Shale Oil and Gas Development: Potential Ecological Impacts in the Appalachians

HEALTH EFFECTS INSTITUTE WORKSHOP
SPECIAL SCIENTIFIC COMMITTEE ON POTENTIAL IMPACTS OF UNCONVENTIONAL OIL/GAS DEVELOPMENT
Pittsburgh, Pennsylvania  June 10, 2014

Nels Johnson, Pennsylvania Deputy State Director
POTENTIAL ENVIRONMENTAL IMPACTS

Air and Water Quality

• Surface Water Pollution
• Groundwater Pollution
• Air Pollution - VOCs, Ozone, Particulates
• Air Pollution - Methane and CO₂ Emissions

Ecological Condition

• Water Use – Quantity, Location, and Timing of Withdrawals
• Water Quality – Sedimentation and Nutrients
• Land Use Change – Habitat Loss, Fragmentation, Species Impacts
UNCONVENTIONAL GAS WELLS PERMITTED BY 2008

[Map of Pennsylvania and surrounding states highlighting locations with red dots indicating unconventional gas wells permitted by 2008.]

[Scale legend: 0, 15, 30 miles. Map credits: Copyright © 2013 Esri, Source: Esri, DeLorme, USGS, NPS.]
Rapid Rate of Development

Shale Gas Development in Bradford County - 2012

Natural Gas Pipelines*
- Built Transport Lines
- Proposed Transport Lines

Built Gathering Lines
- Proposed Gathering Lines

Shale Gas Wells**
- Drilled Wells
- Permitted Wells

* According to pipeline data from Bradford County, as of September 2012.
** According to permit data from PA DEP, as of May 2012.

“This map was created using County of Bradford Geographic Information Systems digital data, but this is a secondary product and has not been verified and is not authorized by the County of Bradford.”
Central Appalachians – Biodiversity Hotspot
ECOLOGICAL CONDITION

Water Use
- Quantity
- Location
- Timing

Water Quality
- Sediment
- Nutrients

Land Use
- Direct Habitat Impacts
- Indirect Habitat Impacts
- Species Impacts
Water Use – Quantity of Withdrawals

Maximum Approved Daily Consumptive Use

Maximum Approved Daily Consumptive Use (in mgd)

- Water Supply
- Power Generation
- Recreation
- Gas Drilling
- Manufacturing
- Other
- Mining
- Education

Current Estimate
Water Use – Location of Withdrawals

Photo: SRBC
Water Use – Timing of Withdrawals

Major flow types and flow needs of species and habitats in the Susquehanna River

- High Flow Events
- Seasonal Flows
- Low Flows

- High Flow-related needs
- Seasonal Flow needs
- Low Flow-related needs

- Channel maintenance and floodplain connectivity
- American Shad spawning migration, egg and larval development
- Overwinter habitat for Fish and Insects
- Resident fish spawning
- Egg, larval, and juvenile growth of fishes and amphibians
- Mussel spawning
- Water quality maintenance

Flow (measured in cubic feet per second, cfs)
ECOLOGICAL CONDITION

Water Use
- Quantity
- Location
- Timing

Water Quality
- Sediment
- Nutrients

Land Use
- Direct Habitat Impacts
- Indirect Habitat Impacts
- Species Impacts
Water Quality – Sediment and Nutrients

Photo: Patrick Drohan – Penn State

Photo: Josh Parrish – TNC
Water Quality – Sediment and Nutrients

Projections (Evans and Kiesecker, 2014)

- Shale development in Appalachians could increase impervious cover 1.5 million acres
- “Sensitive” category watersheds would decrease from 83% to 65% in Marcellus region while “Impacted” watersheds would increase from 13.5% to 25% and “Non-supporting” from 3% to 10%
- Not aware of any projections or observations on nutrients
ECOLOGICAL CONDITION

Water Use
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Measuring Land Use Change
Brittingham et al. 2013

- 4617 pads built or permitted
- 59% forest, 40% agriculture
- 31% in core forest
- Core forest declined from 43.5% to 33.5% in surveyed PA bird atlas census blocks
Land Use – Habitat Loss

Well Pads (3.2 acres/pad)

Photo: Mark Godfrey - TNC
Land Use – Habitat Loss

Access Roads and Other Infrastructure (6 acres/pad)

Gathering Pipelines (19 acres/pad)

Photo: Mark Godfrey - TNC
Land Use – Habitat Loss

Water Storage (3-15 acres/impoundment)

Photo: Mark Godfrey - TNC
Land Use – Habitat Loss

Compressor Stations (5 acres/station)

Photo: Mark Godfrey - TNC
Land Use – Other Direct Impacts

• Between 50-70% of pads built on soils and/or slopes prone to erosion

• 21% built on potentially wet soils with risk of drainage problems

• Alteration of acidic soils by application of fertilizer and lime may exacerbate invasive species spread and abundance

(Drohan and Brittingham, 2012)
### Direct Forest Habitat Loss/Well Pad

#### Average Habitat Loss Per Well Pad in Forest Areas (acres)

<table>
<thead>
<tr>
<th>Description</th>
<th>Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest cleared for Marcellus Shale well pad</td>
<td>3</td>
</tr>
<tr>
<td>Forest cleared for associated infrastructure (roads, water impoundments, etc.)</td>
<td>6</td>
</tr>
<tr>
<td>Forest cleared for gathering pipeline/well pad (1.6 miles)</td>
<td>19</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>28</strong></td>
</tr>
</tbody>
</table>

Source: Johnson et al. 2010; Johnson 2011
Land Use – Direct and Indirect Habitat Loss

Photo: Mark Godfrey - TNC
Edge Effects on Forest Interior Species

- Increased light
- Reduced humidity
- Increased invasive species
- Increased predation
- Increased storm damage (trees)
- Reduced mobility (animals)

Photo: Josh Parrish – TNC
Measuring Indirect Forest Impacts – Edge Effect

Pre-Construction 2006

Post-Construction 2008

<table>
<thead>
<tr>
<th>BEFORE</th>
<th>AFTER</th>
<th>IMPACT</th>
</tr>
</thead>
<tbody>
<tr>
<td>193 acres</td>
<td>174 acres</td>
<td>(-19 acres)</td>
</tr>
</tbody>
</table>

- Forest Patch
- Interior Forest Patch
- Marcellus Well Pad
- New Access Road

~3 acres directly cleared by well pad and road

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## Indirect Forest Habitat Impacts/Well Pad

<table>
<thead>
<tr>
<th>Average Edge Effect Per Well Pad in Forest Areas (acres)</th>
<th></th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest edge habitat created by pads, roads, and water impoundments</td>
<td>21</td>
<td>136</td>
</tr>
<tr>
<td>Forest edge habitat created by gathering pipelines</td>
<td>115</td>
<td></td>
</tr>
</tbody>
</table>

Source: Johnson 2011
## Total Forest Impacts/Well Pad

<table>
<thead>
<tr>
<th>Average Total Habitat Impact Per Well Pad in Forest Areas (acres)</th>
<th></th>
</tr>
</thead>
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<tr>
<td>Forest cleared for pads, roads, water storage and gathering pipelines</td>
<td>28</td>
</tr>
<tr>
<td>Forest edge habitat created by pads, roads, water storage, and gathering pipelines</td>
<td>136</td>
</tr>
<tr>
<td>TOTAL FOREST HABITAT IMPACT PER WELL PAD</td>
<td>164</td>
</tr>
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</table>

Source: Johnson et al. 2010; Johnson 2011
Geographic Projections for Marcellus Development

Modeled the relationship between:

- Drilled and permitted Marcellus wells (from PA-DEP data)
- Spatial variables related to geology and infrastructure:
  - Thermal Maturity
  - Shale Depth
  - Shale Thickness
  - Percent Slope
  - Distance to Roads
  - Distance to Pipelines
Geographic Projections for Marcellus Development

Medium Development Scenario
(10,000 new well pads by 2030 with an average of 6 wells per pad)
Projected Fragmentation of Large Patches

Medium Development Scenario

Large Forest Patches (> 1,000 acres)
- projected to contain Marcellus pads
- not projected to contain Marcellus pads
Projected Fragmentation of Large Forest Patches
## Projected Total Forest Habitat Impacts in PA

<table>
<thead>
<tr>
<th>Projected Total Forest Habitat Impacts in Pennsylvania by 2030 (acres)</th>
<th>Assumes 7,000 – 15,000 well pads, 12,000 – 25,000 miles of gathering lines</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DIRECT</strong></td>
<td></td>
</tr>
<tr>
<td>Forest cleared for pads, roads, water storage and gathering pipelines</td>
<td>100,000 – 250,000</td>
</tr>
<tr>
<td><strong>INDIRECT</strong></td>
<td></td>
</tr>
<tr>
<td>Forest edge habitat created by pads, roads, water storage, and gathering pipelines</td>
<td>600,000 – 1,500,000</td>
</tr>
<tr>
<td><strong>TOTAL POTENTIAL FOREST HABITAT IMPACT</strong></td>
<td>700,000 – 1,750,000</td>
</tr>
</tbody>
</table>

Note: Gathering Pipelines Will Cause Approximately 70 Percent of Projected Impacts Unless They are Co-located with Roads or Existing Utility ROWs
Observed Forest Habitat Impacts

Slonecker et al. 2012

• Bradford County lost 2,200 acres of forest due to Marcellus development between 2004-2010. 306 new forest patches created. Average patch size decreased by 11.2 acres to 102 acres.

• Washington County lost 2,600 acres of forest due to Marcellus development between 2004-2010. 984 new forest patches created. Average patch size decreased by 19 acres to 93 acres

• **Pipelines responsible for most new patches.** Unpublished CMU research shows that constraining pipelines to road ROWs dramatically reduces forest fragmentation (by up to 94%)
Projected Species Impacts – Rare Species

• 329 species tracked by the PA Natural Heritage Program have populations in areas with high probability of Marcellus development.

• 40% of those species are globally rare

• Some of those species are critically endangered or imperiled in Pennsylvania

Examples of species at risk:

Snow trillium (*Trillium nivale*)
73% of known populations

Green salamander (*Aniedes aeneus*)
100% of known populations
Projected Species Impacts – Eastern Brook Trout

PROBABLE MARCELLUS SHALE WELL PAD DEVELOPMENT WITHIN BROOK TROUT WATERSHEDS

Medium Scenario (10,000 new well pads by 2030)

Projected Species Impacts - Birds

Black-Throated Blue Warbler

High Scenario (15,000 new well pads by 2030)

Probable % Reduction in BT Blue Warbler Habitat

- 0%
- 0.1% - 5%
- 5.1% - 10%
- 10.1% - 44.3%
- BTBW Not Present
# Mechanisms For Terrestrial Species Impacts

<table>
<thead>
<tr>
<th>Temporary Impacts (Construction)</th>
<th>Long Term Impacts (Occupancy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Noise</td>
<td>• Habitat Loss</td>
</tr>
<tr>
<td>• Light</td>
<td>• Edge Effects</td>
</tr>
<tr>
<td>• Traffic</td>
<td>• Invasive Species</td>
</tr>
</tbody>
</table>
Human-associated species were more abundant in proximity to Marcellus development (robins, goldfinch, mourning dove, common grackle, house wren)

Forest interior species were less abundant near Marcellus development (black-throated blue warbler, magnolia warbler, red eyed vireo, oven bird, scarlet tanager)

Langlois and Brittingham (2013)
# Mechanisms For Aquatic Species Impacts

<table>
<thead>
<tr>
<th>Temporary Impacts (Construction)</th>
<th>Long Term Impacts (Occupancy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Water withdrawals</td>
<td>• Sediment</td>
</tr>
<tr>
<td>• Leaks/spills of flowback water</td>
<td>• Connectivity</td>
</tr>
<tr>
<td>• Sediment and nutrient delivery</td>
<td>• Shallow groundwater contamination</td>
</tr>
<tr>
<td></td>
<td>• Surface water contamination</td>
</tr>
<tr>
<td></td>
<td>• Invasive species</td>
</tr>
</tbody>
</table>
Observed Freshwater Species Impacts

- No statistical change in cold water fish, salamanders, and crayfish in 27 Susquehanna watersheds (Horowitz et al. 2013)
- Diatom abundance unchanged in higher conductivity streams but species composition changed significantly (Cohen, 2010)
- More than half of all individuals from 3 mayfly families died after 20-30 day exposure to concentrations of <0.5% produced water (Jackson et al. 2014)
- Survey of Eastern brook trout show no regional changes in population density between 1975-2011 but some watersheds with increased land development did show significant declines
- Eastern brook trout affected by low flows, sediment, barriers, and chemicals including TDS, metals, and surfactants (Weltman-Fahs et al., 2013)
Observed Habitat and Species Impacts

DCNR Monitoring Report (PA DNCR 2014)

• 568 of 3,000 projected shale wells (19%) have been drilled on DCNR State Forest lands.

• 191 new well pads, 104 miles of new pipelines, 30 miles of new roads, constructed on DCNR State Forest Lands between 2008-2012.

• 1,486 acres of forest cleared and 4,355 acres of edge habitat created, and loss of 9,242 acres of core forest patches greater than 500 acres.

• Invasive plants found at 77% of pad sites including 11 species. Most abundant was Japanese stilt grass (*Microstegium vimineum*).

• Stream monitoring at 300 locations showed no significant impacts on pH or conductance.

• Approximately 25% of pads, roads, and pipelines constructed on wet or erosive soils.
Ecological Impacts Summary

• Few observed impacts reported as of 2014 – and they are mixed – but monitoring results should start to build soon.

• Projected impacts give us primary insights into possible ecological outcomes (though technology advances could change assumptions).

• Habitat fragmentation rather than habitat loss is the primary mechanism of ecological impacts.

• Habitat generalists likely to prosper, habitat specialists likely to decline.

• Pipelines (especially gathering lines) are the most important threat to terrestrial and aquatic habitats.
Ecological Impacts – Research Priorities

ESTABLISH ECOLOGICAL THRESHOLDS TO MINIMIZE CUMULATIVE IMPACTS

• Forest Loss and Fragmentation
• Sedimentation
• Surface Hydrologic Alterations
• Noise and Light
• Well Density (relationship to air and water quality)

DEVELOP/TEST TOOLS FOR REDUCING ECOLOGICAL IMPACTS

• Habitat and Species Risk Assessment (Mitigation Frameworks?)
• Optimization of Infrastructure Siting
• Recommendations for Leading Practices
• Evaluate Effectiveness of Leading Practices

ECONOMICS OF LANDSCAPE VS SITE PLANNING/PERMITTING

• Permitting/Regulatory Delays Site vs. Landscape
• Allocated Financial Cost of Site vs. Landscape Approach
Discussion

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Photo: Martha Rial