TB10	No	N/A	0.031	Below	0.023	Below
MGR1	No	N/A	0.073	Above	0.033	Below
SBSlipRock-Trib	No	N/A	0.064	Above	0.127	Above
TIPTONRUN-SGL158-LOWER	No	N/A	0.034	Below	0.016	Below
TIPTONRUN-SGL158-UPPER	No	N/A	0.042	Below	0.013	Below
CROSSFORK - Kisik Rod & Gun	No	N/A	0.022	Below	0.018	Below
LITTLEKETTLE	No	N/A	0.027	Below	0.027	Below
REDRUN_Lower	No	N/A	0.036	Below	0.030	Below
DryRun_Loyal	No	N/A	0.027	Below	0.032	Below
BLKMO-LOWER	No	N/A	0.027	Below	0.011	Below
BLKMO-UPPER	No	N/A	0.024	Below	0.007	Below
KingRun_Loyal	No	N/A	0.024	Below	0.027	Below
StonyBrook	No	N/A	0.013	Below	0.010	Below
MehoopLow	No	N/A	0.013	Below	0.010	Below
MehoopUp	No	N/A	0.014	Below	0.009	Below
SUGARRUN-SGL12	No	N/A	0.013	Below	0.029	Below
ShenangoUpper	**Yes**	**4.7**	**0.024**	**Below**	**0.061**	**Above**
SCBIBLE	**Yes**	**0.4**	**0.030**	**Below**	**0.057**	**Below**
HemUpper	**Yes**	**0.6**	**0.049**	**Above**	**0.029**	**Below**
BUFF-WASH-LOW	**Yes**	**2.9**	**0.085**	**Above**	**0.255**	**Above**
BUFF-WASH-UP	**Yes**	**6.3**	**0.087**	**Above**	**0.258**	**Above**
TBRCH-UP	**Yes**	**0.5**	**0.051**	**Above**	**0.028**	**Below**
TBRCH-LOW	**Yes**	**2.9**	**0.044**	**Above**	**0.026**	**Below**
EBTC1	**Yes**	**6.3**	**0.067**	**Above**	**0.066**	**Above**
EBTC2	**Yes**	**2.7**	**0.073**	**Above**	**0.077**	**Above**
EBTC3	**Yes**	**6.2**	**0.093**	**Above**	**0.046**	**Below**
SPC1	**Yes**	**6.3**	**0.045**	**Above**	**0.026**	**Below**
SPC2	**Yes**	**4.9**	**0.047**	**Above**	**0.028**	**Below**
YCMain	**Yes**	**6.6**	**0.067**	**Above**	**0.300**	**Above**
LYC	**Yes**	**6.5**	**0.066**	**Above**	**0.180**	**Above**
BearCk	**Yes**	**9.9**	**0.071**	**Above**	**0.164**	**Above**
BuffCk_But_Upper	**Yes**	**3.7**	**0.120**	**Above**	**0.204**	**Above**
BuffCk_But_Lower	**Yes**	**7.9**	**0.098**	**Above**	**0.148**	**Above**
KETTLECRK-UPPER	**Yes**	**1.0**	**0.011**	**Below**	**0.012**	**Below**
KETTLECK-OLEANA-1	**Yes**	**5.0**	**0.018**	**Below**	**0.020**	**Below**
Ogdonia_Loy	**Yes**	**2.1**	**0.018**	**Below**	**0.024**	**Below**

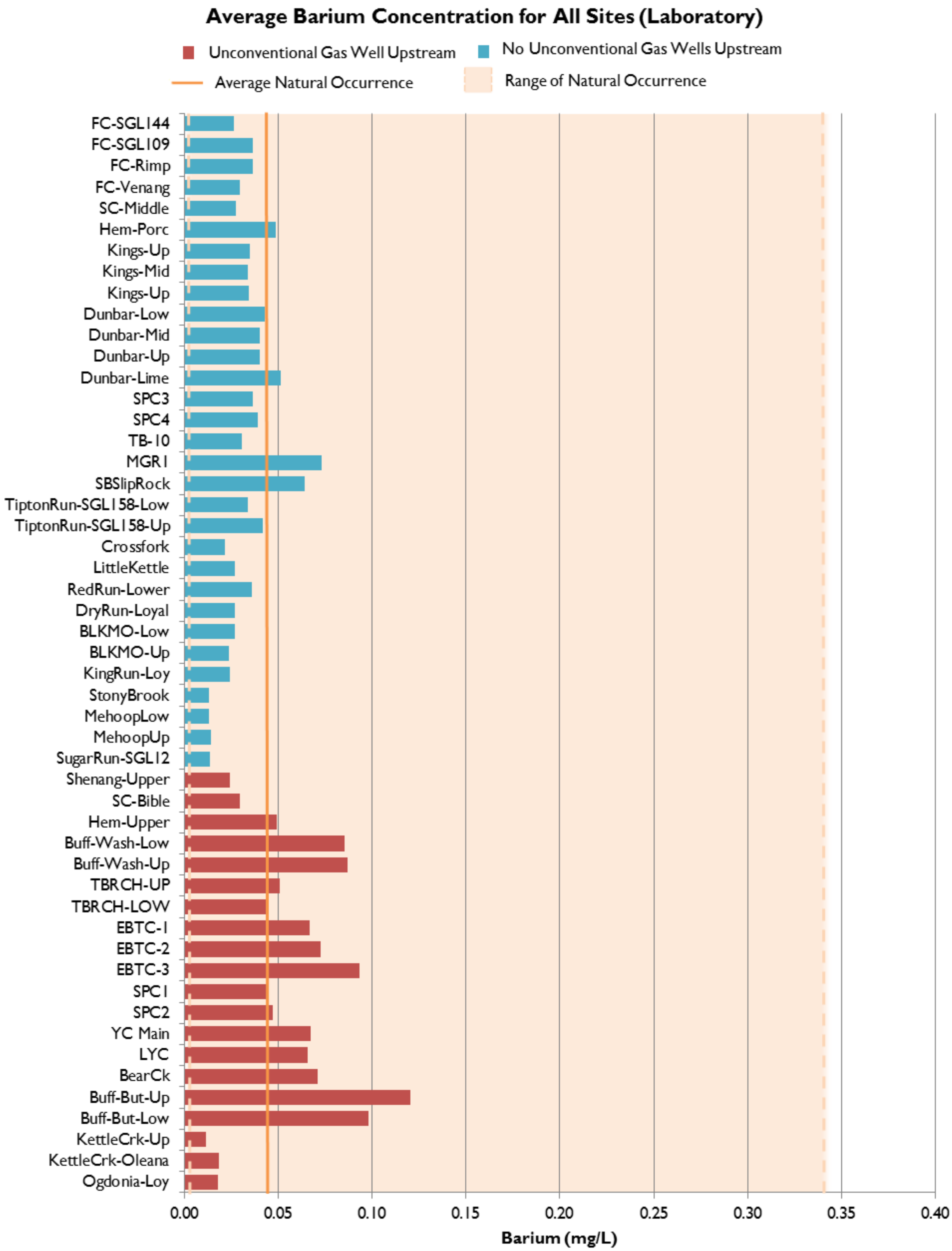


Figure 3.8. Average Barium levels for all sites.

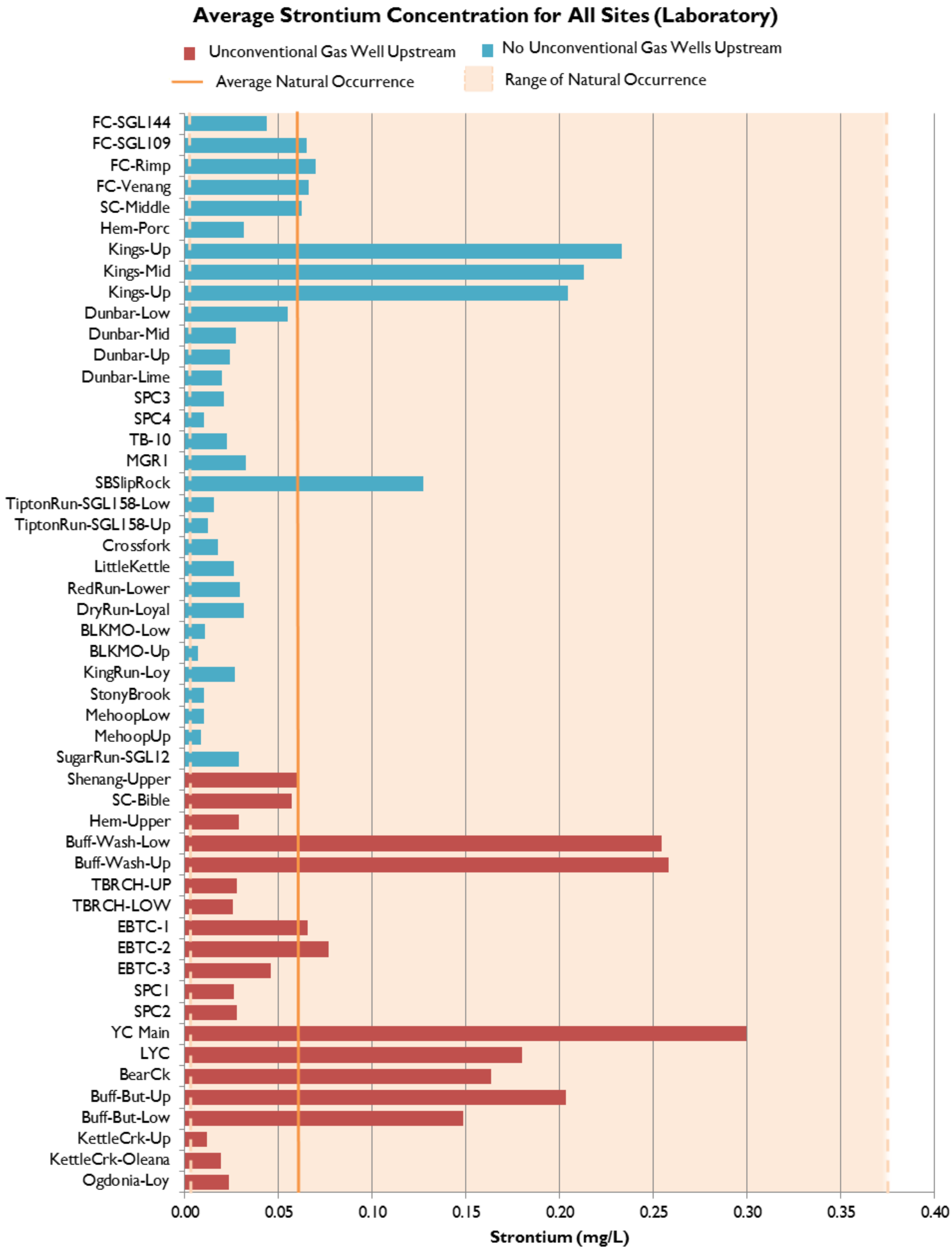


Figure 3.9. Average Strontium levels for all sites

The Pollution Tolerance Index (PTI) measures the likelihood of pollution by assigning a PTI value to an organism or group of organisms. A higher value is associated with a lower pollution tolerance. Summing values for all organisms in a sample yields the PTI score for that sample. A higher score indicates a healthier stream. Scores can be assessed as follows: Poor ≤ 10; Fair 11-16; Good 17-22; Excellent ≥ 23 (Table 3.7). PTI scores for all macroinvertebrate samples were pooled by season (i.e., spring and fall) to identify potential patterns (Figures 3.10 and 3.11) and then shown together (Figure 3.12). A total of 94 sites were sampled in spring and 101 in fall.

Table 3.7. Pollution Tolerance Index

Pollution Tolerance Index Ranking
Excellent ≥ 23
Good 17-22
Fair 11-16
Poor ≤ 10

The resulting PTI indicated the majority of sites as "excellent" (83 percent in spring; 77 percent in fall; 80 percent overall). Most other sites were ranked "good" (13 percent in spring; 21 percent in fall; 17 percent overall). Four sites were ranked "fair," two were located in spring (MehoopLow and StonyBrook) and two in fall (SPC4 and Dunbar-Low). No site was ranked "fair" in more than one sample season. Two sites (FC-SGL144 and BearCk) were ranked "poor" in spring, both of which had less than ten individuals identified from the sample. BearCk was not sampled in spring 2013 but ranked "good" in fall 2013 with only 40 individuals identified and "excellent" in fall 2014 when a sufficient number of individuals were identified. FC-SGL144 was ranked "good" in fall 2013 and excellent for both 2014 samples.

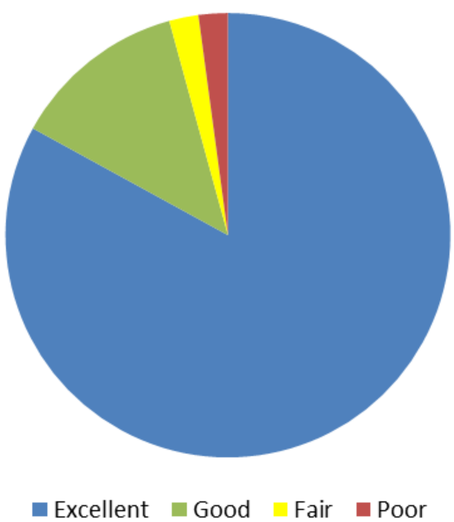


Figure 3.10. Spring PTI scores across all sites.

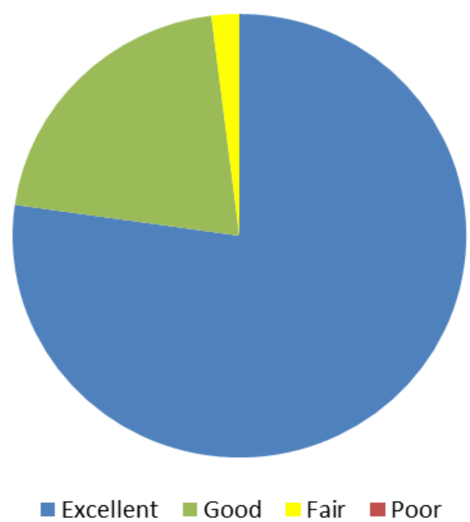


Figure3.11. Fall PTI scores across all sites

BLKMO-Up in the Black Moshannon Creek Focal Area in Blair County was ranked "excellent" in spring 2013 and "good" in all subsequent seasons. Numerical PTI scores for BLKMO-Up generally bordered "good" and "excellent" rankings, contrasting PTI scores for BLKMO-Low, which were all well into the "excellent" range. Higher PTI scores at BLKMO-Low can be attributed to the presence of Aeshnidae and Gomphidae dragonflies and Elmidae and Psephenidae beetles at BLKMO-Low.

Some sites showed greater variation in PTI ranking from one season to the next. MehoopLow and StonyBrook in the Mehoopany Creek Focal Area were both ranked "fair" in spring 2013, "good" in fall 2013, and "excellent' in both 2014 samples. MehoopUp's PTI score bordered the "good"/"excellent" ranking until fall 2014, suggesting this watershed may have been recovering from disturbance during our sampling period. This focal area experienced significant storm damage in 2011 from tropical storm Lee, which caused some of the most severe flooding ever recorded in the area. The storm had a great impact on the landscape of the stream and the species within. As a result, much of the stream habitat was stripped of organic matter and vegetation. The damage is still seen at several sites with large downed trees and flooding debris piled on the floodplain. The absence of shale gas wells upstream of our monitoring points suggests impacts were not from drilling activity. Similar to BLKMO-Low, increasing PTI scores for MehoopLow and StonyBrook also result from increasing abundance of dragonflies, Elmidae and Psephenidae beetles and hellgrammites.

SPC4, in the Spring Creek Focal Area in the Allegheny National Forest, showed variation in PTI scores compared to other sites in the focal area. SPC4 was ranked “fair” in fall 2013, and “good” in both 2014 samples, where all other Spring Creek sites were consistently ranked excellent. SPC4 lacked dragonflies as well as Elmidae and Psephenidae beetles, lowering the PTI for this site.

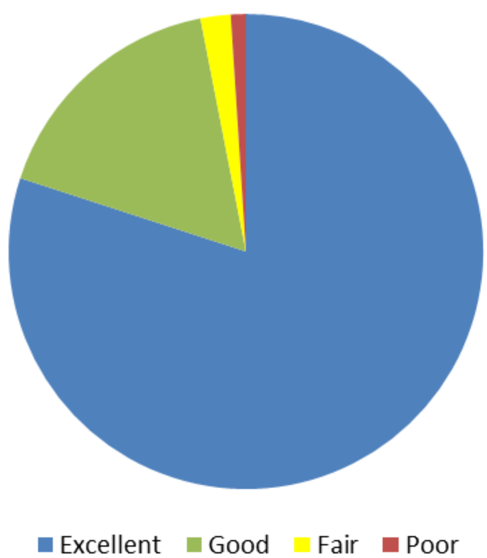


Figure 3.12. PTI scores for all macroinvertebrate samples.

Dunbar-Low shows the most variation in PTI rank among all sites sampled. It was ranked “fair” in fall 2014 after being ranked excellent in all preceding seasons. The most notable driver of this shift is the absence of stoneflies at Dunbar-Low in fall 2014. Compared to other sites, Dunbar-Low was furthest downstream and relatively urbanized. Increasing urban land use often affects biological integrity of a stream (Snyder et. al, 2002). Lack of a forested riparian area and a large flood that occurred in summer 2014 is likely responsible for the absence of stoneflies in the riffle habitats that were sampled, as riffle habitats are heavily impacted by physical disturbance (Roy et. al., 2003). As expected for high quality and exceptional value streams, PTI scores are excellent for most sites. Since legacy effects of disturbance can persist in streams for decades (Maloney et. al., 2008), it is likely that most sites have been free of extensive pollution for some time.

In order to investigate a possible correlation between shale gas development and PTI scores, the sites were sorted into two groups, those that have shale gas wells upstream and those that do not (Figure 3.13). There appears to be no trend between gas well presence and PTI scores. This could be due to all sites having an optimal or sub-optimal score when it comes to the habitat average ranking, and good habitat yields good macroinvertebrate populations.

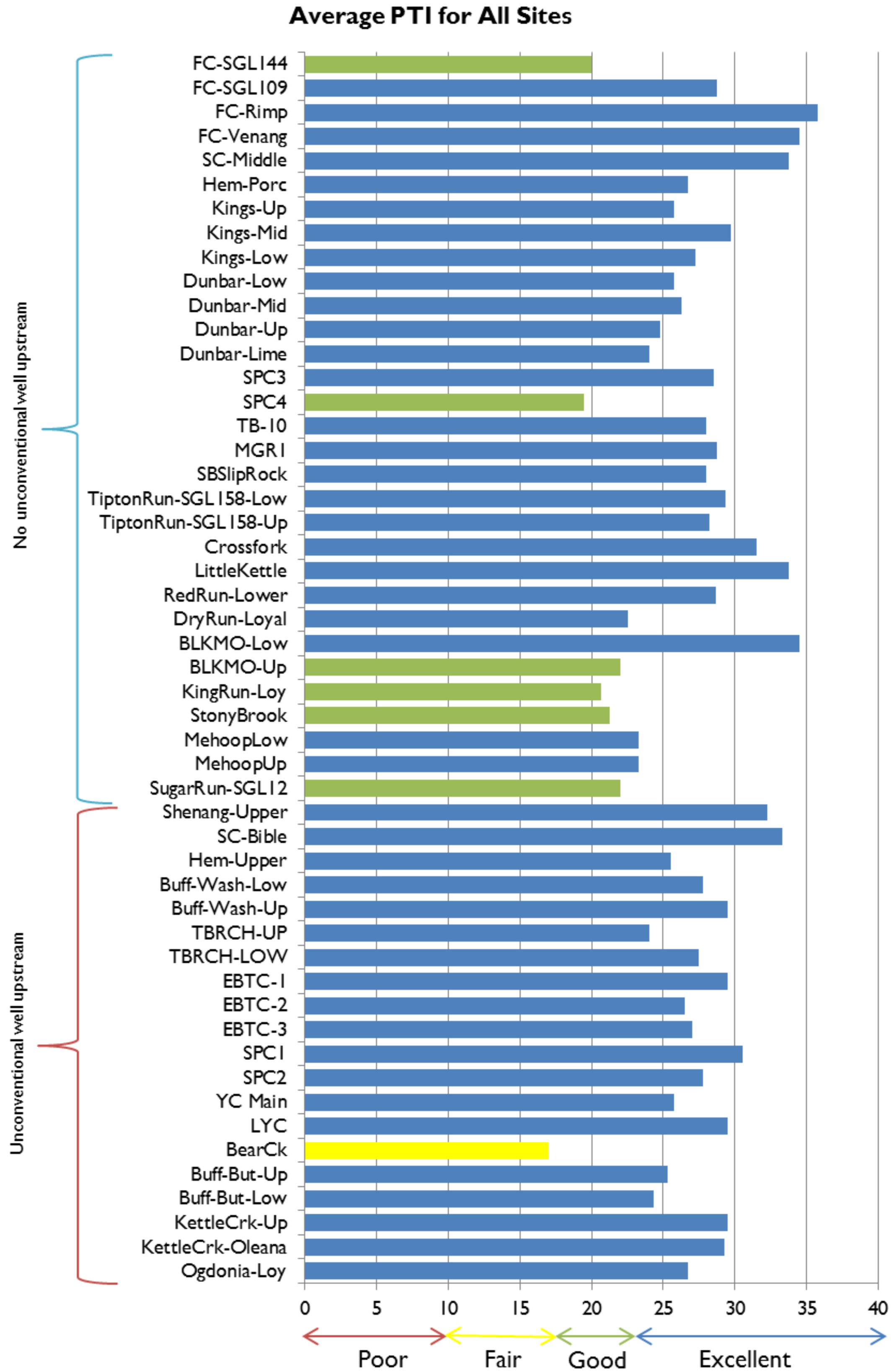


Figure 3.13. Average PTI for all sites sorted by unconventional well presence upstream.

Hilsenhoff (B), a measure of organic pollution in a waterbody was generally low across monitoring sites with few exceptions. Figure 3.14 shows that most sites ranked "very good" (53 percent) or "good" (33 percent) and two sites ranked "excellent" (4 percent). Five sites were ranked "fair" (10 percent), suggesting somewhat significant organic pollution. These include East Branch Tionesta Creek (EBTC3), Christy Run (SBSlipRock) and three French Creek sites (FCSGL144, FCSGL109 and FCRIMP). Sites that were ranked "fair" also had habitat assessment scores in the sub-optimal range which likely contributed to lower water quality.

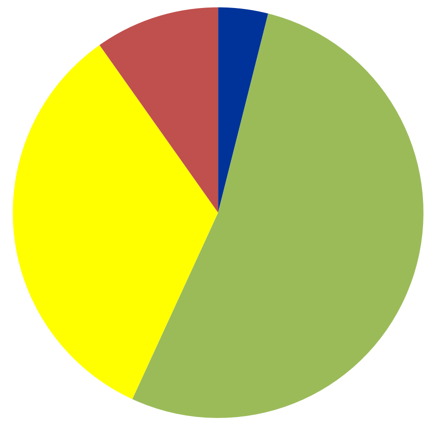
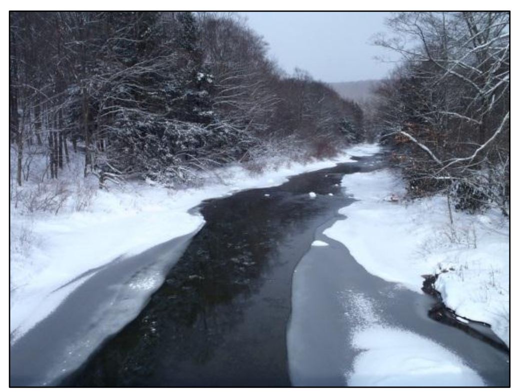


Figure 3.14. Average Hilsenhoff (B) ranking for all 51 sites sampled in the shale gas region from 2013-2014.

Conservation Implications and Future Work

Our baseline of chemical and biological parameters suggested that streams within the focal areas of this study were of relatively high quality. Following two years of study, most sites had expected values when habitat and water quality data were evaluated together; lower scores in indices for aquatic quality, such as the PTI and Hilsenhoff (B) ranks were associated with lower habitat value scores. There were no correlations between water quality indices (e.g., PTI) and the presence of shale gas wells upstream. Combined with site observations, habitat scores, and anecdotal information from our landscape evaluation of focal areas, we believe that historic human development greatly influences the ecological quality of streams in our focal areas, potentially more so than shale development, where it occurred. Recent extreme weather events also contributed to low ecological quality scores, particularly in indices that take diversity and abundance of macroinvertebrates into account. Sites such as our Mehoopany Creek focal area were devastated by catastrophic storm events associated with Hurricane Irene, which scoured the creeks and rivers of the region. This does not exclude shale gas development as a factor in environmental degradation of water quality by any means. Construction of well pads, roads, and pipelines and maintenance of these disturbances are thought to greatly impact water quality at the local level, but clearly, these disturbances are not the only factor. As these disturbance activities increase with increased shale gas development in our focal areas, our results will serve as a baseline for comparison to future values, even in altered landscapes. Our data will provide managers with critical information for management activities to minimize and mitigate impacts from increasing development. Assessment of riparian buffer restoration, improvements in dirt and gravel roads, and best management practices of stream crossings and culverts will all benefit from robust baseline data. We will look to provide our monitoring data to landowners, especially where shale gas development occurs.



WPC

Spring Creek monitoring site in January, Jefferson County.

An interesting finding in our assessment was in regards to certain chemicals detected in laboratory analysis of our quarterly water samples. Our analysis resulted in correlations between strontium and barium and upstream shale gas extraction; the barium values exhibited significant correlation with upstream drilling activities and strontium was positively correlated, but was not significant. Despite the correlations, we cannot be certain that this relationship was due to shale gas extraction. The baseline levels of these two elements in surface water is not known for the sites where our tests were located, and more needs to be done to determine if the sites with higher barium and strontium were due to upstream drilling activities and not simply a function of natural occurrence in surface waters or due to some other human activity, such as aluminum and coal mining, both associated with higher levels of these two elements. Additionally, we found barium and strontium levels higher than the average natural occurrence level in focal areas without upstream drilling activities. Clearly, additional assessment is warranted.

To further investigate this relationship between barium and strontium, and other elements associated with resource extraction, we will need to look to other sources of existing water quality information for streams within or adjacent to focal areas where values were higher than natural averages. Our studies may have been the first to document water quality conditions at these specific locations, and therefore additional assessments, possibly for specific isotopes of barium and strontium associated with the shale may need to be assessed.

For other sites with longer-term monitoring, especially where coal and aluminum mining activities are present, data may be available through DEP or county conservation districts or from local watershed groups. We will reach out to these entities to compare our values with water quality information that may exist, specifically for data taken before shale gas development occurred in Pennsylvania.

Future Assessment

In addition to further analyses of our data taken over the past two years, we recommend continued assessment of water quality and aquatic habitat variables. Future efforts should look to expand our dataset through monitoring in and around existing sites, especially those that are situated downstream of shale gas well pads and pipeline crossings. An additional interesting study would be to place new monitoring sites in areas where our data may be used to determine development thresholds. For example, sites situated in primarily forested areas experiencing heavy development could be instrumental in determining at what point an increased amount of shale development corresponds to greater levels of shale-related pollutants in surface waters. Continued coordination with other conservation organizations, watershed groups, volunteer monitors, and landowners will help to sustain monitoring efforts in high priority watersheds and provide data that can be used to minimize environmental impacts from development activities, including potential impacts of shale gas development.

Conservation Opportunities

A byproduct of our intense water quality assessments was the identification of potential restoration project sites. We noted several sites for riparian buffer restoration while traveling to our sites for water quality monitoring activities. During this project, we identified three sites for stream bank tree planting and utilized riparian restoration funds for implementation. Ten acres of trees were planted at the Rimpa property along French Creek (FC-Rimp site) and two acres of trees were planted along French Creek near Venango, Pennsylvania (FC-Venang site). Additionally, we planted 5.5 acres of trees at the Crossfork site in the Kettle Creek.

Practices to improve the conditions of riparian areas along creeks and rivers in Pennsylvania will work to mitigate potential ecological impacts of shale gas development where it exists upstream. These practices will increase the resiliency of aquatic systems in the face of increased anthropogenic development, in particular from natural gas extraction, as well as other impacts, such as climate change. Our data and observations from field activities in these high ecological value areas will inform conservation prioritization and actions.

WPC

Riparian restoration at the Venango site on French Creek, Erie County.

Forests

Breeding birds are particularly good indicators of anthropogenic impacts due to their dependence on specific habitat types and characteristics. A number of bird species can adapt to human development and habitat conversion, and some even thrive in it – song sparrows, blue jays, and American robins. Other birds are more of habitat generalists, and in Pennsylvania forests there are quite a few species in this category – black-capped chickadees, Carolina wrens, and northern flickers among them. Habitat specialists such as mourning warblers or gray catbirds typically need regular disturbance regimes to maintain their early successional or shrub-dominated habitats. Forest interior-dwelling species of birds (FIDS), which tend to be area-sensitive, requiring large tracts of unfragmented and undeveloped mature forest (i.e., northern hardwoods, dry-oak heath, etc.) at least 100 meters from hard edges like roads, housing developments, well pads, or pipelines.

Black-throated Blue Warbler

WPC

FIDS, which include many Neotropical migrant wood-warblers, thrushes, and vireos, need this core forest to breed successfully and maintain healthy populations. Birds like scarlet tanager, ovenbird, and wood thrush can be susceptible to negative impacts from edge effects. Edge effects are the result of breaking an intact forest and creating a new patch edge. Such impacts include increased nest predation from both avian and mammalian predators, temperature and humidity fluctuations, increased pollution (e.g., noise and trash), increased invasive species, and increased brood parasitism from brown-headed cowbirds (i.e., cowbird females lay their eggs in the nests of other birds leaving the host parents to rear the young and often the young cowbird will either destroy or outcompete the host nestlings).

A number of FIDS are species of conservation concern and are listed as at-risk by agencies and organizations such as Partners in Flight, U.S. Fish and Wildlife Service Birds of Conservation Concern, Pennsylvania State Wildlife Action Plan (SWAP) (PGC-PFBC 2005), and the Pennsylvania Natural Heritage Program. Some forest interior birds have had steep declines in Pennsylvania during recent decades, like eastern whip-poor-will (-42 percent), Kentucky warbler (-29 percent), and cerulean warbler (-7 percent) (Wilson et al. 2012). Other FIDS may not be declining at the state scale, but have continental populations that are at-risk or declining like Canada warbler and wood thrush. Through SWAP efforts some FIDS such as scarlet tanager, worm-eating warbler, and Louisiana waterthrush are identified as Species of Greatest Conservation Need (SGCN), and Responsibility species for Pennsylvania due to the substantial proportion of overall populations found in the state (PGC-PFBC 2005).

Certainly the main cause for concern for these birds is the loss or modification of the forested breeding habitat they need to survive. Increased shale gas development results in direct loss of forest interior habitat (Johnson et al. 2010) and threatens to further fragment Pennsylvania's core forests, resulting in substantial edge effects, which greatly impact the suite of forest birds that call it home.

Methods for Monitoring

Site Selection

We selected 25 sites for bird monitoring from among the focal areas. With the most significant shale gas development impacts for birds and their habitats coming as a result of forest fragmentation and loss, we focused avian monitoring on important areas for FIDS – specifically those that require large patches of mature, intact forest to maintain healthy populations. We used results from the 2nd Atlas of Breeding Birds in Pennsylvania (Wilson et al. 2012), which indicate areas of high FIDS density, to select focal areas among the highest 25 percent in the state, with most ranking among the highest 5-10 percent in the state. Within focal areas, we selected forest interior patches from an analysis of Pennsylvania forest patches (TNC – WPC 2011) as the sampling unit for bird survey sites on the basis of size, accessibility, and suitability to represent focal areas across the shale play.

Point Count Methods

Using selected forest interior patches, we established all survey points at least 250 meters from the forest edge to avoid sampling edge habitat. We used the Geospatial Modeling Environment (GME) suite of tools with R statistical software and ArcGIS to generate independent survey points spaced at a minimum of 250 meters apart to adequately cover each interior forest patch selected within a survey site (Ralph et al. 1993, Ralph et al. 1995, Hamel et al. 1996, Martin et al. 1997, Heckscher 2000, Forcey et al. 2006). We surveyed a total of 446 points during the study, with each site containing 15-20 point locations.


WPC

David Yeany II conducting a bird point count survey.

Point count surveys took place during the height of the avian breeding season in Pennsylvania forests, between 25 May and 15 July (Wilson et al. 2012) in each year of the study, 2013 and 2014. We surveyed each point count location twice during the season to account for intra-season environmental and phonological variability and variation in bird detectability: 25 May – 18 June (early season) and 19 June – 15 July (late season). We conducted surveys during the first five hours after sunrise when detection rates are most stable, generally between 0500 and 1000 EST (Ralph et al. 1993, Ralph et al. 1995, Wilson et al. 2012). At each count, we recorded weather and wind conditions following the Beaufort wind scale and standard weather codes. We avoided during high wind conditions (>12 mph), dense fog, steady drizzle, snow, or prolonged rain (Martin et al. 1997). At the request of cooperating researchers from West Virginia University, we used sound level meters (Extech Instruments 407730) in 2014 to record noise levels in decibels before each point count survey to detect any changes due to shale gas development activities.

Surveys at each point location were 5 minutes in duration, with counts split between an initial 3-minute period and the following 2-minute period. With travel time between point count locations estimated at less than 15 minutes, this count length maximized the number of survey points across the sample area without compromising the quality of data from a single survey point (Ralph et al. 1995). We recorded all birds seen or heard during the count period within three estimated distance bands: 50 meters, 50-100 meters, and beyond 100 meters (Buskirk and McDonald 1995, Ralph et al. 1993, Ralph et al. 1995, Martin et al. 1997, Dettmers et al. 1999, Heckscher 2000) to aide in bird density estimates. For birds observed flying above the canopy or through the habitat, and new species encountered between points, we made separate observations (Ralph et al. 1995). We recorded the presence of singing males from other detections to allow us to make breeding population estimates.

Point count protocols vary considerably in terms of duration and the radius in which birds are counted. The protocol employed here is the one most generally used in recent and current breeding bird studies in the northeast region, accounting for 56 percent of the studies listed for the region in the USGS Bird Point Count Database (USGS 2009).

Vegetation Surveys

During year two of the project (2014), we assessed the habitat conditions, vegetation community type, and local disturbances with significance to birds at each bird survey point following modifications of James and Shugart 1970, Hamel et al. 1996, Martin et al. 1997, and Weber et al. 2006. Vegetation and habitat condition data served the purpose of establishing baselines for tracking plant community and habitat changes over time and aide in the detection of development impacts. We estimated habitat variables for a 25 m radius plot and disturbance for a 50 m radius plot, both centered at each of the 446 point count locations.

At the center of each point count location, we recorded elevation; aspect and slope were measured using Trimble GPS, compass, and clinometer. We classified forest cover according to NatureServe plot sampling categories (Strakosch-Walz 2000): leaf type (broad-leaf, semi-broad-leaf, semi-needle-leaf, needle-leaf, broad-leaf herbaceous, graminoid, pteridophyte), leaf phenology (deciduous, semi-deciduous, evergreen, perennial, annual), and physiognomic type (forest, woodland, sparse woodland, scrub thicket, shrubland, dwarf shrubland, dwarf scrub thicket, sparse dwarf shrubland, herbaceous, non-vascular, sparsely vegetated). We visually estimated total overstory canopy, mid-story canopy, shrub canopy, and herbaceous canopy: percent canopy cover and dominant species (≥ 40 percent cover). Following an assessment of dominant plant species, we assigned each survey point to a plant community type according to Fike (1999) for upland sites and Zimmerman et al. (2012) for wetlands. We used the point centered-quarter method to estimate basal area, stand density, and approximate height for each stand. For basal area and density, we measured diameter at breast height (DBH) and distance to each of the four nearest trees to the plot center. For each point we recorded the height of four dominant tree species, one in each quarter of the plot using a laser range finder. We recorded the number of standing snags and live cavity trees within the 25 meter plot, along with the presence of water and noted the presence of invasive plant species, and if present, we recorded dominant invasive species and estimated percent cover.

We applied a rapid habitat condition assessment to evaluate disturbance type and intensity within the 50 m plot at each point, which used a categorical percent cover (0,<1 percent, 1-5 percent, 6-10 percent, 11-25 percent, 26-50 percent, 51-75 percent, 76-100 percent) for infrastructure (paved roads, unpaved roads, power lines, paved trails), ground disturbance (large ditch, small ditch, grading, equipment tracks), vegetation alteration (pine plantation, recent clearcut, logging within 30 years, mowing, grazing, understory removal, deer browse), garbage, and natural disturbance (recent fire, blow downs, tree disease, tree pest, landslide). We recorded disturbances directly related to shale gas development (well pads, roads, pipelines, seismic survey transects) separately with an estimate of distance from the point count location to activity.

Forest Bird Data Analysis

We assigned each bird species to one of ten habitat guilds based upon known habitat associations: Boreal Forest, Early Successional, Edge Habitat, Emergent Wetland, FIDS (Forest interior-dwelling species), Forest Generalist, Forested Wetland, Generalist, Grassland, and Wetland. We assessed total bird diversity across all sites by habitat guild richness and each site using habitat guild richness, Shannon diversity (*H*'), and evenness (*E*) (Nur et al. 1999). We determined richness as the cumulative number of bird species recorded at each site in each habitat guild. Shannon diversity is an index which accounts for both the number of species and their abundance and is used as a gauge of ecological condition. Evenness is another index which isolates the distribution of abundances across all species at a site (Nur et al. 1999).

We estimated the abundance of bird species at both the habitat guild level and at the individual species level and determined habitat guild abundance as a percentage of the overall abundance or number of detections across sites and within each site. To eliminate variation in observer abilities, double-counting possibilities, and other biases, we only used counts made within 100 meters of each point location for abundance estimates. We estimated mean abundance and density for each survey year and across years for all sites and for each site individually. We based mean abundance on the maximum number of detections for each species per sample unit (i.e., point count area within a 100 meter radius), and averaged them across all survey points at each site. We also calculated bird species detection frequency based on presence/absence across all points at each site within each year.

Monitoring Effort and Results

Bird Diversity

Across all 25 forest and bird monitoring sites, we detected 102 species of breeding birds during 2013 and 2014. The most diverse assemblage was the FIDS habitat guild with 37 species (Figure 3.15). Disturbance-dependent birds of the Early Successional guild and Edge Habitat (also referred to as "synanthropic" or species which breed in and near human development, benefiting from anthropogenic habitat changes) species combined to make up about 22 percent of all detected bird species. Disturbance dependent or adaptive species are indicative of less than pristine and mature forest conditions across our sites.

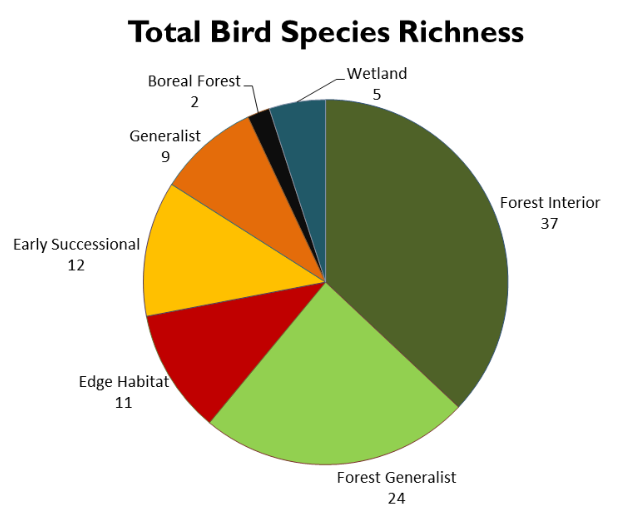


Figure 3.15 Bird species richness by habitat guild across all 25 sites surveyed during 2013 and 2014.

Bird Abundance

Red-eyed vireo was the overall most abundant bird, followed by ovenbird, eastern towhee, scarlet tanager, and black-throated green warbler (Table 3.8). While blue jay, American robin, and indigo bunting were the overall most abundant Edge Habitat species detected. Not surprisingly, the survey sites support a collection of the more common and widespread FIDS; one Early Successional species was also among the five most abundant birds recorded during each year and overall (Table 3.8).

Table 3.8. All bird species recorded during 2013 and 2014 with associated habitat guilds, yearly mean abundance, and conservation status and state Breeding Bird Atlas trend for conservation species.

Common Name	Scientific Name	Habitat Guild	2013 Mean RA	SE	2014 Mean RA	SE	Total Mean RA	SE	Continental	Regional	State	2005 SWAP	PA BBA Trend
Acadian Flycatcher	*Empidonax virescens*	FIDS	0.222	0.024	0.251	0.029	0.237	0.019		PIF, PIF-S		MC	39%
Alder Flycatcher	*Empidonax alnorum*	Forested Wetland	0.002	0.002	0.002	0.002	0.002	0.002				MC	161%
American Crow	*Corvus brachyrhynchos*	Edge Habitat	0.022	0.009	0.025	0.010	0.024	0.007					
American Goldfinch	*Spinus tristis*	Edge Habitat	0.022	0.008	0.013	0.005	0.018	0.005					
American Redstart	*Setophaga ruticilla*	FIDS	0.287	0.028	0.372	0.030	0.330	0.021					
American Robin	*Turdus migratorius*	Edge Habitat	0.269	0.029	0.249	0.025	0.259	0.019					
American Woodcock	*Scolopax minor*	Early Successional	--	--	0.002	0.002	0.001	0.001		SB		MC	-7%
Baltimore Oriole	*Icterus galbula*	Generalist	0.004	0.003	0.018	0.006	0.011	0.004					
Barred Owl	*Strix varia*	FIDS	0.007	0.004	--	--	0.003	0.002					
Black-and-white Warbler	*Mniotilta varia*	FIDS	0.309	0.025	0.379	0.026	0.344	0.018					
Black-billed Cuckoo	*Coccyzus erythropthalmus*	FIDS	0.011	0.005	--	--	0.006	0.003		PIF, PIF-S		MC	5%
Blackburnian Warbler	*Setophaga fusca*	FIDS	0.090	0.017	0.220	0.023	0.155	0.014		PIF		MC	72%
Black-capped Chickadee	*Poecile atricapillus*	Forest Generalist	0.191	0.021	0.132	0.018	0.161	0.014					
Black-throated Blue Warbler	*Setophaga caerulescens*	FIDS	0.415	0.033	0.419	0.032	0.417	0.023				MC	72%
Black-throated Green Warbler	*Setophaga virens*	FIDS	0.666	0.039	0.675	0.037	0.670	0.027				MC	48%
Blue Jay	*Cyanocitta cristata*	Edge Habitat	0.300	0.036	0.274	0.027	0.287	0.022					
Blue-gray Gnatcatcher	*Polioptila caerulea*	Forest Generalist	0.025	0.009	0.013	0.005	0.019	0.005					
Blue-headed Vireo	*Vireo solitarius*	FIDS	0.188	0.024	0.099	0.016	0.143	0.015					
Blue-winged Warbler	*Vermivora cyanoptera*	Early Successional	0.031	0.009	0.009	0.004	0.020	0.005					
Broad-winged Hawk	*Buteo platypterus*	FIDS	0.009	0.004	0.011	0.006	0.010	0.004				MC	-16%
Brown Creeper	*Certhia americana*	FIDS	0.040	0.009	0.036	0.009	0.038	0.006					
Brown Thrasher	*Toxostoma rufum*	Early Successional	0.002	0.002	0.004	0.003	0.003	0.002		PIF, PIF-S		MC	8%
Brown-headed Cowbird	*Molothrus ater*	Edge Habitat	0.036	0.009	0.043	0.010	0.039	0.007					
Canada Goose	*Branta canadensis*	Generalist	--	--	--	--	--	--					
Canada Warbler	*Cardellina canadensis*	FIDS	0.135	0.022	0.157	0.024	0.146	0.016	WL, PIF	FWS, NE, PIF		MC	9%
Carolina Chickadee	*Poecile carolinensis*	Forest Generalist	0.013	0.007	0.025	0.013	0.019	0.007					
Carolina Wren	*Thryothorus ludovicianus*	Forest Generalist	0.007	0.004	0.011	0.006	0.009	0.004					
Cedar Waxwing	*Bombycilla cedrorum*	Forest Generalist	0.191	0.025	0.130	0.018	0.160	0.016					
Cerulean Warbler	*Setophaga cerulea*	FIDS	0.036	0.010	0.027	0.008	0.031	0.007	WL, PIF	FWS, NE, PIF, PIF-S		SGCN, HC-R	-7%
Chestnut-sided Warbler	*Setophaga pensylvanica*	Early Successional	0.283	0.031	0.296	0.030	0.289	0.022					
Chipping Sparrow	*Spizella passerina*	Edge Habitat	0.040	0.010	0.020	0.007	0.030	0.006					
Common Grackle	*Quiscalus quiscula*	Edge Habitat	--	--	0.009	0.006	0.004	0.003					
Common Raven	*Corvus corax*	FIDS	--	--	0.007	0.005	0.003	0.003					
Common Yellowthroat	*Geothlypis trichas*	Early Successional	0.368	0.032	0.383	0.032	0.376	0.023					
Cooper's Hawk	*Accipiter cooperii*	Generalist	0.002	0.002	--	--	0.001	0.001					
Dark-eyed Junco	*Junco hyemalis*	FIDS	0.141	0.021	0.166	0.020	0.154	0.014					

Table 3.8. con't. All bird species recorded during 2013 and 2014 with associated habitat guilds, yearly mean abundance, and conservation status and state Breeding Bird Atlas trend for conservation species.

Common Name	Scientific Name	Habitat Guild	2013 Mean RA	SE	2014 Mean RA	SE	Total Mean RA	SE	Continental	Regional	State	2005 SWAP	PA BBA Trend
Downy Woodpecker	*Picoides pubescens*	Forest Generalist	0.038	0.010	0.027	0.008	0.033	0.006					
Eastern Bluebird	*Sialia sialis*	Forest Generalist	0.002	0.002	--	--	0.001	0.001					
Eastern Kingbird	*Tyrannus tyrannus*	Grassland	0.002	0.002	--	--	0.001	0.001					
Eastern Phoebe	*Sayornis phoebe*	Edge Habitat	0.020	0.009	0.013	0.010	0.017	0.007					
Eastern Screech-Owl	*Megascops asio*	Forest Generalist	--	--	--	--	--	--					
Eastern Towhee	*Pipilo erythrophthalmus*	Early Successional	0.724	0.045	0.776	0.053	0.750	0.035					
Eastern Wood-Pewee	*Contopus virens*	Forest Generalist	0.132	0.016	0.126	0.016	0.129	0.012					
Eastern Whip-poor-will	*Antrostomus vociferus*	FIDS	--	--	--	--	--	--		PIF, PIF-S	PNHP - S3B	MC	-42%
Field Sparrow	*Spizella pusilla*	Early Successional	0.020	0.009	0.011	0.006	0.016	0.005					
Gray Catbird	*Dumetella carolinensis*	Early Successional	0.040	0.011	0.063	0.014	0.052	0.009					
Great Blue Heron	*Ardea herodias*	Wetland	--	--	0.004	0.003	0.002	0.002		WB	PNHP-S3S4B, S4N	MC	27%
Great Horned Owl	*Bubo virginianus*	Forest Generalist	--	--	--	--	--	--					
Great-crested Flycatcher	*Myiarchus crinitus*	Forest Generalist	0.029	0.009	0.013	0.005	0.021	0.005					
Hairy Woodpecker	*Picoides villosus*	FIDS	0.052	0.011	0.096	0.015	0.074	0.009					
Hermit Thrush	*Catharus guttatus*	FIDS	0.085	0.015	0.103	0.015	0.094	0.011					
Hooded Warbler	*Setophaga citrina*	FIDS	0.498	0.037	0.428	0.035	0.463	0.025					
House Wren	*Troglodytes aedon*	Generalist	0.002	0.002	--	--	0.001	0.001					
Indigo Bunting	*Passerina cyanea*	Edge Habitat	0.103	0.015	0.101	0.016	0.102	0.011					
Kentucky Warbler	*Geothlypis formosa*	FIDS	0.034	0.010	0.063	0.011	0.048	0.008	WL, PIF	FWS, PIF, PIF-S		MC	-29%
Least Flycatcher	*Empidonax minimus*	Forest Generalist	0.034	0.009	0.045	0.012	0.039	0.007					
Louisiana Waterthrush	*Parkesia motacilla*	FIDS	0.020	0.007	0.054	0.012	0.037	0.007		NE, PIF, PIF-S		SGCN, R	29%
Magnolia Warbler	*Setophaga magnolia*	FIDS	0.083	0.016	0.103	0.016	0.093	0.011					
Mourning Dove	*Zenaida macroura*	Edge Habitat	0.065	0.013	0.049	0.011	0.057	0.009					
Mourning Warbler	*Geothlypis philadelphia*	Early Successional	0.007	0.004	0.004	0.003	0.006	0.003					
Northern Cardinal	*Cardinalis cardinalis*	Generalist	0.117	0.017	0.110	0.019	0.113	0.013					
Northern Flicker	*Colaptes auratus*	Forest Generalist	0.072	0.013	0.112	0.015	0.092	0.010					
Northern Parula	*Setophaga americana*	FIDS	0.002	0.002	--	--	0.001	0.001					
Northern Waterthrush	*Parkesia noveboracensis*	Forested Wetland	--	--	0.002	0.002	0.001	0.001					
Ovenbird	*Seiurus aurocapilla*	FIDS	1.211	0.048	1.444	0.052	1.327	0.035					
Pileated Woodpecker	*Dryocopus pileatus*	FIDS	0.049	0.010	0.036	0.009	0.043	0.007					
Pine Warbler	*Setophaga pinus*	Forest Generalist	0.004	0.003	--	--	0.002	0.002					
Prairie Warbler	*Setophaga discolor*	Early Successional	0.002	0.002	--	--	0.001	0.001					
Purple Finch	*Haemorhous purpureus*	Boreal Forest	0.002	0.002	0.004	0.003	0.003	0.002					
Purple Martin	*Progne subis*	Generalist	0.004	0.003	0.009	0.004	0.007	0.003					
Red Crossbill	*Loxia curvirostra*	Boreal Forest	--	--	--	--	--	--				PA-VU	83%
Red-bellied Woodpecker	*Melanerpes carolinus*	Forest Generalist	0.070	0.012	0.025	0.007	0.047	0.007					
Red-eyed Vireo	*Vireo olivaceus*	FIDS	1.679	0.059	1.857	0.047	1.768	0.038					
Red-headed Woodpecker	*Melanerpes erythrocephalus*	Grassland	--	--	--	--	--	--	WL, PIF	NE, PIF	PNHP-S3B,S4N	MC	-46%
Red-shouldered Hawk	*Buteo lineatus*	FIDS	0.002	0.002	--	--	0.001	0.001				MC	55%

Table 3.8. con't. All bird species recorded during 2013 and 2014 with associated habitat guilds, yearly mean abundance, and conservation status and state Breeding Bird Atlas trend for conservation species.

Common Name	Scientific Name	Habitat Guild	2013 Mean RA	SE	2014 Mean RA	SE	Total Mean RA	SE	Continental	Regional	State	2005 SWAP	PA BBA Trend
Red-tailed Hawk	*Buteo jamaicensis*	Generalist	--	--	0.004	0.003	0.002	0.002					
Red-winged Blackbird	*Agelaius phoeniceus*	Generalist	--	--	--	--	--	--					
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	Forest Generalist	0.247	0.024	0.307	0.028	0.277	0.018					
Ruby-throated Hummingbird	*Archilochus colubris*	Forest Generalist	0.027	0.008	0.025	0.007	0.026	0.005					
Ruffed Grouse	*Bonasa umbellus*	Early Successional	0.011	0.005	0.009	0.004	0.010	0.003					
Scarlet Tanager	*Piranga olivacea*	FIDS	0.814	0.038	0.596	0.031	0.705	0.025		PIF-S		SGCN, R	6%
Sharp-shinned Hawk	*Accipiter striatus*	FIDS	0.002	0.002	0.002	0.002	0.002	0.002				MC	-20%
Song Sparrow	*Melospiza melodia*	Edge Habitat	0.020	0.007	0.031	0.009	0.026	0.006					
Swainson's Thrush	*Catharus ustulatus*	FIDS	--	--	0.002	0.002	0.001	0.001			PNHP-S2S3B, S5N	PA-VU	128%
Swamp Sparrow	*Melospiza georgiana*	Emergent Wetland	0.009	0.004	0.009	0.005	0.009	0.004					
Tufted Titmouse	*Baeolophus bicolor*	Forest Generalist	0.083	0.014	0.081	0.014	0.082	0.010					
Turkey Vulture	*Cathartes aura*	Generalist	--	--	--	--	--	--					
Veery	*Catharus fuscescens*	FIDS	0.298	0.032	0.408	0.032	0.353	0.023					
Warbling Vireo	*Vireo gilvus*	Forest Generalist	0.004	0.003	--	--	0.002	0.002					
White-breasted Nuthatch	*Sitta carolinensis*	Forest Generalist	0.130	0.017	0.173	0.020	0.151	0.013					
White-eyed Vireo	*Vireo griseus*	Early Successional	--	--	0.002	0.002	0.001	0.001					
Wild Turkey	*Meleagris gallopavo*	Forest Generalist	0.013	0.006	0.007	0.005	0.010	0.004					
Winter Wren	*Troglodytes hiemalis*	FIDS	0.038	0.010	0.029	0.008	0.034	0.006					
Wood Duck	*Aix sponsa*	Wetland	0.002	0.002	0.002	0.002	0.002	0.002					
Wood Thrush	*Hylocichla mustelina*	FIDS	0.469	0.042	0.321	0.030	0.395	0.026	WL, PIF	PIF, PIF-S		SGCN, R	2%
Worm-eating Warbler	*Helmitheros vermivorum*	FIDS	0.002	0.002	0.011	0.005	0.007	0.003	WL, PIF	PIF, PIF-S		SGCN, R	48%
Yellow Warbler	*Setophaga petechia*	Forest Generalist	0.016	0.007	0.004	0.003	0.010	0.004					
Yellow-bellied Sapsucker	*Sphyrapicus varius*	FIDS	0.186	0.025	0.141	0.018	0.164	0.015					
Yellow-billed Cuckoo	*Coccyzus americanus*	Forest Generalist	0.061	0.012	0.043	0.010	0.052	0.008					
Yellow-rumped Warbler	*Setophaga coronata*	FIDS	0.011	0.007	0.002	0.002	0.007	0.004					
Yellow-throated Vireo	*Vireo flavifrons*	FIDS	0.011	0.006	0.004	0.003	0.008	0.003		PIF, PIF-S		MC	44%
Yellow-throated Warbler	*Setophaga dominica*	Forest Generalist	--	--	0.002	0.002	0.001	0.001					

As a measure of forest quality and condition, we compared bird community abundance across sites between forest interior birds (FIDS) and birds associated with disturbance (Edge Habitat and Early Successional). Forest interior birds comprised more than 50% of total bird abundance at all but one site, Lick Run, and more than 70% of total bird abundance at more than half of all sites (Figure 3.16). Conversely, disturbance birds made up more than 25% of total bird abundance at just four sites: Black Moshannon Creek, Spring Creek, Lick Run, and Slate Run – all of which showed higher disturbance levels, prevalent disturbance throughout the site, or very recent disturbance (Figure 3.16).

Forest Disturbance Assessment

As part of our efforts to document baseline forest conditions, we assessed the types of habitat disturbance currently found at each bird survey location. We summarized disturbance into 11 different classes based on the proportion of points impacted by each type (Figure 3.17). Not surprisingly given the history of timber harvesting and the immense forest resources statewide, the *evidence of logging in past*

30 years was the most prevalent disturbance class recorded at 52% of points. The second-most common disturbance type at 30% was the *natural canopy disturbance*, which included naturally occurring blowdowns or canopy loss (i.e., defoliation from frost or pest); disturbance from *invasive plants* and *deer herbivory* were both above 25 % frequency.

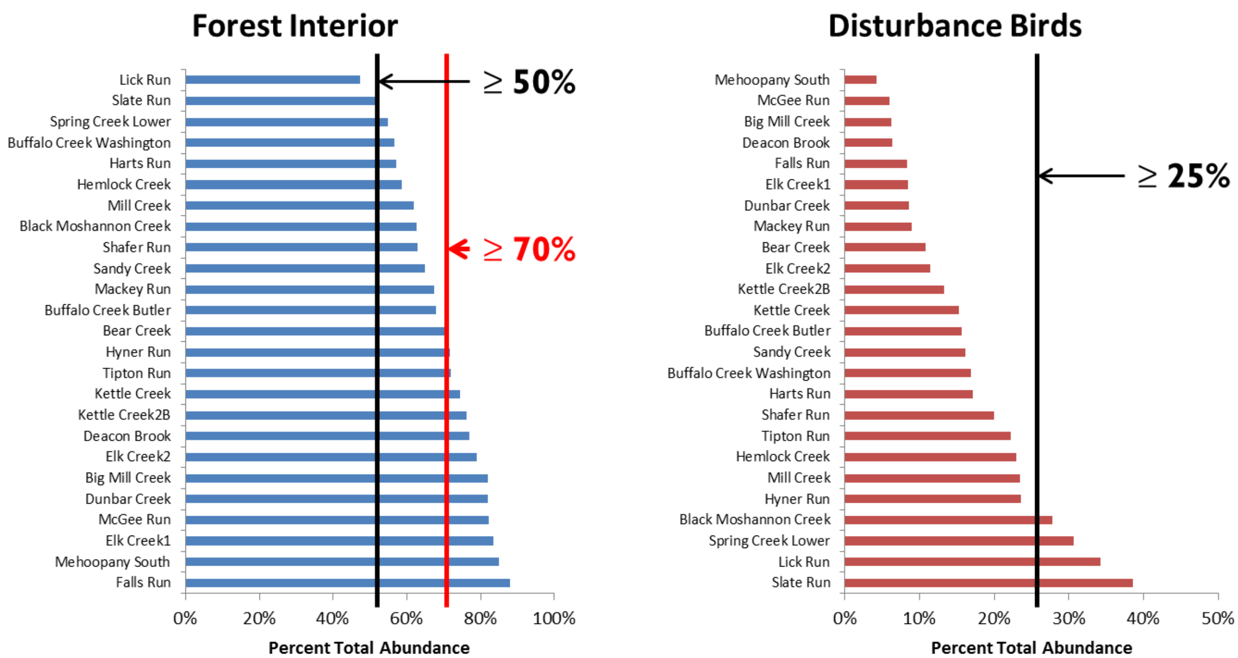


Figure 3.16. Percent total abundance as proportion of total detections by site for forest interior birds (FIDS) and disturbance-associated birds (Edge Habitat and Early Successional).

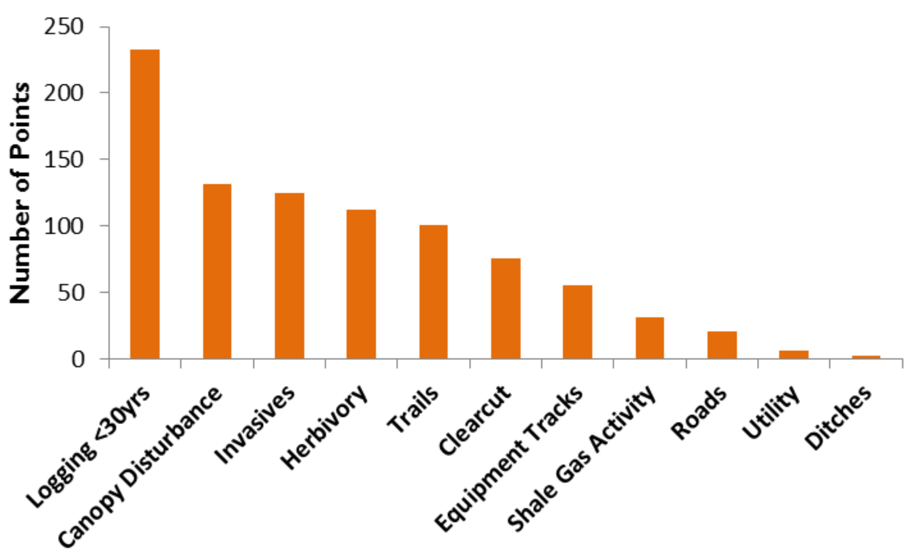


Figure 3.17. Total number of bird survey points where each disturbance type was recorded (n = 444).

Despite the fact that all sites were located in core forest, the presence and prevalence of disturbance across sites indicates that even interior forests which support high percentages of FIDS are in less-than-pristine condition under current disturbance conditions. We used cumulative disturbance, as the sum of disturbance classes per point, to classify points as having a Low level of disturbance (0-3 types) or a High level of disturbance (4-7 types) (Table 3.9). We found that across all forest community types, 41percent of forest bird survey points had a High disturbance level at present conditions.

Bird Species Response to Disturbance

To determine species level responses to base levels of disturbance, we examined relative abundance for 16 individual bird species. These included 15 FIDS that are widely accepted as having strong ties to interior forest conditions and brown-headed cowbird, a nest parasite and Edge Habitat species. We used non-parametric Kruskal-Wallis tests to determine whether mean relative abundance was significantly different for these species between points with High disturbance and points with Low disturbance. There were eight FIDS with higher abundance in Low disturbance conditions and six of these were significantly higher (Figure 3.19). Four remaining FIDS had higher abundance where disturbance was High, but abundances were very similar between Low and High disturbance points and did not differ significantly. Curiously, three FIDS had significantly higher abundance where disturbance was High (Figure 3.19). These three species are often associated with riparian zones and/or eastern hemlock (*Tsuga canadensis*) and the majority of detections for Acadian flycatcher and Louisiana waterthrush were found in the southern survey sites of the highly developed Pittsburgh Low Plateau and Waynesburg Hills. Despite a small sample size for brown-headed cowbird, it was found at a significantly higher density under High disturbance conditions.

Table 3.9. Proportion of bird survey points where each disturbance type was recorded (n = 446).

Disturbance Class	% Total Points
Logging <30yrs	52%
Canopy Disturbance	30%
Invasives	28%
Herbivory	25%
Trails	23%
Clearcut	17%
Equipment Tracks	12%
Shale Gas Activity	***7%***
Roads	5%
Utility	1%
Ditches	0.5%

Natural gas pipeline in Harts Run Focal Area, Greene County, Pennsylvania

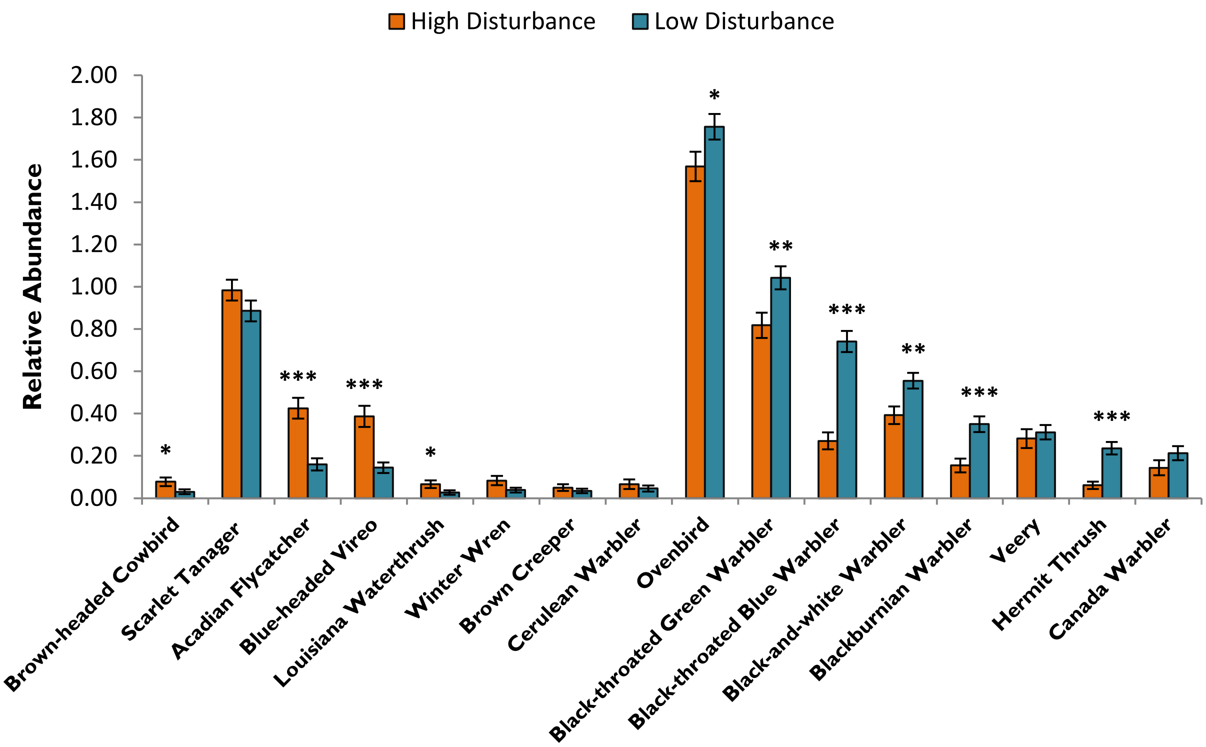


Figure 3.18. Comparison between High and Low disturbance points using mean maximum relative abundance for 15 FIDS widely accepted as having strong relationships with core forest habitat and brown-headed cowbird, a nest parasite and Edge Habitat species used as an indicator of human development (* indicates significant and highly significant differences).

Existing disturbance conditions likely play a role in the density of certain forest interior birds. For species like ovenbird, black-throated blue warbler, or hermit thrush, the cumulative influences of resource development, invasive plants, deer herbivory, and small-scale fragmentation like trails may impact their ability to maintain higher densities. Across our monitoring sites there is a pattern for particular FIDS responding with higher abundance where disturbance levels are Low. Further investigation should involve teasing apart which specific indirect disturbance types are most impactful. There are implications that some FIDS, like the six showing strong positive relationships with Low disturbance, may be better indicators of "*high quality core forest*" and that forest condition, not just distance from habitat edge, may be an important factor. Particular forest interior birds likely have a lower threshold for habitat disturbance and this sensitivity may vary from species to species. Additionally, the higher abundance of brown-headed cowbird with High disturbance levels was supported by field observations and is cause for concern due to their ability to directly impact the reproductive success of forest birds.

Bird Community Response to Disturbance

Just like different species of forest interior birds respond differently to disturbance, bird communities of particular forest types also respond differently. Recent studies demonstrate that one impact of human development on natural communities is biotic homogenization or the process through which assemblages of species that are naturally distinct become more similar to each other. Essentially, there is a loss of biodiversity – unique community structure or composition found in particular habitat types disappears and communities become more alike than they were in the absence of human development. In core forests this may mean that forest interior birds are replaced by disturbance-dependent species or forest interior bird abundance decreases while disturbance bird abundance increases due to newly available habitat.

Following Thomas et al. (2014), one-way Analysis of Similarity (ANOSIM) was conducted using the statistical software program PAST. ANOSIM is a way to measure between group similarity and produces R-values which indicate how similar the community structure is between groups (R=1 completely different, R = 0 completely the same). We used p-values at ≤0.05 to indicate significantly different communities. We compared bird communities consisting of three habitat guilds (FIDS, Early Successional, and Edge Habitat) across survey points in the PA Wilds region (High Plateau, Deep Valleys, and Glaciated Low & High Plateaus, n= 208) looking at differences between 1) northern hardwoods vs. oak forest, 2) High disturbance vs. Low disturbance within northern hardwoods and oak forest, and 3) northern hardwoods vs. oak forest within both High and Low disturbance groups.

Bird communities were significantly different between northern hardwoods and oak forest (*R*=0.346, *P*<0.001), indicating that forest community types likely influence the bird community structure (Figure 3.19). Bird community composition also differed significantly between High disturbance and Low disturbance points within each forest type, but communities were more dissimilar in oak forest (*R*=0.480, *P*=0.002) versus northern hardwoods (*R*=0.195, *P*=0.001). Finally, bird communities were significantly different between northern hardwoods and oak forest across Low disturbance points (*R*=0.437, *P*=0.001), but bird community structure was not significantly different between the two forest types across points with High disturbance (*R*=0.123, *P*=0.082).

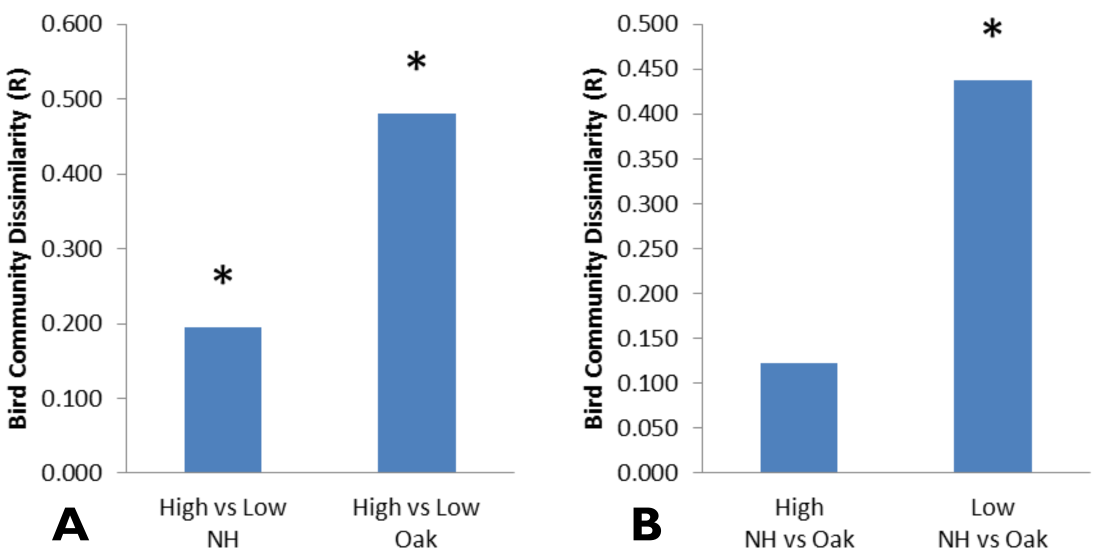


Figure 3.19. Bird community dissimilarity at the point level across monitoring sites located in the PA Wilds during 2013 and 2014; (A) community dissimilarity between High and Low disturbance points within northern hardwoods (NH) and oak forest, and (B) community dissimilarity between northern hardwoods and oak forest across High and Low disturbance points (* indicates significantly different bird communities).

Forest bird community composition differs across regions and between forest types. Disturbance impacts to bird communities appear to be cumulative and differ between northern hardwoods and oak forests, with oak forests potentially showing greater resilience as reflected by higher dissimilarity between bird communities in High and Low disturbance areas. Northern hardwoods forests may be more vulnerable to cumulative disturbance impacts. The ANOSIM results support documentation of biotic homogenization similar to other findings in Pennsylvania with respect to shallow gas well impacts

(Thomas et al. 2014). Our study found a similar result for cumulative disturbance with no significant difference between northern hardwoods and oak forest bird community composition when High disturbance levels were present. Yet where disturbance levels were Low, oak and northern hardwoods bird community structure was very different – indicating more natural differences in composition and diversity.

Conservation Implications and Future Work

The development of the shale gas resources in Pennsylvania has the potential for widespread impacts on both wildlife and habitats. Effects on terrestrial ecosystems include direct habitat loss from well pads and pipelines, forest fragmentation and edge effects, and possible indirect effects of contaminated water resources. Species and natural communities most vulnerable to these impacts are those with high sensitivity to disturbance. In Pennsylvania this is especially concerning because about 59 percent of all shale gas well pads are situated in forested habitat with even more, 68 percent, sited in forests within the north central regions (Brittingham et al. 2014a). (Brittingham et al. 2014b). In our study, 13 of our 25 forest monitoring sites had at least one well pad within 5 km and all but six sites had a well pad within 10 km (Figure 3.20).

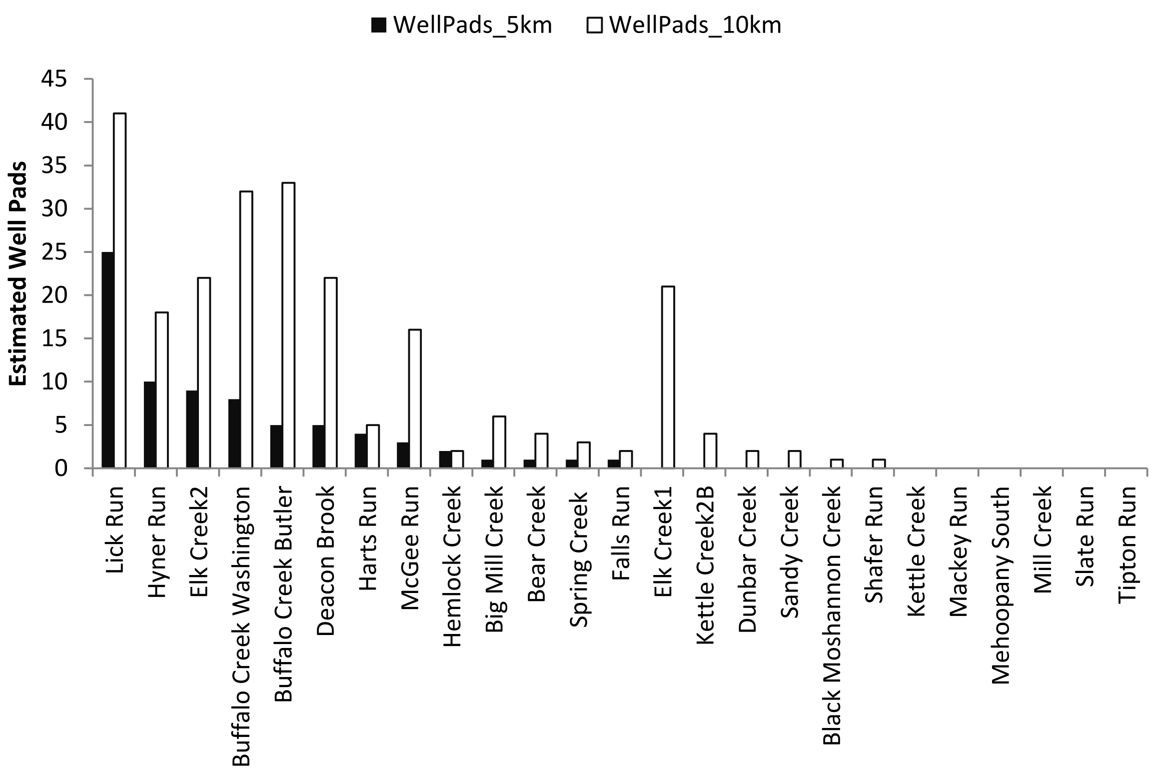


Figure 3.20. Number of shale gas well pads near each forest monitoring site (DEP data, September 2014).

Forest bird and habitat monitoring in 2013 and 2014 served to establish baseline conditions for bird abundance, forest structure, and disturbance at sites of high ecological value. These conditions should be monitored into the future for changes as a result of changing disturbance levels from shale gas or other development. We also established relationships between forest bird communities and current disturbance levels which should function as a way to measure holistic impacts of accumulating disturbance over time.

It should be recognized that both forest conditions and forest bird communities vary by region across Pennsylvania. Going forward, studies should make efforts to stratify results based on physiographic regions and/or forest community types. Different forest communities respond to disturbance and habitat changes in different ways and will subsequently impact their bird communities in different ways. More work is needed to better understand how shale gas impacts may vary across community types.

While long-term monitoring at sites where baselines have been established should be a goal for assessing shale gas impacts, there is also a need for more hypothesis-driven studies which look at direct impacts of well pad and pipeline placement. Unpublished studies have demonstrated that the primary impacts to forest birds at this time appears to occur at the local scale (i.e., at the well pad or pipeline and immediate areas) and not at greater distances (>300m) from development (Brittingham et al. 2014b). Localized impacts include significant declines in forest interior bird abundance and increases in Edge Habitat species, coupled with changes in bird community structure.

Having demonstrated varying levels of disturbance across sites and both forest bird community and FIDS relationships to this disturbance, there are implications for management at these sites, especially with respect to shale gas. Our assessment suggests that higher disturbance levels may negatively impact natural bird community composition and at least some FIDS may have lower densities where disturbance is high. Disturbance types included in our study are similar to those seen during gas development. Increased shale gas activity will lead to increased disturbance levels from many of these factors – recent logging, invasive plants, equipment tracks, trails and roads, etc. Increased disturbance should be minimized in all areas of high ecological value, but especially where a number of these disturbance types already persist to avoid further risk to degrade core forest conditions, reducing breeding densities of FIDS or contributing to homogenizing bird communities.

There are further implications for differing effects of disturbance across forest community types with bird communities of northern hardwoods forest demonstrating greater vulnerability to disturbance. These effects will be difficult to mitigate due to the high percentage of well pads being developed in the north central (PA Wilds) region where northern hardwoods dominate. However, efforts should be made to consider forest community type and condition before new shale gas activities are undertaken at a site. Impacts to forest bird communities may be minimized by avoiding more vulnerable forest community types when possible. We recommend future assessment work investigate direct impacts from well pads and pipelines in areas of high ecological value and include paired study designs that compare adjacent undisturbed habitats.

Rock Outcrops

The green salamander (*Aneides aeneus)* is a medium sized (8-12 cm) Plethodontid salamander with very specific habitat needs. Its geographic range stretches from southern Pennsylvania to northern Alabama. It also can be found in south-central Ohio, eastern Kentucky and Tennessee, to north eastern Georgia. In Pennsylvania, the green salamander is found in Fayette County south of the Youghiogheny River along Chestnut Ridge. The green salamander's preferred habitat is shaded rock outcrops (sandstone, limestone, granite) and trees and logs in humid forests (Gordon 1952). The salamanders can be found seeking refuge in crevices and cracks, and underneath tree bark (Wilson 2003). The crevices it prefers are narrow, shaded, damp, but not wet, and do not vary in temperature (Gordon 1952). The use of trees, fallen logs, and ground environments are lesser known but is reported in literature (Pope 1928, Wilson 2003). It does appear that throughout its range that rock habitats are central to its distribution; recent literature suggests the importance of intact older growth forest areas surrounding the rock habitats.


WPC

Green salamander (*Aneides aeneus)*

Protection of these rock habitats and the forest surrounding them is key to the persistence of the green salamander in Pennsylvania. Quarrying, mining, and oil and gas infrastructure installation has damaged and eliminated rock outcrop habitats in Pennsylvania (R. E. Miller, C. Bier, personal observation). Other activities that are known to have indirect negative effects on the suitability of green salamander habitat that have been observed are the removal of trees and vegetation, road building, poor forest management practices, and recreational rock climbing (Marsh and Beckman, 2004, R. E. Miller personal observation). The removal of trees and vegetation negatively affects the ambient environment of the rock outcrops and surrounding forests. This usually causes warmer and drier environments not suitable to the green salamander.


WPC

Rock outcrop habitat adjacent to a natural gas pipeline, Fayette County, Pennsylvania.

It has been suggested that the green salamander, as well as other terrestrial salamanders, may see significant range reductions with the expansion of shale gas development in the Appalachian Region due to the scattered and isolated nature of their populations (Brand et al. 2014). We believe that in the case of the green salamander, it is particularly true with pipeline development and expansion. Further isolation of these populations due to creation of new pipelines across Chestnut Ridge or, more likely, the expansion of existing pipeline infrastructure could threaten future the viability of green salamander populations through lack of gene flow and inability to recolonize habitats lost to other historic anthropogenic disturbances.

We evaluated the condition of five rock outcrop ecosystems situated near existing natural gas infrastructure known to support populations of green salamanders along Chestnut Ridge between July

2013 and October 2014. In this activity, we inventoried the population through systematic survey of crevices in the sandstone rock outcrops and large woody debris in the immediate vicinity, took measurements of the surrounding forest community composition, condition, and structure, and evaluated the extent of human disturbances to each site within the salamander focal areas.

Methods for Monitoring

During this study we examined five locations with known green salamander populations that were adjacent to gas pipelines. These sites were situated in three focal areas, all on Chestnut Ridge: the Mason Dixon Pipeline Site, running along the Pennsylvania/West Virginia border, the Chestnut Ridge Pipeline, also known as White Rocks, and three within the Dunbar Creek Focal Area, the Texas Eastern Pipeline (Dunbar West Site), Texas Eastern Pipeline (Dunbar East Site), and the third in SGL 51, near a compressor station and smaller mid-stream pipeline (Compressor Gathering Pipeline) (Figure 3.21).

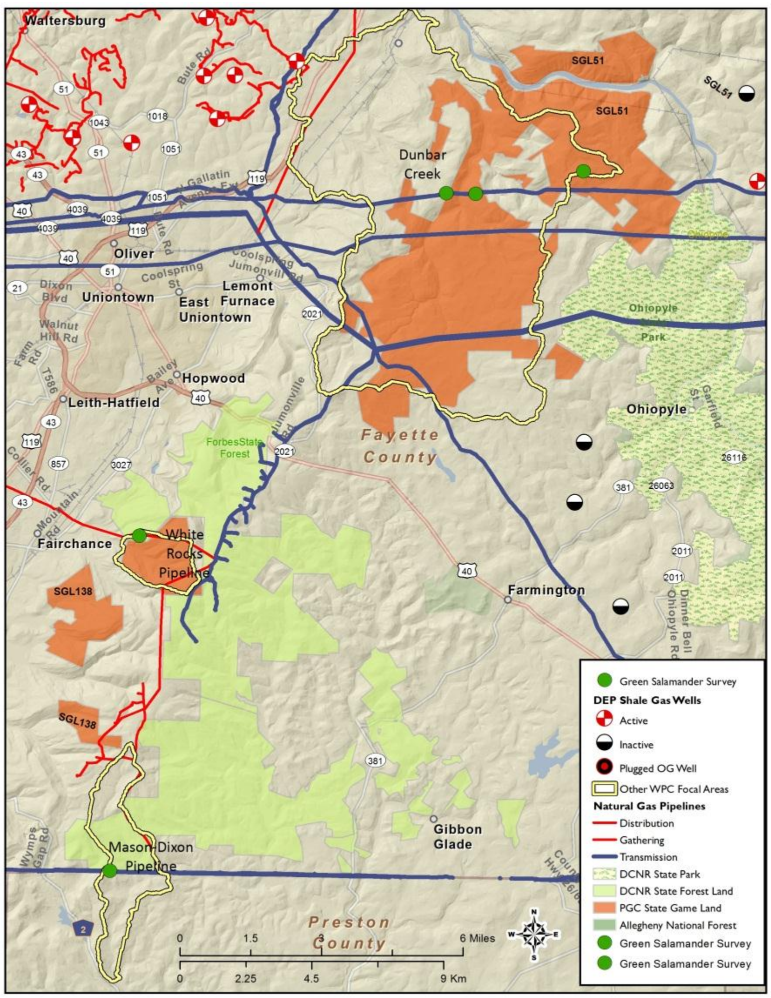


Figure 3.21. Map of green salamander study sites with the Dunbar Creek, White Rocks Pipeline, and Mason-Dixon Pipeline Focal Areas, Fayette County, Pennsylvania.

At each location, we recorded the location and physical and environmental characteristics of the pipelines (width, vegetation characterization), as well as location and physical and environmental characterization of the rock habitats and the forest surrounding the habitats (distance from pipeline, average height of rock habitat, vegetation characterization, forest community type). We used a one hour timed constrained survey to assess the populations of green salamanders in the rock habitats adjacent to the pipelines. The rock faces and crevices were searched with artificial light to locate and count individual green salamanders and their locations were recorded with GPS.

Monitoring Effort and Results

Through this work, we confirmed the presence of green salamanders at all five sites, with occurrences ranging from one salamander observed to multiple individuals in the crevices of the rock outcrops. Overall, the rock outcrop habitat was suitable to excellent for green salamanders at all sites with mosses and lichens covering the rocks, and what appears to be sufficient moisture to support the animals. Historic pipeline construction at four of the five sites surveyed permanently removed or destroyed green salamander habitat. These pipelines were constructed before the green salamander was listed as a state threatened species. In addition to direct impacts of the pipelines, there were a number of indirect effects of the pipeline activity. We noted ATV activity and invasive plants at a number of sites and pipelines and roads have also improved access for recreational rock climbers, who may further disturb green salamander habitat.

The Mason-Dixon, SGL 51 compressor, and Dunbar East and West sites are all directly impacted by pipeline right of ways, which bisect the rock habitats used by the green salamanders. These pipelines essentially cut what once was one contiguous rock habitat into two distinct pieces of habitat with an area of no habitat. At a fifth site (Chestnut Ridge Pipeline) the rock habitat runs parallel to the pipeline and the pipeline only affected the composition of the forest buffer around the rock.

At two of the sites bisected by large pipeline right-of-ways, green salamanders were only detected on one side of the rock formation. At the Dunbar West site, 16 individual green salamanders were found in a one hour survey on the south side of the pipeline; no salamanders were found north of the pipeline, despite having similar habitat and environmental conditions. One plausible explanation for this is that the construction of the pipeline cut the available habitat off from the hibernacula. The existing pipeline could be serving as a migration and dispersal barrier. WPC observed a similar pattern at the Dunbar East site, where one green salamander was detected on the north side of the pipeline and no salamanders were found on the south side of the pipeline. However, because only one salamander was found on this particular survey, it is difficult to draw significant conclusions about disturbance impacts at this site.

At the SGL 51 compressor gathering pipeline, we observed salamanders on both sides of the pipeline. However, this pipeline was the smallest (8.5 meters wide) analyzed in this study. The pipeline also seemed unmaintained with almost complete canopy cover and a thick vegetative layer. In its current state, it is unlikely that it serves as a barrier.

We only found one salamander at the Mason-Dixon site in the one hour survey. Previous surveys in recent years have yielded multiple individuals at this site over a similar amount of effort. It is possible that some of the salamanders had entered hibernation at the time of the survey. One thing that has been constant at this site during this survey and the previous efforts was the distance that the salamanders were detected from the edge of the pipeline. The individual detected during this survey was approximately 30 meters from the pipeline edge during this survey. In previous surveys, green salamanders have been never been detected closer to the pipeline than 30 meters. This could be due to the edge effects (warmer and drier conditions in the edge) and suggests that green salamanders require the cooler, moister conditions of the forest interior.

The Chestnut ridge site does not seem to be directly impacted by the adjacent pipeline. The average estimated distance from the rock habitat to the pipeline is 150 meters. The forest between the pipeline and the rock habitat seems to be mature and healthy enough to provide a buffer from the effects of the disturbed area of the pipeline. Studies have shown that green salamanders will travel as far as 42 meters from the rock habitats and forage in the forest. Since this study focused primarily on the rock habitats for green salamander occupancy, it is unknown if the pipeline corridor has caused any changes to the patterns of forest use of the green salamander at any of the sites.

Conservation Implications and Future Work

Pipeline construction at four of the five sites surveyed permanently removed or destroyed green salamander habitat. These pipelines essentially cut what once was one contiguous rock habitat into two distinct habitat fragments and at two sites, the salamander numbers were markedly different from one side to the other.

One plausible explanation for this is that the construction of the pipeline cut the available habitat off from the hibernacula. The existing pipeline could be serving as a migration and dispersal barrier. While there were not enough populations surveyed to provide a statistically significant result, the size of the pipeline right-of-way and the condition of the forest community surrounding the rock outcrop may be a factor in dispersal ability of a population. At the SGL 51 compressor gathering pipeline site, salamanders were detected on both sides of the pipeline, which was the smallest (8.5 meters wide) analyzed in this study.

Right-of-way management could negatively impact the microclimate of the rock habitats by allowing wind and higher ambient air temperatures to dry the rocks to unsuitable levels. At the SGL 51 compressor gathering pipeline site the pipeline also seemed unmaintained with almost complete canopy cover and a thick vegetative layer. In its current state, it is unlikely that it serves as a barrier. Co-location of pipelines, a best management practice recommended by many land management agencies and conservation organizations (see DCNR, TNC, etc.), may actually result in more loss of salamander habitat than just the right-of-way itself due to creation of larger barriers or further disturbance of outcrop habitat. These findings also suggest that pipeline development impacts may be minimized through proper right-of-way management. Alternatively, if the vegetation were to be killed or removed (through herbicide spraying or mowing), it is likely that these right-of-ways would serve as a barrier.

The condition of the surrounding forest buffers around the rock outcrops is also important to salamander populations. Multiple years of study at the Mason-Dixon suggest that fragmentation/edge greatly affects the green salamander. Individuals detected during this survey and previous studies (including PNHP 2012) were found greater than 30 meters from the pipeline edge, even when available habitat was present. Again, this could be due to the area of disturbance negatively impacting the microclimates of the rock habitats, causing them to be warmer and drier than what is preferred by the green salamander.

This is further supported by the results at the Chestnut Ridge site, in which the population on the rock outcrop does not seem to be directly impacted by the adjacent pipeline, approximately 150 meters from the rock outcrop. At this site, the forest between the pipeline and the rock habitat seems to be mature and healthy enough to provide a buffer from the effects of the disturbed area of the pipeline.

Studies have shown that green salamanders will travel as far as 42 meters from the rock habitats and forage in the forest. Since this study only surveyed the rock habitats for occupancy it is unknown if the pipeline corridor has caused any changes to the patterns of forest use of the green salamander at any of the sites; however, the results of this study suggest that habitat disturbances from pipelines can negatively impact the green salamander and its habitat.

The greatest conservation strategy to avoid these impacts to this sensitive species would be to avoid constructing pipelines through green salamander habitat. A buffer of at least 100 meters should also be employed to make sure that forests surrounding the habitat remain intact (Petranka 1998). Intact forest buffers will maintain the microclimates suitable to the green salamanders and should provide enough area for dispersal and forest foraging.

The results of this work suggest that the size of the fragmenting feature and perhaps the management of the pipeline right-of-way may be influencing dispersal and movement within green salamander populations. Longer term monitoring and studies to determine patterns of salamander use of forests surrounding the rock outcrop will help determine how fragmentation impacts the green salamander and green salamander requirements of forest buffers.

Certainly, avoiding construction of new pipelines through green salamander habitat would reduce impacts; however with the expansion of natural gas drilling and pipeline development in the Appalachians, this may not be possible. For existing pipelines bisecting rock outcrop habitat, landowners should work to maintain closed canopy forest as much as possible; project developers and pipeline right-of-way maintenance plans should allow for buildup of coarse woody debris and growth of native shrubs and small trees on the corridor, especially at critical areas between rock outcrops supporting green salamanders.

Rare and Important Species

We obtained information on rare plants, animals, and natural communities from the Pennsylvania Natural Heritage Program (PNHP) to identify occurrences of rare species in the focal areas. Many of these species are subject to environmental review via the Pennsylvania Natural Diversity Inventory (PNDI) tool. Following this, we conducted targeted surveys for important plant and wildlife species within the 35 focal areas that are considered species of special concern or that we identified as species potentially threatened by shale (or pipeline) development. In particular, we focused our efforts in and nearby stream and forest assessments sites within the focal areas and used specific surveys to obtain quantitative population and habitat data for these specific targets:

- Riparian plants
- Fish species, specifically brook trout (*Salvelinus fontinalis*)
- Streamside salamanders
- Eastern hellbender (*Cryptobranchus alleganiensis alleganiensis*)
- Freshwater mussels
- American water shrew (*Sorex palustris*) and other small mammals of riparian habitats

These data serve as valuable baseline information to assess future impacts from development.

In addition, we conducted general surveys following PNHP standard inventory methodology. For all rare species, information on the location, associated species, and condition of the habitat were submitted to the PNHP program for inclusion in the Pennsylvania Natural Diversity Inventory.

Our approach and findings are presented below for each one of the species groups above.

Pennsylvania Natural Heritage Program Database Assessment

A Natural Heritage Area (NHA) is an area containing one or more plant or animal species of concern at state or federal levels, exemplary natural communities, or exceptional native biological diversity. NHAs include both the immediate habitat and surrounding lands important in the support of these elements. They are mapped according to their sensitivity to human activities, with designations of Core Habitat and Supporting Landscape areas:

- Core Habitat – areas representing critical habitat that cannot absorb significant levels of activity without substantial negative impacts to elements of concern.
- Supporting Landscape – areas directly connected to Core Habitat that maintain vital ecological processes and/or secondary habitat that may be able to withstand some lower level of activity without substantial negative impacts to elements of concern.

The sensitivity of each designation varies significantly according to the particular plant, animal, or natural community habitat that the area represents and is discussed in detail in each NHA's Site Description available on the PNHP website (http://naturalheritage.state.pa.us/). In order to assess the potential impact of shale gas development on these sites, we intersected in GIS existing NHAs with the shale gas region.

We queried the PNHP database, selecting (based on standard PNHP methodology) all tracked species and natural community element occurrences that are considered extant and have been observed since 1985. We created summaries of the number of occurrences and species for both for the shale region and the whole state.

Data obtained on species of concern and natural communities during the field work of this monitoring project were combined with existing data to create and/or update NHAs within the region.

Methods and Results

A majority of Pennsylvania's critical habitats for rare and important plant and wildlife species fall within the Shale Region. The Pennsylvania Natural Heritage Program (PNHP) calculated that over 45percent of the areas identified as Core Natural Heritage Areas in County Natural Heritage Inventories are found within the region of Pennsylvania underlain by the Utica and Marcellus Shale formations, the primary targets for deep gas extraction in Pennsylvania (Table X).

Further analysis of PNHP's rare species data indicates that 724 species tracked by PNHP and approximately 62 percent of all species occurrences in the state are found within the combined Marcellus and Utica regions (Table 3.9); 346 of these species have more than 70 percent of their occurrences in the shale gas region.

A total of 284 species of special concern are found in our 35 focal areas; there are 713 total occurrences within the focal areas. Only the Big Mill Creek Focal Area, an intact forest patch in the Allegheny National Forest in Elk County, did not have any occurrences of rare species.

Table 3.9. Species of Special Concern from the Pennsylvania Natural Diversity Inventory within the Shale Region of Pennsylvania

	Shale Region	State	Focal Areas	%
Species/Natural Communities	724	1165	284	62%
Element Occurrences	5996	13424	713	45%

The data in this report represents a snapshot of the region's natural resources at the time the report was written. Many potential high quality natural habitats in the region have never been surveyed for species of concern, or may have been visited in a season not conducive to the documentation of the species present. Any further work in the area could yield additional records of species of concern while future land use changes may result in the extirpation of species documented in this report. This is partially due to the fact that natural systems are dynamic and constantly changing due to natural and human induced pressures. Additional survey efforts are encouraged for these reasons. PNHP sees this report as a working document that can and should be updated as new information is available.

Riparian Vegetation

The riparian zone, especially those associated with headwater streams, provides important ecological functions that influence the overall health of a river system. This zone serves to trap and retain upland pollutants, nutrients, and sediments from entering the aquatic environment. Healthy, native riparian vegetation provides shading which helps maintain the typically cold temperatures of headwater streams. Native vegetation also stabilizes the streambank and reduces erosion. Riparian plant litter and woody debris supply nutrients to the aquatic food chain and contribute to instream habitat and structure. Alterations to the vegetation of the riparian zone may result in degraded water and habitat quality of a river system.

Disturbance is a natural process within the riparian zone that can greatly impact the plant community. Due to the close proximity to flowing water, this zone is prone to overbank flooding. Short-term inundation, flow stress, and sedimentation are the main impacts, but plant communities within this zone tend to be well adapted to the flood disturbance regime and are likely able to withstand these periodic events. However, anthropogenic disturbance differs from flooding and usually involves changes in specific water table features or has damaging effects on specific plants (Winward 2000) that, in turn, can impact plant community composition.

Given the ecological importance of the riparian zone and its potential susceptibility to watershed level changes due to anthropogenic disturbance such as shale gas extraction, we implemented a monitoring protocol for riparian vegetation to document the quality of the plant communities of riparian areas in the focal areas.

Activities such as water withdrawal, fragmentation, and construction of infrastructure, as well as new inputs to streams may impact plants found at the aquatic/terrestrial transition. Invasive plant species are a direct result of human disturbance. The purpose of riparian plant monitoring is to document current conditions of the riparian zones of streams in the focal areas and to lay the groundwork to monitor short- and long-term changes in the composition of these communities. Data collected are available for adaptive management activities to limit impacts associated with development activities of all kinds, including, but not limited to shale gas resources.

Methods for Monitoring

We focused plant monitoring on sections of the streams with concurrent water quality sampling. Riparian vegetation data was collected at 22 focal areas. One to three transects were recorded at separate locations within most focal areas, although more transects were recorded in a few larger areas.

We chose riparian vegetation sampling points along stream reaches that represented the vegetation within focal areas and could serve as good reference points for ongoing monitoring efforts. The goal was to document baseline conditions that could be compared to the findings of future monitoring efforts in order to examine potential changes in riparian zones, such as changes in plant composition and introduction of invasive species, which may be attributed to human disturbance, including development activities associated with shale gas extraction.


WPC

Vegetation surveys along Little Yellow Creek, Yellow Creek Focal Area, Indiana County.

We implemented a transect sampling approach during the summer field season (June – August) in 2013 to characterize the current plant communities and condition of the riparian zone of representative stream reaches in the focal areas, near where water quality monitoring was taking place. Applying methods similar to those implemented in a riparian community characterization project funded by the EPA and Pennsylvania DEP and DCNR, we established a transect line at each site perpendicular to the stream and recorded plant species and ecosystem variables in each zone of the riparian area along the transect. High water marks, where the vegetation transitioned to upland vegetation, bounded the transects on either side of the creek. We visually delineated zones of the riparian zone into sections along the transect that represented the different communities found on each bank and recorded the coordinates of the stream center and both ends of the transect with a GPS unit. From stream center, we took photographs of upstream and downstream and the left and right banks along the transect.

Along each transect, we collected the following information: general site information, plant species composition and community structure for each bank, and lastly, the upland community associated with each bank. Specifically, data included the following:

- Species richness and cover, as well as descriptors of the environmental setting including soil, unvegetated surface characteristics, and flooding regime
- General site information included identifier details such as site name (watershed) and location (stream name and county), transect ID, directions to site, survey date with start and end times, the name of surveys, and details about photographs taken. The GPS locations and associated units and accuracy of the stream center and transect end points were also recorded in this section. In addition, we recorded specific indicators of human disturbance, including invasive plant species
- Riparian vegetation community composition and structure data organized into right bank communities and left bank communities to account for differences in characteristics/composition between banks. We identified community zones and noted their physiographic setting within the riparian zone (e.g., low terrace) and the topographic position, aspect, and slope were recorded along with width and distance from stream edge (recorded in meters using a meter tape). We dug a shallow pit to characterize the soil within each community type and recorded the following soil variables: soil moisture regime, soil drainage, soil pH (using a rapid pH field kit), average texture, and stoniness. Other community related-variables were hydrologic regime, percent unvegetated surface, and overall vegetation height range and cover estimates by stratum. In addition to community characteristics, we recorded all plant species within the community, by canopy stratum (overstory, understory, tall shrub, short shrub, and herbaceous), and assigned each species to a relative cover class category. We compiled a list of dominant plant species and their abundance and classified the community in the appropriate category based on Pennsylvania's plant community classification (Zimmerman et al. 2012).
- Upland communities by recording vegetation characteristics, elevation, aspect, and slope at a point located at least 20 m beyond the riparian zone (documented using GPS location). Specific community characteristics included leaf type (broad leaf/needle leaf) and physiognomic class (forest, shrubland, grassland/herbaceous).

Monitoring Effort and Results

Plants occurring in the riparian zones of assessed streams were those typical of river floodplains and headwater streams of their region. Floodplains along, as expected, exhibited characteristics of floodplain communities described in Terrestrial and Palustrine Plant Communities of Pennsylvania (Zimmerman et al. 2012).

In a large proportion of the focal areas, invasive species threaten to further impair the ecological value of riparian areas for native plant and animal species.

A third of the transects (13) already have invasive populations established; a third (13) have pioneer individuals present, but no established populations yet; and a third (13) have no invasive species documented at the transect. In slightly more than half of the cases where multiple transects were collected in a single focal area (7), the transects had the same level of invasive species present; in 6 cases, the transects within the same focal area had different levels of invasive establishment. For Dunbar Creek, Dry Run, and Slate/Red Run, the transects lower in the watershed had more invasive plants, while those higher in the watershed had fewer. Sandy Creek and French Creek are large focal areas in highly fragmented landscapes, and invasive establishment did not correlate with position in the watershed.

Conservation Implications and Future Work

Invasive plants are capable of displacing native plants from natural communities, especially those with rare, vulnerable, or limited populations. This initial impact is worsened by the tendency for native wildlife to prefer native species over invasive species for food. In some cases, a switch to the invasive plant food supply may affect the physiology of the prey species. For example, many invasive shrubs, such as non-native bush honeysuckles (*Lonicera* spp.), provide fruits that native birds find attractive, yet these fruits do not provide the nutrition and high-fat content the birds need in their diets (Swearingen et al. 2002).

Aggressive invasive plants can also transform a diverse small-scale ecosystem, such as a wetland or meadow, into a monoculture of a single species, drastically reducing the overall plant richness of an area and limiting its ecological value. The decrease in plant biodiversity can, in turn, impact the mammals, birds, and insects in an area, as the invasive plants do not provide the same food and cover value as the natural native plant species (Swearingen et al. 2002).

Invasive plant species occurrences are thought to increase with forest loss from development and widespread conversion of interior forest to edge habitat as a result of construction of shale gas infrastructure. Additionally, new invasive species may be introduced, further degrading natural habitat and displacing native species. This continuous threat requires active management to prevent the spread of invasive species into areas of high ecological value and must be addressed for any successful restoration project.

Future work should focus directly on identifying sensitive areas within riparian corridors, such as seeps, high quality interior forest patches, and biologically diverse forest and wetlands within the headwater areas of high value ecological areas where shale development is probable. For all shale gas development activities, a restoration plan should be developed, complete with the long-term desired condition for the landscape and site (PA DCNR 2011). The goal is that the sites will be restored to a point in which, over time and through natural succession, the sites will reflect the natural conditions of the surrounding area.

Prevention or control of invasive plant species during the early stages of an infestation is the best strategy and should be a part of any restoration plan. In areas where invasive plants are well established, multiple control strategies and follow-up treatments may be necessary. After the infestation has been eliminated, regular maintenance of the site to prevent a new infestation may also be needed. Specific treatment depends on the target species' biological characteristics and population size. Invasive plants can be controlled using biological, mechanical, and/or chemical methods.

Fish

Pennsylvania has an extremely diverse fish community represented by 141 taxa living in lentic (lakes, ponds, and manmade impoundments) as well as lotic (1st thru 8th order rivers and streams) environments (PFBC 2002). The collection and identification of fish species and communities is an important component of fisheries management that PFBC has actively been completing since its inception in 1866. Recently, PFBC efforts have focused on attempting to survey all 137,767 km (85,623 miles) of streams found in the commonwealth to document fish species and communities.

As a result, the Unassessed Waters program was established in 2010 to allow professional fisheries researchers to work as contractors for PFBC to collect more baseline data of streams that have never been surveyed. We have been an active partner in the Unassessed Waters (UA) program of the PFBC since 2011. This work is focused on surveying all of the streams found in Pennsylvania for native brook trout, wild brown trout, and wild rainbow trout utilizing backpack electrofishing equipment. By identifying streams that contain naturally reproducing trout, the streams are afforded additional protection through Chapter 93 of the DEP regulations and PFBC.

Monitoring Methods

We conducted fish surveys using the PFBC's Unassessed Waters protocol (PFBC, 2011). This survey methodology utilizes single pass electrofishing, which is an effective sampling tool for quickly gathering data about presence or absence of fish species while allowing researchers to sample numerous streams in a given day (Meador et al. 2003). All fish surveys we completed were 100 m in length (100 m reach). Survey work entailed physical habitat measurement, water quality monitoring, and the collection, identification, and enumeration of all fish species present. All trout collected were measured to the nearest millimeter and subsequently released after photographic documentation. In addition to the UA surveys, we also performed several targeted fish surveys in regions that had important fish species, including but not limited to state listed fish, and potential new sites for tracked species. We also obtained information from the PFBC for sites in our focal areas that had been surveyed by others.

WPC

WPC staff sorting and identifying fish – Potter County.

Monitoring Efforts and Results

We conducted a total of 178 surveys across the shale gas region of Pennsylvania from 2013 to 2014. In addition to our surveys, we obtained data from PFBC for 36 survey sites sites for a total of 214 fish surveys within and in close proximity to the 35 focal areas. Between our surveys and PFBC, we documented 80 species of fish representing coldwater, warmwater, and transitional water types. Numerous streams surveyed contained new records of native and wild reproducing trout species, which we will submit to the wild trout list by PFBC in the near future; this will increase environmental protections for those streams through additional regulations.

Species diversity trends followed Strahler stream order patterns with 1st order streams having lower diversity as would be expected given the height in the watershed (Schlosser 1995). Larger streams such as Aunt Clara's Fork (Kings Creek Focal Area) had higher diversity with 14 species collected, but no streams compare to French Creek with regards to fish diversity, which had 40 different species of fish including several candidate, threatened, and endangered species present.

In addition to the data submitted to the PFBC for the Unassessed Waters program, we submitted all records of rare species to the PNHP for use in the PNDI environmental review.

Conservation Implications and Future Work

The Unassessed Waters program is an important conservation tool in Pennsylvania. When documented, streams receive automatic conservation status as having naturally reproducing populations of trout species. This status directly protects high quality aquatic ecosystems under Chapter 93 by calling for additional measures that must be implemented to maintain the quality of the habitat. This designation is critical for protection of coldwater habitats.

WPC

Fish identification can be done through inspection of mouth shape – Washington County.

Additionally, a variety of important non-game fishes were also found in certain areas and those species will also contribute to designating protected status to the streams through conservation measures provided through the PFBC's environmental review and the DEP permitting process.

Streamside Salamanders

Most species of salamander utilize cutaneous respiration; essentially their skin serves the function that human's lungs perform, and just as our lungs are sensitive to toxins, amphibian skin is highly sensitive to toxins making them suitable bioindicators (Gibbs et al. 2007). A group of salamanders, known as the brook (genus *Eurycea*) and dusky (genus *Desmognathus*) salamanders, are typically found within a few meters of flowing waters. They prey on aquatic and terrestrial invertebrates, as well as other salamanders, and are, themselves, prey for mammals, birds, fish, large invertebrates, reptiles and other amphibians; they provide a primary transfer of energy from aquatic to terrestrial ecosystems. Since their prey items are also susceptible to pollution, salamanders offer us a unique window into the health of the aquatic and riparian environment.

WPC

The long-tailed salamander (*E. longicauda*) along Spring Creek – Jefferson County

The brook salamanders (genus *Eurycea*) tend to be indicators of good water quality since the adults are susceptible to pollution; they lay their eggs, develop, and hatch entirely in streams, and the larvae are bound to water. Brook salamanders are thought to have shorter lifespans than other salamander species, with the long-tailed salamander (*E. longicauda*) having a reported longevity in captivity of nearly five years (Snider & Bowler 1992) and the northern two-lined salamander (*E. bislineata*) probably not more than 5 years (Sever 2005).

Dusky salamanders (genus *Desmognathus*) also serve as indicators of high water quality since the adults are also susceptible to pollution events. While the larvae develop in the water, they lay their eggs in moist areas in the uplands. Members of this genus are relatively long-lived, with the northern dusky salamander (*D. fuscus*) living more than 4 years (Snider & Bowler 1992), seal salamander (*D. monticola*) documented living well at least 11 years in the wild (Bruce et al. 2002), and the Allegheny mountain dusky (*D. ochrophaeus*) living nearly 20 years in captivity (Snider & Bowler 1992). While they do produce relatively large numbers of eggs, recruitment to adulthood is often quite low given the intense predation on smaller individuals. Therefore, the presence of mature adults of dusky salamanders suggests that water quality is not only suitable, but has been suitable for quite some time.

Two other species frequently encountered in stream settings, are the northern spring salamander (*Gyrinophilus porphyriticus*) and northern red salamander (*Pseudotriton ruber*). These large salamanders are specialized to prey on the smaller salamanders that live along streams. The presence of these two species typically indicates a healthy population of brook and/or dusky salamanders. When brook and dusky salamanders are found with bobbed tails, frequently one can find either northern spring salamanders or northern red salamanders occupying the same area. Both northern spring salamanders and northern red salamanders may stay in the larval stage for years, grown to considerable size. Both of these species are long lived, with northern spring salamanders not maturing to adulthood until as much as 6 years and northern red salamanders documented living more than 20 years (Snider & Bowler 1992). Other species of salamanders, including the woodland salamanders (genus *Plethodon*), can also be found while searching along streams. The woodland salamanders are not usually associated with flowing water, but are so abundant in the uplands that individuals are found straying into streamside habitats including the eastern red-backed salamander (*Plethodon cinereus*), widely known as the most abundant vertebrate in the northeast. Likewise the juvenile red-spotted newt (*Notophthalmus viridescens*), called an eft, can be found in most any habitat and may inadvertently be found along streamsides.

We evaluated the composition of stream salamanders within 31 stream segments (62 paired transects) to determine the baseline condition of streams in the select focal areas, near water quality monitoring sites. We did not evaluate all focal areas as there was not available habitat at some sites.

Methods for Monitoring

We used a protocol intended to measure the effects on stream salamander populations due to stream degradation (Jung et al. 2004). This protocol is a simple, standardized, repeatable method that makes the survey effort quantifiable by area, time, and number of cover objects searched.

The species that the protocol is intended to quantify are members of the genera Desmognathus and Eurycea. While all salamanders are recorded and measured, the large, predatory, cannibalistic species such as northern spring salamander and northern red salamander are not measures of habitat quality as they tend to occur at widely varying densities; incidental species, such as eastern red-backed salamander and red-spotted newt, are not thought to be a major component of the streamside salamander community. Not all species were expected as every site, because the ranges for certain species did not coincide with our selected survey sites, certain species do not prefer the habitats being surveyed, or species exist in lower concentrations or have spotty distributions. For these reasons, the protocol is intended to focus on the captures of the genera *Desmognathus* and *Eurycea*, the two most common and abundant genera found along Pennsylvania streams.

Our chosen protocol utilized two 15x2 meter belt transects at each location, established at the stream edge, which creates two side-by-side 15x1 meter transects, with one of these transect halves representing the damp (but not inundated) edge of the stream while the other half is conducted in the stream channel. Working in teams of two, surveyors conducted the passes side-by-side so that if a salamander was escaping, the other surveyor could assist with capture. We used a small aquarium net to capture the salamanders (adults and larvae). The protocol requires a minimum of three passes through the 15x2m transect, for each pass recording the time spent searching as well as the number of cover objects turned. A fourth pass is required if more species of Desmognathus or Eurycea are captured on the third pass than on the first and second passes combined.

We classified all captured salamanders by life stage (larvae, juvenile, adult), measured, and released them at the end of the survey. We also recorded a number of habitat and weather parameters and collected coordinates of the transects using a GPS. We took pictures upstream and downstream from start of the transect.

We identified and measured all species of salamanders and released them once the timed survey was complete. We also photographed atypical and questionable specimens for further review.

A note on species identification: identification of Pennsylvania's adult salamander species is typically clear to most that are familiar with the species assemblages found in the state. However, identification of larval salamanders is difficult since the larvae are small in size, the identifying characteristics are subtle, the larvae often look drastically different from the adults (in some cases resembling the patterns found in the adults of other species). Because capturing the identifying characteristics of larva using photographs is difficult, most keys to larval salamanders rely on written descriptions of the characters. For this project, we relied on the most detailed keys and descriptions of larvae available, and most heavily relied on the information found in Phingsten and Downs (1989) and Phingsten et al. (2013).

Dodd (2004), Hulse et al. (2001), and Petranka (1998) were also relied upon for identification of larval salamanders.

Monitoring Efforts and Results

Throughout the course of the project, we conducted 62 individual transects on 31 streams in 12 counties, flipped 28,297 cover objects, searched for 102 hours and 12 minutes, and observed 1,043 total salamanders. Of this total number of salamanders observed, 191 escaped, leaving 852 total salamanders processed, 772 of which were included in the analysis because they belonged to *Desmognathus* or *Eurycea*. Eighty salamanders that we documented were not included in the analysis (per Jung et al. 2004) because they were predatory species or they were considered incidental.

Over the entirety of our surveys, the average number of streamside salamanders (*Desmognathus* and *Eurycea*) per paired transect (60 m^2) was 24.9. Although we searched for the most suitable habitat in the stream segments, results per paired transect varied widely and appeared to be mostly dependent on the quality of the microhabitat. Those without much streamside structure yielded few salamanders (as low as 5), while those with ample streamside structure yielded many (as high as 68). For this reason, and the fact that we conducted the surveys across seven different physiographic province sections, the data should be only viewed on a site by site basis. Species lists for each site and information regarding stream quality can be found in focal area site accounts.

Species assemblages at each site were as we expected, with the genus *Desmognathus* making up nearly 80 percent of all salamanders captured and the genus *Eurycea* making up just over 20 percent of all salamanders captured. No long-tailed salamanders were observed during this project. Although the species is common throughout Pennsylvania, they are very spotty in their distribution and their absence from the survey results is not all that surprising. Northern red salamanders were only recorded at in one location (within the Aunt Clara's Fork stream in the Kings Creek Focal Area). Although this species is common and can be found in the habitats we surveyed, the species tends to inhabit seeps and springs with abundant graminoids and mosses, more so than the swifter flowing waters that were surveyed. The scarcity of northern red salamander in the surveys we conducted is a reflection of suitable, but less than ideal habitat for this species. These results do differ from those found by Rocco (2007) who found that northern red salamander made up 58 percent, Allegheny Mountain dusky 17.9 percent, northern dusky salamander 13.5 percent, northern spring salamander 7.4 percent, seal salamander less than 3.5 percent.

Likewise, we recorded eastern red-backed salamander and red-spotted newt at multiple sites during our surveys. These species are considered only incidental in this habitat, as eastern red-backed salamander is known as a woodland salamander, inhabiting uplands living under rotting logs, leaves, bark, and rocks on the forest floor. Eastern red-backed salamander lays its eggs away from standing or flowing water. This species is the most abundant vertebrate in the northeastern United States and therefore common, even in atypical and not preferable habitat. Red-spotted newt has a unique life history, quite different from all other salamanders in the state. The fully aquatic adults breed and lay eggs in still water, usually lakes, beaver ponds, oxbow wetlands, and manmade ponds. Once the eggs hatch, the larvae quickly metamorphose into a terrestrial juvenile stage known as an eft. The brilliantly-colored efts boldly wander about the forest since their skin is highly toxic if eaten, and few species actually prey on the efts. Efts may stay in this terrestrial juvenile stage for 2-7 years, eventually returning to their natal areas when they metamorphose into fully-aquatic adults. We recorded red-spotted newt in their eft stage at multiple sites. This is not surprising since they can be found quite some distance from their natal ponds throughout the forest, including along streams during this portion of their life cycle. Both eastern red-backed salamander and red-spotted newt are considered some of the most common species of salamanders in Pennsylvania.

Conservation Implications and Future Work

Perceived higher quality sites generally resulted in higher total densities of streamside salamanders. However, the results represent only one site visit to any one transect, making meaningful conclusions regarding streamside salamander densities and stream quality difficult, as multiple site visits are necessary to detect any changes in streamside salamander populations due to human disturbance. However, these data do provide a quantitative and qualitative baseline dataset suitable for future monitoring, and general assessment of stream quality.

Given how widely variable the microhabitat appears to affect results, it is necessary that repeat surveys be conducted at the same locations to ensure comparable datasets.

Salamanders are good indicators of ecological quality and offer us a unique window into the health of the aquatic and riparian environment. Since they are somewhat long-lived and commonly found in higher quality habitats with good substrates, they are excellent subjects for monitoring and can be used to assess the degradation of streams, especially from upstream impacts in the watershed. The species may be especially sensitive to acute pollution events that compromise their food sources, which are also tied to the streams. However, they may be a good indicator of the impacts of management decisions that compromise the quality of riparian habitats, such as road and pipeline crossings. While these are not limited to shale gas development, the infrastructure that is predicted to be developed will almost certainly result in direct impacts to riparian habitats. Management practices that minimize impacts downstream are necessary to maintain native biodiversity. A suggested avenue for future study would be to focus on specific disturbance impacts such as pipeline and road crossings, which are most likely the main anthropogenic disturbances in headwater ecosystems.

Eastern Hellbender Salamander

The eastern hellbender (*Cryptobranchus alleganiensis alleganiensis*) are the largest salamander species in the northeastern United States and one of the most unique aquatic species found in Pennsylvania. Stream habitats for eastern hellbenders are typically larger streams and rivers with good flow, large substrate for nest rock locations, and an abundant supply of crayfish (Hulse et al 2001; Humphries and Pauley 2005). First and foremost, eastern hellbenders require exemplary water quality in order to survive and reproduce. Dams, poor agricultural practices, heavy logging, and acid mine drainage have greatly reduced eastern hellbender populations throughout its range (Burgmeier et al. 2011). Introduction of the aggressive non-native rusty crayfish (*Orconectes rusticus*) is thought to have impacted eastern hellbender populations as well (PNHP 20011). Secondly, eastern hellbenders are long-lived – up to fifty years. A stream with adult eastern hellbenders indicates stable water quality. Eastern hellbenders feed almost exclusively on native crayfish. In winter, when crayfish become less active, eastern hellbenders will feed on several minnow species and hellgrammites (Hillis and Bellis 1971). Like other salamanders, eastern hellbenders are often used as bioindicators due to their inability to tolerate contaminants due to cutaneous respiration.

Western Pennsylvania Conservancy's Watershed Conservation Program began monitoring eastern hellbender populations in 2007. To date we have surveyed over 47 miles of streams in the Allegheny, Juniata, and West Branch of the Susquehanna River watersheds in an attempt to document eastern hellbender populations. Our efforts are focused on documenting new eastern hellbender populations and then monitoring long-term health of individual animals utilizing mark and recapture surveys. We have tagged over 300 sub-adult and adult eastern hellbenders with passive integrated transponders (PIT) since 2007. In addition to mark and recapture surveys, we have partnered with five other conservation partners to examine eastern hellbender populations from New York to Virginia utilizing environmental DNA (eDNA) to document new populations of this often difficult to sample amphibian species. Numerous partners have joined our research efforts including Clarion University, Pittsburgh Zoo and PPG Aquarium, Purdue University, and Smithsonian National Zoo, all of which are working towards conserving this imperiled species in the Appalachian Region. Future efforts will focus on continuing population monitoring and more effort will be placed on documenting eastern hellbender juveniles which are critical to showing successful reproduction in western Pennsylvania streams.

The eastern hellbender salamander is considered an amphibian species of special concern by PNHP, listed as S2S3, and tracked by the PNHP. However, it is not considered a threatened or endangered species by the PFBC.

We utilized the experience of our Watershed Conservation Program to document eastern hellbenders in focal areas with suitable habitat. Sites surveyed for hellbenders included sites within the Buffalo Creek (Washington County), French Creek, Spring Creek, Kettle Creek, Yellow Creek, and Tionesta Creek focal areas.

Monitoring Methods

We conducted a number of "lift and turn surveys" within focal areas with appropriate habitat. At each location we measured water quality parameters (pH, total dissolved solids, dissolved oxygen, water temperature, and conductivity) and location information. If we found animals, we recorded the location of the rock and its length, width, and thickness. In addition to lift and turn surveys, we took a water sample for eDNA analysis. The water sample is filtered utilizing a 500 micron filter in the hopes of collecting trace amounts of eastern hellbender DNA on the filter paper. The filter paper is then digested for observation utilizing quantitative polymerase chain reaction (qPCR) techniques. If eastern hellbender

DNA is present it will be shown in the resulting graphs created using qPCR. This technique is a minimally invasive survey procedure that could be used for determining if eastern hellbenders are present but currently scientists are not able to identify how many animals are present in the surveyed reach. eDNA could have broad implications for eastern hellbender conservation work in the near future (Olson et al 2012).

Monitoring Efforts and Results

Eastern hellbender surveys were conducted in the West Branch of the Susquehanna River and Ohio River watersheds during 2013-2014 field seasons (Figure 3.22). Lift and turn surveys were successful in finding a new population of eastern hellbenders in the upper Allegheny River watershed in 2014. Preliminary results from the eDNA surveys show locations that have eastern hellbender DNA present (yellow circles) and those areas will be surveyed in 2015 and 2016. Several locations were surveyed in 2013 and 2014 that did not contain eastern hellbenders, which was surprising given the habitat conditions [see Figure 3.22: Crossfork (6) and Little Yellow Creek (12)]. Pennsylvania is fortunate to have some of the most robust populations of the eastern hellbender in the animal's known range even though chytrid fungus is present in many populations (Regester et al. 2012).

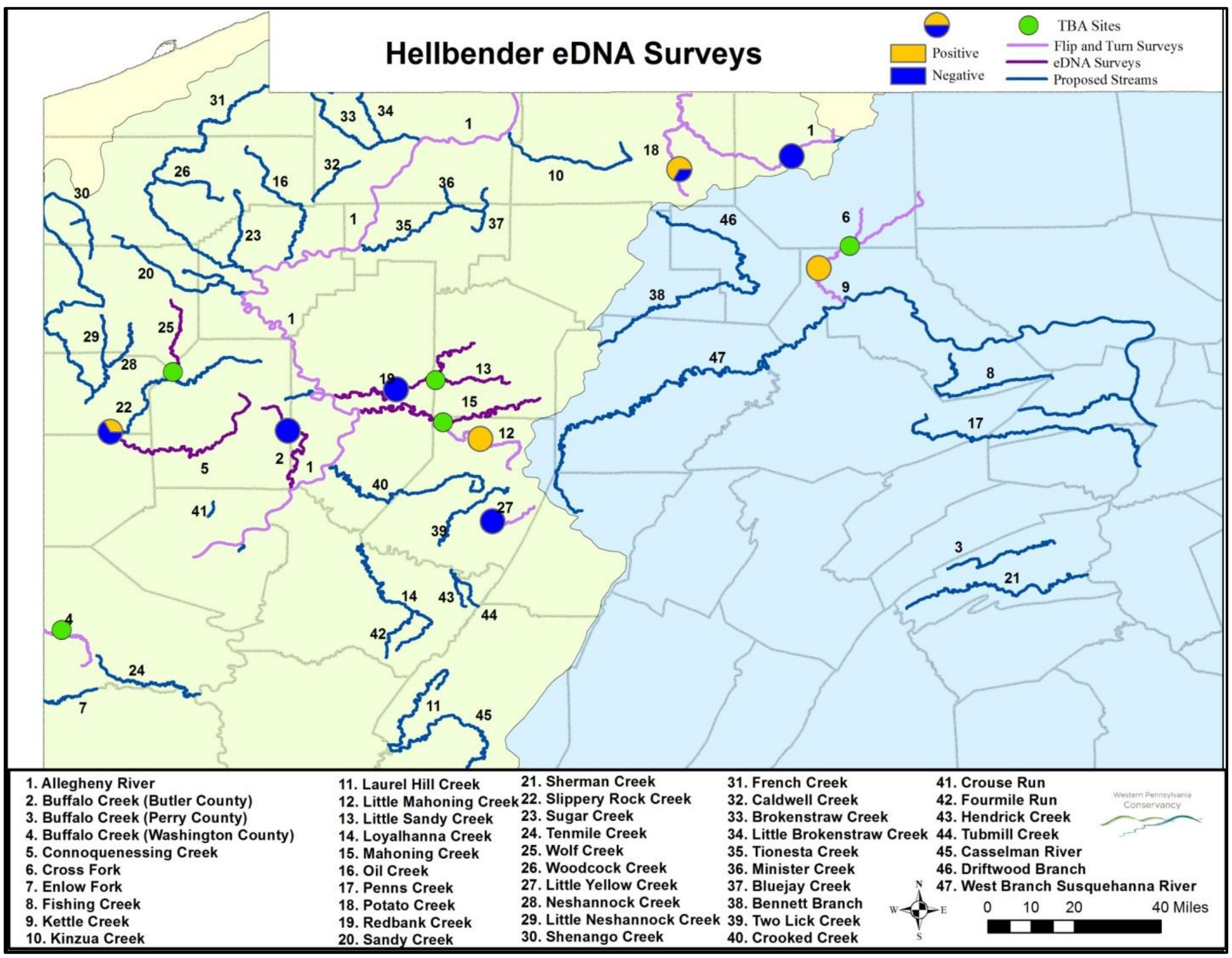


Figure 3.22. Eastern hellbender survey locations in the West Branch Susquehanna and Allegheny River watersheds.

Conservation Implications and Future Work

Eastern hellbender salamanders are an important indicator of stream health and ecological condition. Given the fact that amphibians are often the first group of species to disappear from an impacted aquatic habitat therefore it is imperative that their range and population status be determined in Pennsylvania. We have been actively documenting eastern hellbender populations across Pennsylvania and will continue to do so into the future. Discovering isolated populations of this imperiled species is of utmost importance to WPC because the eastern hellbender is currently under consideration to be added to the Federal Endangered Species list. The eastern hellbender is an excellent monitoring subject to assess impacts of shale gas development on aquatic ecosystems. Presence of eastern hellbenders is a good indication of clean water and a functioning ecosystem. Loss of eastern hellbenders in watersheds with heavy shale gas development would almost certainly indicate environmental degradation due to development. Sediment, briny flowback and produced water, and reduction in water quantity from water withdrawal could have devastating effects on eastern hellbender populations. In particular, the eastern hellbender population within the Buffalo Creek (Washington County) focal area should be monitored closely, with the rapid development of shale gas. Already, chloride concentrations and TDS/TSS were among the highest in this study. Riparian vegetation is minimal along some streams in parts of the watershed and there are many dirt and gravel roads, which contribute significantly to reduced conditions. We anticipate that this population will decline over time without improvements in the watershed to reduce chloride/salts and sediment.

Freshwater Mussels

Freshwater mussels are a group of long lived species, potentially living 100 years, with a unique reproduction strategy that relies upon the use of a fish or salamander host to complete its life cycle (McNichols et al. 2007; O'Dee and Watters 2000; Strayer and Jirka 1997). Some of the freshwater mussels that are found in Pennsylvania are currently on the Federal Endangered Species list. There are 13 federally listed species including those species historically found in Pennsylvania (Welte 2015). Examples include the northern riffleshell, (*Epioblasma torulosa rangiana)*; clubshell (*Pleurobema clava*); snuffbox (*Epioblasma triquetra*) and several others.

Mussel shells found in Sandy Creek – Mercer County

Freshwater mussels are considered biological indicators of the ecological health of aquatic systems. If freshwater mussels begin to disappear from a known location it is often an indication of pollution or habitat degradation. Industrial activity in the region caused pollution and sedimentation of the region's creeks and rivers causing significant declines in the Ohio River basin in the early 1900s (Ortmann 1909). Freshwater mussels are rather intolerant of habitat modifications (i.e., excessive sedimentation, dredging) and changes in flow regime, which often causes extensive die-offs and loss of whole communities (Ortmann 1919; Watters 1995 and 2000; Brim Box and Mossa 1999).

Mussel observed in French Creek - Erie County.

When significant populations of freshwater mussels are identified it often means that water quality has been stable for quite some time. Currently many streams across the commonwealth have been surveyed but recent anthropogenic activities could facilitate the need to re-survey to determine if populations are remaining stable given the increase in habitat modifications from shale gas development in particular.

Current mussel populations could face significant threats from unconventional gas well drilling. First, large volumes of water must be extracted (~3-5 million gallons of water per well) from existing surface water features or groundwater sources in order to fracture wells for gas production. The extraction of water from streams must be carefully managed in order to maintain existing stream uses, which include maintaining habitat (i.e., quantity of water). Currently existing stream uses are maintained through Pennsylvania Department of Environmental Protection policy to impose a 20% average daily flow passby restriction on Marcellus Shale water withdrawals for warmwater streams and a 25% average daily flow passby requirement for coldwater streams. Although the passby requirement is in place for the Ohio River basin, currently there are no regulatory mechanisms to monitor the amount of water that is being extracted in order to determine the cumulative consequences of these extractions in the basin. Regulatory frameworks to monitor cumulative impacts to water withdrawals are in place for other Pennsylvania drainages through the Susquehanna and Delaware River Basin Commissions.

The second concern is that a portion (~10-25%) of the water injected into wells to fracture the shale formation flows back ("flowback") to the surface and must be treated. Currently industry is recycling a large portion of these fluids and has voluntarily stopped sending these fluids to waste treatment facilities that are not capable of fully treating wastes; however, some fluids do need to be treated and may be discharged into waters of the commonwealth. This is true primarily downstream of brine water treatment plants on our larger rivers in Pennsylvania. There are currently few treatment facilities capable of treating unconventional (shale) natural gas flowback fluids which are usually high in total dissolved salts (TDS), especially chlorides. In a recent survey of freshwater mussel populations in the Allegheny River at Warren, Pennsylvania the U.S. Fish and Wildlife Service (USFWS) documented a substantial dead zone in the river, with the mussel population only returning to what are thought of as natural conditions many kilometers downstream (Patnode et al. 2014). The cause of the deadzone was determined to be brine waste water from natural gas operations released from a wastewater (brine) treatment plant in Warren. The USFWS found that concentrations of salts were many times their normal levels in the Allegheny River and these pollutants were found to be lethal to freshwater mussel species through direct field experiments in which live freshwater mussels were placed downstream of the effluent from the water treatment (Patnode et al. 2014). It must be noted that public water treatment facilities stopped accepting flowback and produced water from unconventional shale operations in 2013, and many shale gas drilling companies now recycle most of the waste water produced in the hydraulic fracturing process. However, shallow gas (conventional) operations may still produce significant amounts of brine waste, which can be disposed of at private wastewater treatment facilities. The USFWS study shows the importance of practices to limit discharges of brine waste, even from treatment facilities, as these water treatment plants are not equipped to handle large volumes of brine water.

Another concern is isolated spills of drilling muds, production fluids, and flowback water. These incidents have been regionally common, but locally infrequent as Marcellus Shale gas development intensifies. One event of dissolved solids can create osmotic pressure or release a toxic substance, creating a relatively high level of risk to extant mussel populations that are within the shale gas range in Pennsylvania.

The last concern is the accelerated development of infrastructure associated with shale gas development, including dirt and gravel roads, pipeline construction, compressor stations, and stream crossings. These activities are likely to increase sedimentation to streams. Accidents such as chemical spills and groundwater pollution have the potential to destroy localized or downstream mussel populations or their habitats.

Monitoring Methods

We selected six sites to survey for freshwater mussels within two focal areas with appropriate habitat. We also queried the PNHP database to provide information on known populations of freshwater mussels within the focal areas. We conducted timed surveys at specific sites using a protocol described in Chapman and Smith 2008. A GPS point was taken at the beginning and the end of each survey reach using a Garmin etrex 20 handheld unit. Mussel surveys were conducted in an upstream direction to allow for sediment to clear rapidly for optimal visualization of the stream bottom.


WPC

Mussel survey in Mercer County.

A designated person would start the time and the survey would begin. Searchers would use either a mask and snorkel or viewing buckets to conduct their search scanning the stream bottom for mussels in an upstream fashion. Searchers were instructed to collect all mussels encountered including dead shells. When the survey was completed, the search time was recorded and all the distributed collection bags were collected.

Collected mussels were then separated into species, with live, fresh dead, or weathered dead individuals being recorded separately. Live mussels were measured for length in millimeters to determine if recruitment was occurring at a site. Photo documentation of all mussel species that were found was completed and then all living mussels were properly placed back into the stream. A specimen of each dead mussel species was kept for a voucher to be ascended into the collection at the Carnegie Museum of Natural History in Pittsburgh, Pennsylvania.

Monitoring Efforts and Results

We completed surveys for freshwater mussels at six locations within the Sandy Creek and Shenango River focal areas (four on Sandy Creek in Venango and Mercer counties and two on the Shenango River in Mercer County) over the course of this study. The surveys required between two and six people each, for a total of 1,975 minutes of search time, or 32.9 hours of effort in the attempt to locate freshwater mussels. Overall, our surveys resulted in 363 living mussels, 47 fresh dead, and 222 weathered dead representing 20 species (Table 3.10). We documented a total of 19 living species during our survey efforts, with several taxa listed as species of special conservation concern.

At Sandy Creek, all sites had at least seven species with live individuals, with the most diverse site sampled containing 14 species (live and dead). We documented several species including spike (*Elliptio dilatata*), mucket (*Actinonaias ligamentina*), wavy-rayed lampmussel (Lampsilis fasciola), and floater (Pyganodon grandis) at many of the sites surveyed; these are considered common for the areas surveyed. Two federally listed species were observed in Sandy Creek as well. Our surveys documented the first known population of the northern riffleshell (*Epioblasma torulosa rangiana*) for Sandy Creek. We also documented clubshell (*Pleurobema clava)* in Sandy Creek; however, we only documented the presence of weathered dead shells. This species, though, has been known to burrow into soft substrate and can easily go undetected and weathered dead shells are an indication of its presence in the creek.

In the Shenango River, we found nine species of mussel at two total sites. We documented one federally endangered species, the snuffbox mussel (*Epioblasma triquetra*), which is known to be present throughout the drainage.

Table 3.10. All freshwater mussels collected during 2013-2014 from the six sampling sites in Sandy Creek and Shenango River Focal Areas, Venango and Mercer Counties, Pennsylvania. Mussels recorded as live, fresh dead = FD or weathered dead = WD.

Site: Sandy Creek, Venango County, Mineral Township, SR 965 bridge, September 10, 2013
Search time: 1:37 (5 people); 45 min (2 people) = Total search time: 575 minutes (9.58 search hours)

Species	Total live	Fresh dead	Weathered dead
Alasmidonta marginata	3		1
Elliptio dilatata	105	43	TMTC
*Epioblasma torulosa rangiana**	4		1
Lampsilis cardium			1
Lampsilis fasciola	1		
Lampsilis siliquoidea	5		
Lasmigona costata	1		
Pleurobema sintoxia		2	
Pyganodon grandis	1		2
Strophitus undulatus	2		
Total	122	45	5

Site: Sandy Creek, Venango County, Mineral Township, Raymilton bridge site, September 10, 2013
Search time: 50 minutes (7 people) = Total search time: 350 minutes (5.83 search hours)

Species	Total live	Fresh dead	Weathered dead
Actinonaias ligamentina	2		1
Alasmidonta marginata			2
Elliptio dilatata	93		83
Lampsilis cardium	1		
Lampsilis fasciola	1		
Lampsilis siliquoidea	5		11
*Pleurobema clava**			6
Pleurobema sintoxia			1
Ptychobranchus fasciolaris			1
Pyganodon grandis	20		6
Strophitus undulatus	3		
Utterbackia imbecillis		1	1
Total	125	1	112

Table 3.10. con't. All freshwater mussels collected during 2013-2014 from the six sampling sites in Sandy Creek and Shenango River Focal Areas, Venango and Mercer Counties, Pennsylvania. Mussels recorded as live, fresh dead = FD or weathered dead = WD.

Site: Sandy Creek, Venango County, Mineral Township, Intersection of Reeds Furnace and Farrell Roads, September 10, 2014

Search time: 35 minutes (6 people) = Total search time: 210 minutes (3.5 search hours)

Species	Total live	Fresh dead	Weathered dead
Actinonaias ligamentina	1		3
Elliptio dilatata	6		1
Lampsilis cardium	1		0
Lampsilis fasciola	1		1
Lasmigona compressa	2		1
Ligumia recta	1		0
Pleurobema sintoxia	1		4
Ptychobranchus fasciolaris	2		4
Pyganodon grandis	2		
Utterbackia imbecillis	5		
Total	22	0	14

Site: Sandy Creek, Mercer County, Mineral Township, SGL 130 near old gas well, September 10, 2014

Search time: 60 minutes (6 people) = Total search time: 360 minutes (6 search hours)

Species	Total live	Fresh dead	Weathered dead
Actinonaias ligamentina	1		
Elliptio dilatata	8		25
Lampsilis cardium	1		1
Lampsilis fasciola	1		
Lampsilis siliquiodia			2
Lampsilis costata			5
Lasmigona compressa	4		1
Ligumia recta		1	
*Pleurobema clava**			4
Pleurobema sintoxia			26
Ptychobranchus fasciolaris			3
Pyganodon grandis	48		17
Strophitus undulatis	1		
Utterbackia imbicillis	2		1
Total	66	0	14

Table 3.10. con't. All freshwater mussels collected during 2013-2014 from the six sampling sites in Sandy Creek and Shenango River Focal Areas, Venango and Mercer Counties, Pennsylvania. Mussels recorded as live, fresh dead = FD or weathered dead = WD.

Site: Shenango River, Mercer County, Delaware Township, Schaller Road Bridge, May 31, 2013
Search time: 120 minutes (2 people) = Total search time: 240 minutes (4 search hours)

Species	Total live	Fresh dead	Weathered dead
Actinonais ligamentina	1		1
Amblema plicata	11		
Elliptio dilatata	1		
Lampsilis siliquoidea	1		
Obovaria subrotunda	1		
Total	15	0	1

Site: Shenango River, Mercer County, Pymatuning Township, Kidds Mill Bridge. May 31, 2013
Search time: 120 minutes (2 people) = Total search time: 240 minutes (4 search hours)

Species	Total live	Fresh dead	Weathered dead
Alasmidonta marginata			2
Amblema plicata	11		3
*Epioblasma triquetra**	1		1
Lampsilis ovata	1		
Strophitus undulatus			1
Total	13	0	6

Conservation Implications and Future Work

Mussel diversity is driven by several factors including overall water quality, substrate condition, and host species presence (Chapman and Smith 2008; McRae et al. 2004). The populations surveyed during this study face a number of challenges from human development activities in the surrounding watersheds. Sedimentation is likely the greatest threat to these populations, particularly from the development of new pipeline and road construction associated with shale gas development. Given the global significance of the Allegheny River watershed and its tributaries to freshwater mussel populations, we recommend continued survey efforts, especially as shale gas development increases in the region.

Care should be taken when drilling in watersheds with relatively intact mussel communities like Sandy Creek and the Shenango River. Well pads should be situated away from the streams and should be self-contained in the event of a chemical spill or leak. Transportation of chemicals and products to and from the well site should be performed with care as well. Spills and leaks from railroad and tanker accidents (although not common) can cause devastating and irreversible damage to aquatic communities.

Pipeline stream crossings should be engineered carefully as well. Horizontal directional boring under a stream is the preferred method for installing a new pipeline under a stream bed. This method is less invasive than using heavy machinery to dig a trench and bury the pipeline across the stream. Although, boring is preferred it is not without risks. "Frackouts" or "inadvertent returns" of drilling muds, surfactants, and other chemicals have been known to happen during the boring process under streams. This can introduce excess bentonite and other chemicals into the stream often coating the stream bottom and negatively killing aquatic life.

Inadequate wastewater treatment has been shown to negatively impact mussel populations (Patnode et al. 2014). Considerable efforts must be made to bring private wastewater treatment facilities up to code. We recommend further assessment of aquatic ecosystems and freshwater mussel populations downstream of potential sources of shale development-related pollution, such as brine treatment plants, pipelines, and sites where well pads are located very close to flowing water habitats. Known significant mussel populations near shale gas development activities should be monitored to determine if shale gas development activity, as well as other anthropogenic development is having a negative impact on mussel populations.

Small Mammals

The American water shrew (*Sorex palustris*) is considered a habitat specialist due to its reliance on clean aquatic systems for foraging (Hart 2010). Typical habitats usually include vegetated mountain streams with rocky bottoms (Merritt 1987) as well as marshes and floodplain forests. Streamside structures and cover including riparian vegetation, undercut stream banks, rock with interstices, and exposed tree root balls provide protection and travel corridors for the American water shrew (Hart 2010). WPC selected the American water shrew as a primary target species as a baseline indicator because of its vulnerability to environmental changes and usefulness as a bioindicator to monitor the overall health of these delicate systems (PGC - PFBC 2005).

WPC

Northern water shrew. Inset photo depicts characteristic hind foot hair fringe.

As shale gas development increases within the home range of the American water shrew, specific areas may be negatively impacted by development. Since these shrews rely on aquatic systems for foraging, their presence is usually indicative of good water quality and healthy functioning systems. In addition to direct habitat destruction to high quality riparian zones, where American water shrews live, water quality can greatly affect shrew populations. Increases in sediment and runoff from new roads, well pads, and pipelines, and potentially, chemicals used in the fracturing process can substantially degrade habitat resources

It is important to note that Pennsylvania is home to two subspecies of the American water shrew: the northern water shrew (*S. p. albibarbis*), and the West Virginia water shrew (*S. p. punctulatus*). The northern water shrew subspecies has a range in Pennsylvania that extends from Monroe County in the northeastern part of the state, southwestward into Mifflin County and northwestward along the border of Elk and Forest counties, while the West Virginia water shrew is limited to the southwest region of the state (Hart 2010). Both subspecies were targeted during these surveys.

We evaluated high quality medium to high-gradient streams within select focal areas to assess the small mammal community of riparian habitats and specifically to target American water shrews.

Methods for Monitoring

Prior to field work in 2013, we chose potential sites for small mammal surveys along riparian areas in GIS, using existing habitat information and available aerial imagery. Sites included areas with the project's focal areas as well as other sites in conjunction with surveys requested and funded by DCNR Bureau of Forestry. Following the preliminary site selection, we inspected the potential riparian study areas for appropriate water shrew microhabitats, and conducted surveys on the stream reaches that appeared to be most suitable (Table 3.11). Priority survey sites were those that exhibited extensive streamside rock and naturally undercut stream banks along with woody debris and exposed tree roots. Streams exhibiting these characteristics typically provide extensive corridors that facilitate safe travel for water shrews as well as other terrestrial small mammals.

Table 3.11. Summary of small mammal trap line locations and trapping effort.

Stream trapped	Focal Area	Approximate central survey coordinates	County [Township]	2013 Dates Trapped	Trap Nights	Water Shrews
Tubb Run	Tipton Run	40◦ 36' 53"; -78◦ 27' 11"	Cambria [Dean]	3Jun-06Jun	150	No
Shaw Run	Tipton Run	40◦ 38' 24"; -78◦ 23' 41"	Blair [Antis]	3Jun-5Jun	50	Yes
Three Springs Run	Tipton Run	41◦ 21' 12"; -77◦ 50' 22"	Blair [Snyder]	3Jun-04Jun	50	Yes
Wolf Run	Tipton Run	40◦ 46' 29"; -78◦ 13' 59"	Centre [Rush]	3Jun-04Jun	50	Yes
Benner Run	Black Moshannon Creek	40◦ 56' 17"; -78◦ 01' 30"	Centre [Rush]	3Jun-04Jun	100	Yes
Nelson Branch	Kettle Creek	41◦ 29' 16"; -77◦ 53' 34"	Potter [East Fork]	15Jul-18Jul	150	No
Hammersly Fork	Kettle Creek	40◦ 36' 53"; -78◦ 27' 11"	Potter [East fork]	15Jul-18Jul	150	No
Morris Run	Red Run	41◦ 31' 38"; -77◦ 31' 41"	Lycoming [Brown]	26Aug-29Aug	150	No
Wolf Run	Red Run	41◦ 25' 57"; -77◦ 29' 29"	Clinton [McHenry]	17Sep-18Sep	50	Yes
Elk Lick Run	Kettle Creek	41◦ 30' 07"; -77◦ 49' 08"	Potter [Stewardson]	15Apr-16Apr	50	Yes
Little Indian Run	Kettle Creek	41◦ 35' 45" -77◦ 42' 13"	Potter [Abbott]	15Apr-17Apr	100	Yes
Indian Run	Kettle Creek	41◦ 34' 57"; -77◦ 39' 03"	Potter [Abbott]	15Apr-17Apr	100	Yes
Sliders Branch Kettle Creek	Kettle Creek	41◦ 37' 03"; -77◦ 36' 17"	Potter [Abbott]	16Apr-19Apr	150	No

Table 3.11 con't. Summary of small mammal trap line locations and trapping effort.

Stream trapped	Focal Area	Approximate central survey coordinates	County [Township]	2013 Dates Trapped	Trap Nights	Water Shrews
Dagherty Branch	Red Run	41o 30' 46"; -77o 32' 22"	Lycoming [Brown]	6May-7May	50	Yes
Bonnell Run	Red Run	41o 26' 24"; -77o 30' 35"	Lycoming [McHenry]	7May-10May	150	No
Porcupine Run	Hemlock Creek	41o 25' 43"; -79o 32' 58"	Venango [President]	19Aug-21Aug	100	Yes
Reese Run	Hemlock Creek	41o 24' 30"; -79o 30' 46"	Venango [Pine Grove]	19Aug-20Aug	50	Yes
Korb Run	Hemlock Creek	41o 25' 58"; -79o 29' 38"	Venango [President]	19Aug-22Aug	150	No
Unnamed trib. to Hemlock Creek	Hemlock Creek	41o 26' 06"; -79o 30' 31"	Venango [President]	19Aug-20Aug	50	Yes
Limestone Run	Dunbar Creek	39o 55' 23"; -79o 34' 44"	Fayette [Dunbar]	12Nov-15Nov	150	No
Elk Rock Run	Dunbar Creek	39o 57' 04"; -79o 34' 34"	Fayette [Dunbar]	12Nov-15Nov	150	No
Unnamed trib. to Mountain Creek	Laurel Hill Creek	39o 46' 09"; -79o 44' 07"	Fayette [Georges]	12Nov-15Nov	150	No
Blue Hole Creek	Laurel Hill Creek	39o 59' 22"; -79o 18' 19"	Somerset [Middlecreek]	14Nov-15Nov	50	No
Cole Run	Laurel Hill Creek	39o 59' 04"; -79o 17' 15"	Somerset [Middlecreek]	14Nov-15Nov	50	No

From April through November 2013, we deployed 24 trap lines throughout different regions of the state for a total of 1,650 trap nights. Of the 24 trap lines, we established 21 targeting the northern water shrew and 3 targeting the West Virginia water shrew.

Habitat representative of the American water shrew (Porcupine Run, Venango Co., PA).

We used trapping protocols that consisted of 25 stations of two traps deployed for 3 consecutive nights, yielding 150 trap nights. Small mammal surveys used Museum Special traps (Woodstream Corp., Lititz, PA) and FSI Museum Traps (Forestry Suppliers Inc., Jackson, MS), dipped in paraffin, and secured to vegetation or rocks with approximately 1 meter of nylon string to prevent trap loss. We baited the traps with masticated oatmeal and checked them once daily and refreshed when necessary. Once a water shrew was captured, we removed the trap line from the site, despite having not met the 150 trap night maximum. Therefore, some surveys consisted of 50 or 100 trap-nights. We placed the traps under overhanging banks, within rock interstices, under streamside debris, and in exposed tree root balls. We collected standard habitat data describing the stream and streamside structure, and surrounding forest structure and plant composition. We photographed the stream corridor upstream and downstream of stations 1, 5, 10, 15, 20, and 25 along each trap line.

We prepared specimens of all species either as round museum study skins or in a fluid preservative and deposited them at The State Museum of Pennsylvania (SMPA). Also, we preserved heart, liver, and kidneys of all American water shrews in 95 percent ethanol for future genetic analysis, or analysis of shale gas pollution indicators (e.g., barium and strontium). We submitted all documented occurrences to PNHP.

Monitoring Efforts and Results

In total, we collected 306 specimens of terrestrial mammals from the 24 sampling sites, representing 12 different species (Table 3.12). All of the sites represented high quality riparian habitats, with little or no nearby human disturbance. Fourteen of the 24 sites contained northern water shrews. Our efforts did not detect any West Virginia water shrews with the focal areas of the study. Our work confirmed northern water shrews in Blair and Venango counties, marking the first occurrence of this species within these counties.

Table 3.12. Capture summary of terrestrial small mammals collected by WPC staff

Stream trapped	Soci	Sofu	Sopa	Blbr	Tast	Pele	Pema	Clga	Mipe	Syco	Zahu	Nain	Total
Blue Hole Creek	2	3	-	-	-	-	3	-	-	-	-	-	**8**
Cole Run	1	-	-	-	-	2	-	-	-	-	-	-	**3**
Tubb Run	-	-	-	-	-	-	-	-	-	-	1	4	**5**
Shaw Run	-	1	1	-	-	-	-	-	-	-	-	2	**4**
Three Springs Run	-	-	1	-	-	-	1	3	-	-	-	-	**5**
Wolf Run	-	1	2	-	-	2	-	10	-	-	-	-	**15**
Benner Run	-	-	1	-	-	-	-	2	-	-	-		**3**
Nelson Branch	-	1	-	3	-	5	8	2	1	-	-	1	**21**
Hammersly Fork	-	-	-	-	-	3	4	3	2	1	1	2	**16**
Morris Run	-	1	-	2	-	-	-	1	-	-	-	1	**5**
Wolf Run	-	1	1	3	-	7	-	18	1	-	-	-	**31**
Elk Lick Run	-	-	1	-	-	8	4	1	-	-	-	-	**14**
Little Indian Run	-	-	2	-	-	2	5	-	1	-	-	1	**11**
Indian Run	-	2	1	1	-	1	7	4	1	-	-	-	**17**
Sliders Branch	-	-	-	-	-	-	13	1	-	-	-	-	**14**
Dagherty Branch	-	-	1	-	-	7	1	-	-	-	-	3	**12**
Bonnell Run	-	-	-	-	-	12	8	1	-	-	-	-	**21**
Porcupine Run	-	-	1	-	-	3	-	10	-	-	-	1	**15**
Reese Run	-	-	1	1	-	5	-	2	-	-	-	2	**11**
Korb Run	-	-	-	-	-	1	-	4	-	-	-	4	**9**
Trib. To Hemlock Creek	-	-	1	-	-	1	1	7	-	-	-	1	**11**
Limestone Run	-	-	-	1	-	7	3	5	-	-	-	-	**16**
Elk Rock Run	-	2	-	8	1	8	1	-	-	-	-	-	**20**
Trib. to Mountain Creek	-	-	-	2	-	1	5	9	-	-	-	-	**17**
Total	**3**	**12**	**14**	**21**	**1**	**75**	**64**	**83**	**6**	**1**	**2**	**22**	**304****
% of total capture	*1.0*	*3.9*	*4.6*	*6.9*	*0.3*	*24.7*	*21.1*	*27.3*	*2.0*	*0.3*	*0.7*	*7.2*	

*Soci-Sorex cinereus, Sofu-S. fumeus, Sopa-S. palustris, Blbr-Blarina brevicauda, Tast-Tamias striatus, Pele-Peromyscus leucopus, Pema-P. maniculatus, Clga-Clethrionomys gapperi, Mipe-Microtus pennsylvanicus, Syco-Synaptomys cooperi, Zahu-Zapus hudsonius, Nain-Napaeozapus insignis

Though water shrews were captured at 50 percent of the targeted sites, they only accounted for 4.6 percent of the total capture. This low capture percentage attests to their relative rarity within suitable riparian habitats in Pennsylvania.

Habitat representative of the American water shrew (Porcupine Run, Venango Co., PA)

Conservation Implications and Future Work

All 24 sites surveyed met the criteria for headwater riparian monitoring: high quality forested stream reaches where shale gas development was thought to be probable. However, we only observed water shrews at 14 sites.

The 306 individual specimens collected through this work and past work housed at the State Museum could serve to determine the prevalence, presence, or absence of various chemicals used in the shale gas extraction process. As the top semi-aquatic predators of primary and second order streams, their close tie to aquatic habitats and small home ranges make the species ideal for this type of analysis. For focal areas where upstream shale gas development is occurring, we will look for opportunities to conduct these analyses. Recent research by the National Aviary found a significant relationship between levels of strontium in the feathers of Louisiana waterthrush and shale gas development in the watershed (Latta et al. 2014). With preserved tissue samples, we may be able to do this for our water shrew and small mammal specimens.

In addition to providing a baseline of streams in the Shale Gas Region of Pennsylvania, this work provided data to expand the known range of the American water shrew. We suspect the known range could be expanded with more survey effort. Of particular need for more inventory is the area between the known ranges of the two subspecies, the American northern water shrew and West Virginia water shrew. Although descriptions of these subspecies do indicate minute morphological differences, most Pennsylvania mammologists distinguish the subspecies based on capture location only. We surmise that if further work were conducted in the gap between the two subspecies known ranges, more specimens would be captured, enough for a formal analysis of the uniqueness of both of the subspecies.

4. Conclusion

First and foremost this work represents a baseline of the ecological conditions of select high ecological value areas threatened by future shale gas development activities. For many of our focal areas, shale gas development has not yet occurred or sites have just begun to be touched by development activities. However, there were a number of interesting findings from the analysis of ecological data collected in this study.

We found that the landscape condition and fragmentation varied greatly from one focal area to another due to historic human development, and the wildlife species within these areas exhibited significant differences, linked to disturbance factors like roads, forest management activities, and land development history. Our assessment of landscape condition provides a baseline which can be used to assess land use change over time as sites are developed to produce shale gas, as well as for other development purposes. Analysis of landscape data suggested that our areas differed markedly from one region of Pennsylvania to another, with the northwestern and southwestern portions of the state much less forested and exhibiting a higher road and pipeline density. Fifteen of our 35 focal areas contain shale gas wells, and many others have experienced impacts from the construction of road and transmission infrastructure. Shale gas development was the primary cause of forest loss and fragmentation at some sites, particularly predominantly forested focal areas; for others, the extent landscape impact associated with shale gas pales in comparison to other human development activities, such as agriculture or residential development. It remains to be seen how fragmentation from shale gas development will impact wildlife species in these areas and more needs to be done to categorize development types, characterize potential impacts, and assess direct and indirect impacts of fragmentation.

Our water quality analyses indicated that most of our sites were of high ecological quality, as most have yet to be impacted by the effects of shale gas development. While the intent of the project was to obtain baseline data prior to intense shale gas development, some sites were impacted leading up to and over the course of our study. We found correlations between shale gas drilling activities and certain chemicals associated with shale gas development pollution in surface waters. We must continue to look for historic water quality data for our focal areas to determine if current levels of salts and elements associated with shale gas development have changed since drilling took place. Pre-drilling baselines for chemicals such as barium, strontium, and chloride would be very valuable in assessing impacts from current drilling activities. Coal mining and other industrial activities were common to many watersheds of Western Pennsylvania and this may have influenced the amount of barium and strontium detected in the water. Winter road maintenance and agriculture often contribute to high chloride levels and total dissolved solids (TDS).

From our forest assessments, we found a connection between habitat quality and bird species, with a greater proportion of "edge species" present with increasing disturbance factors. This suggests that with further shale development in our forested landscapes, we will see a shift towards birds common to suburbs and old fields. We can speculate that with increased development and fragmentation from construction of well pads, roads and pipelines, we will see a continued trend of higher densities of edge species in forest ecosystems where interior forest birds are currently dominant.

The results of the targeted inventories for rare and important species indicated that our focal areas were indeed areas of high ecological value. This reinforces the need for continued inventory and conservation measures to protect and maintain high ecological value areas as these places often support multiple species of concern.

Engaging in this work provided us an opportunity to collaborate with other conservation organizations, state agencies, and industry groups on efforts to develop best management practices and policies to ensure that important habitats and critical resources are maintained in order to support our important wildlife and plant species. This project contributed to the already significant work on assessing the streams in Pennsylvania for naturally reproducing populations of native brook trout. In this effort, university and non-profit data are used directly to support designation of special protection water status. Through this project, we were able to increase the breadth and depth of science staff involvement in our organization's recommendations for changes to laws, regulations, and policies that protect rare species and high value conservation areas, including changes to policies governing water use and quality, habitat fragmentation, and setbacks (e.g., DEP's Chapter 78 of Pennsylvania's Oil and Gas Law). Collaboration was evident in the chemical and biological assessments protocols used to assess aquatic habitats, which were similar to those used by the DEP and most non-governmental organizations (watershed organizations, professional assessments). Portions of the data will be shared with DEP and larger assessment and monitoring database efforts (Penn State University Shale Gas Network Database and West Virginia University's 3RQ database). Fish survey data were shared with Pennsylvania Fish and Boat Commission.

We expect shale gas development to continue in Pennsylvania and that a large majority of the focal areas, identified in GIS and studied in this field study, will experience some form of development in the form of well pads, pipelines, and other infrastructure. We continue to be concerned with cumulative ecological impacts of multiple shale gas development activities on high ecological value areas and future studies should incorporate investigation of long term cumulative effects on plants and wildlife in these areas. We hope that our data and findings will contribute to devising and applying measures to avoid and minimize impacts to Pennsylvania's most critical habitat. Data collected through this assessment and monitoring work will allow us and our conservation partners to make specific, science-based recommendations on management actions and policies to minimize impacts to high value ecological areas and rare and important wildlife and plant species.

Conservation Recommendations

Establishing baselines of species occurrence and the quality of their habitat is important in the face of landscape fragmentation from all types of anthropogenic development and is important to assess impacts of climate change. However, monitoring alone, without application of the data to management and policy actions will not protect our high quality ecological areas, rare species, and critical habitat resources.

We suggest that future efforts focus on the following actions:

- *Continue assessment and monitoring activities in areas where shale gas development is imminent and develop effective mechanisms to use data in management of areas of high ecological value.* In addition to continuing our own studies, we will work to support the efforts of our partners to document current conditions and evaluate the impacts of specific development activities on critical habitats and rare and important plant and wildlife species. We will support efforts by state agencies to incorporate data collected by non-governmental organizations (NGOs), university researchers, and others not directly affiliated with state regulatory and management agencies, in management actions and to support policy positions. NGOs and volunteer groups are actively engaged in monitoring activities in Pennsylvania (see FracTracker 2014) and these efforts can possibly work to overcome capacity limitations within agency departments for some aspects of ecological monitoring and assessment efforts. Specifically, baseline water quality data, bird community assessment, and invasive plant species documentation are all ecological impacts currently being monitored by NGOs and volunteer groups that can be incorporated into agency programs. For these programs to be relevant to agency efforts, however, a mechanism to incorporate these data must be developed and the agencies and non-governmental entities must agree on standards for data collection and management. Already the larger citizen monitoring programs in the region have developed standards, such as the Alliance for Aquatic Resource Monitoring (ALLARM, https://www.dickinson.edu/allarm), and Trout Unlimited Pennsylvania Coldwater Conservation Corps (http://www.tu.org/connect/groups/node-63), however a direct avenue for use of these data for management and policy at the agencies has not been established. The PFBC's Unassessed Waters Program, in which we are an active participant, is one mechanism in which data generated by NGOs and university researchers will be used for direct conservation action – with streams found to have natural reproduction of wild trout granted wild trout stream status, providing a degree of protection from negative impacts associated with development. Larger existing databases, such as ShaleNetwork (http://www.shalenetwork.org/) may serve as an effective repository for volunteer data (Brantley et al. 2014); however, agencies must develop a set of goals and identify a use for the data for these efforts to be worthwhile. As part of our efforts in this direction, we organized meetings between environmental policy and advocacy groups and NGO and university water quality monitoring programs to determine how organizations use non-governmental ecological data in their messaging, advocacy, and management recommendations, and what more may be needed. This dialogue must continue, and land management and regulatory agencies must be at the table, in order to develop an effective mechanism for use of data in agency management efforts and in support of policies on development of natural gas in Pennsylvania.

- *Develop more hypothesis-driven studies which look to directly assess the impacts of specific development activities on wildlife species and critical habitats and seek solutions for the impacts*. These studies are critical to project ecological impacts of specific shale gas development activities and develop policies that work to avoid impacts and best management practices to minimize the impacts. For example, more work needs to be done to understand downstream impacts of shale gas infrastructure (well pads, pipelines, and road crossings) on aquatic ecosystems.

- *Evaluate the benefits of particular management practices on specific wildlife species.* There are many "best management practices" for activities associated with shale gas development in Pennsylvania available from industry groups (MSC 2012, API 2012), management agencies (DCNR 2011), and conservation organizations (PEC 2010). However, few best management practices have been evaluated through field studies in areas of development. Field studies would help to determine if the best management practices are effective or if other best management practices would provide for greater protection of the resources. For example, our study indicated that green salamanders may be able to use pipelines if there is adequate overstory canopy cover. Could planting tree and shrub species along pipelines, or adding coarse woody debris to areas in an around known green salamander habitat effectively reduce impacts from fragmentation? Additionally, our work and others (see Thomas et al. 2014) on interior forest birds suggested that edge species will potentially increase in landscapes developed for shale gas and that human disturbances greatly promote a "homogenization" of the bird community (Thomas et al. 2014). Are there particular forest management practices that could be implemented in "edge habitat" to lessen fragmentation impacts on interior forest birds? Can some of the indirect or cumulative impacts of fragmentation be mitigated or moderated through specific forest management actions?

- *Continue to systematically assess stream and forest habitats for rare and important species that serve as indicator of short- and long-term water quality change*. This provides information for direct protection of high quality aquatic ecosystems under Chapter 93 of DEP regulations and helps to avoid and reduce impacts in high quality or sensitive ecological areas, critical to the needs of rare, threatened, and endangered species. This specific activity does not single out shale gas development as the only cause of environmental degradation that can be avoided through protected stream status designation; however, the status requires developers to address conservation through avoidance measures. In addition to continuing to survey streams for reproducing trout species, we recommend continuing systematic surveys for American water shrew, eastern hellbender, and freshwater mussels – all species of high quality habitats which are indicators of development impacts.

- *Support policies and incentives to encourage development and implementation of best management practices to limit impact of development activities on high quality ecological areas and critical habitats*. Water is well regulated in Pennsylvania and special protections exist through DEP's Chapter 93 regulations. Streams supporting wild trout are further protected through PFBC regulations. However, high quality forests receive no such protection outside of DEP regulations enacted to protect critical habitats for threatened and endangered species. Critical interior forest habitats for interior bird species have been identified by TNC, Pennsylvania Audubon, and others, and best management practices for infrastructure siting, where possible, should be implemented to avoid direct and indirect impacts of development activities. Use of the PNHP Natural Heritage Areas information (http://www.gis.dcnr.state.pa.us/maps/index.html?nha=true) and new planning tools that will be included with the update to the PNDI tool in 2015 will also help inform management and siting decisions. Use of decision support tools during the planning and siting process, such as TNC's "In-Situ" program (Gagnolet et al. 2014), enable developers and planners to evaluate economic and ecological tradeoffs in site development, which can be very beneficial in protecting critical ecological resources.

- *Support establishment of a river basin commission for the Upper Ohio Basin an equivalent entity of jurisdiction to regulate water quantity or quality*. Water management plans are a critical component to maintaining the quality and quantity of water in Pennsylvania. Act 13, enacted in 2012, requires gas operators to obtain approval of a water management plan from DEP for use of surface water for hydraulic fracturing of any natural gas well (PA DEP 2015). For the Susquehanna River Watershed, water withdrawal from all streams is regulated by the Susquehanna River Basin Commission (SRBC). Likewise in the Delaware, the Delaware River Basin Commission (DRBC) regulates this activity, and also has jurisdiction over the quality of the water. The two river basin commissions in Pennsylvania not only regulate water use and its quality, they are able contribute significantly to efforts to monitor shale gas development activities and contribute to management. For example, the SRBC provides biological assessments on DCNR Forestry lands, which provides information to guide management on state land. There is no river basin commission for the watersheds of the Ohio River Basin of Pennsylvania, and water management plans are reviewed and approved by the DEP. A River Basin Commission, with the ability to regulate water use, and conduct its own monitoring activities would enhance the capacity to assess potential development impacts and proactively guide development.

- *Support the establishment of adequate setbacks from streams and springs through existing statutes such as the Pennsylvania Clean Streams Law*. Act 13 attempted protect stream buffers by requiring setbacks of between 100 and 300 feet from "blue-line" streams and springs (DEP 2015), however a Supreme Court decision struck down this provision. Buffers are critical to maintaining the quality of streams and rivers in Pennsylvania. While some operators have agreed to honor the buffer zones spelled out in Act 13, there currently is no standard buffer.

- *Provide support to land management agencies in monitoring efforts and provide information for adaptive management activities to avoid and minimize impacts from development of shale gas on state land*. Several of the focal areas in which our monitoring occurred over the past two years are on public lands. The Pennsylvania DCNR manages over 600,000 hectares (1.5 million acres) of forest land in the Marcellus Shale (DCNR 2014), with over 44 percent available for gas development; the DCNR continues to evaluate management decisions with a critical eye so that conservation and recreation values are maintained. WPC supports the standing moratorium on additional gas leasing of our state forest lands and we feel that the DCNR Bureau of State Parks is managing development on state lands well. The other large landowner in Pennsylvania is the Pennsylvania Game Commission (PGC) and the details of subsurface ownership and control of natural gas and minerals for lands managed by the PGC is unclear. The PGC has actively engaged in shale gas development activities, using some of the activities to promote certain wildlife species, primarily edge species. We will continue to encourage the PGC to take interior forest species into account when managing for shale gas and limit development of well pads, pipelines, roads, and other infrastructure through large areas of contiguous forest.

- *Seek opportunities to protect high value ecological areas through acquisition.* We continue to be concerned with cumulative ecological impacts of multiple shale gas development activities on high ecological value watersheds; securing these lands by purchasing them in fee or through conservation easements will work to reduce impacts by essentially placing surface development activities away from critical habitats or otherwise sensitive areas.

Limestone Run tributary in the Dunbar Creek focal area, Fayette County, Pennsylvania

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