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Reducing Ecological Impacts of Shale Development: RECOMMENDED PRACTICES FOR THE APPALACHIANS

ROAD DEVELOPMENT

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The construction and maintenance of roads to transport materials, equipment and resources accounts for a large part of the footprint of shale oil and gas development. In a single Pennsylvania county, 140 miles of road were constructed in a six-year period. Roads have the potential to degrade ecosystems through habitat loss and fragmentation; air, noise and light pollution; the spread of invasive species; and increased erosion and sedimentation. These effects can impact the behavior and distribution of wildlife and affect watershed health. Proper location, design and maintenance of roads can help lessen impacts on freshwater resources and wildlife habitats in the Appalachian region.

STATE OF THE RESEARCH

Extensive research exists regarding road design and maintenance, including studies specific to the Appalachian region. Studies show that poorly located, constructed and maintained unpaved forest roads can be considerably damaging to forest and stream ecosystems.[1-3]

The major effects of roads include direct mortality, barriers to movement, and changes in the behavior of wildlife; increased noise and visual disturbance from vehicles; habitat loss and fragmentation; spread of invasive plant species; and impacts to watershed health.[2-10] Impacts to the surrounding ecosystems can vary greatly from road to road, depending on the initial siting, slope, width, drainage system, support strength, surface material, ongoing maintenance, and the type, timing and volume of traffic.[11,12]

Wildlife responses to disturbances associated with roads vary as well, according to species, sex and age. Studies show many groups of wildlife being affected in some way by the presence of roads, including small and large mammals, birds, reptiles, amphibians, fish and plants.[8,13-19]

Road development is a permanent impact that alters the hydrology of an area, affecting stream habitat, runoff patterns and overall watershed health.[12,17,20,21] Improperly designed, constructed and maintained roads are often the single-greatest source of sediment to streams in forested landscapes.[1,2] Erosion and sedimentation can be of particular concern where roads cross or encroach on streams. Research on the impacts of individual roads is fairly extensive; however, few studies explore the potential cumulative impacts of road networks.[7] The risk of spills and leaks associated with the transport of fluids, mud, solids, waste and other materials via roads is not discussed in this document but is an additional threat to freshwater systems.

Shale development brings new roads and truck traffic to the Appalachian region. © Tamara Gagnolet, TNC

EVIDENCE OF IMPACT

Road Mortality

Vehicle-wildlife collisions are a direct impact of roads, including access roads for shale infrastructure. Rates of road mortality depend on the surrounding landscape and habitat features; road characteristics, like surface type, traffic volumes and road width; time of day and time of year; and species life stage, age and sex.[6–8] Some species are more vulnerable to the impacts of road mortality than others. Rare species that occur in small populations are especially vulnerable, while highly populated species might not be as severely impacted.[6] Individuals within a species, such as dispersing young and females migrating to nesting grounds, can be more susceptible to road mortality. These impacts, along with isolating populations and reducing gene flow, can affect local population dynamics.[4,7,22-24]

Mammals might be the most evident taxonomic group affected by road mortality. Higher road density increases the exposure of species to hunting because it allows access to otherwise remote areas.[25]

Amphibians and reptiles are particularly vulnerable to road mortality. Some species are relatively slow-moving, can be immobilized by headlights and vibration from traffic, and might also be attracted to the relative warmth of roads to regulate body temperature.[3,4,26] Mortalities more frequently occur during seasonal movements and between important habitats, such as wetlands.[4,7,27] Roads can also obscure olfactory and pheromone cues used in migration and orientation.[4] For example, male garter snakes have more difficulty following pheromone trails of females when they cross a road.[28]

Habitat Avoidance and Abandonment

Road avoidance behavior and habitat displacement have been documented in species of birds, reptiles and large mammals.[6,7,9,28-30] Displacement can reduce access to resources necessary for successful reproduction and survival. Noise from traffic and construction can cause some species to avoid roads or change activity patterns. For example, several bat species avoid foraging near roads because the noise from traffic affects their ability to communicate and echolocate.[6,7,31] Research suggests these changes are variable, depending upon species, sex, road type and traffic volume, but commonly increase where road densities are higher.[7,30,32]

Mammals sometimes exhibit road avoidance behaviors, and are displaced to less suitable habitats.[3,33,34] Studies have attributed changes in the abundance and distribution of black bears and other large mammals to the presence of roads. Some species will use roads as travel corridors if traffic is limited.[6,7,35-38]

Some amphibians, including the red-spotted newt, avoid forest-road edges and have difficultly crossing roads. © Kent Mason

Birds have also been shown to avoid habitat near roads, varying by species and traffic level.[7,39] For example, one study found no significant effects on bird distribution in response to low traffic levels, but as traffic increased so did the effects.[7]

Habitat Loss and Degradation

The development of roads not only causes habitat loss and fragmentation, but also reduces the quality of habitat in the surrounding areas by acting as a source of pollution in terms of erosion, noise, light, emissions, and products used in construction and maintenance (salts, chemicals, sediments).[6,7,30,32,34,40] Excessive sediment in cold water streams, which are common in the Appalachian region, can destroy food sources and cover for juvenile trout and reduce the reproductive success of mature fish.[41]

Soil compaction, edge effects and dust from road development can also

Timber rattlesnakes inhabit heavily forested habitat in the Allegheny Plateau – an area that might undergo significant landscape changes as a result of shale development, and have been shown to actively avoid roads.[23] © Anne Day

One of the biggest impacts of road and pipeline development is habitat fragmentation. © Mark Godfrey, TNC

contribute to declining tree growth and altered plant communities.[3] Dust from unpaved roads can reduce the ability of some plant species to photosynthesize, affecting growth rates and survival. Moreover, they might become unsuitable for wildlife to eat.[7,31]

Amphibians are also vulnerable to dust suppressants and other chemicals used to minimize airborne dust. Substances used to control dust have been associated with mass salamander deaths, and vehicular byproducts can affect reproduction and growth, as well.[4,26]

Increased Forest Fragmentation

One of the biggest impacts of road development is forest fragmentation. Fragmentation can alter the reproductive success, habitat use and distribution, and behavior of some species by creating edge effects, restricting the movement and dispersal of species, and accelerating the spread of invasive species.[3,5-7,10,42-44] The severity of the relationship between fragmentation and wildlife varies widely across species. Forest edges provide attractive habitat to some species, mainly habitat generalists (species that can thrive in a variety of environments), but are usually detrimental to habitat specialists (species that require a specific habitat or food source) and forest-interior species that are important and unique to the Appalachian region.[45-48] Evidence also suggests that fragmentation might be related to the extinction rates and thresholds of some species.[7,49,50]

Forest-interior birds are negatively impacted by forest fragmentation, mainly because of habitat loss and higher rates of parasitism and predation near forest edges.[51-59] For example, the cowbird, a species that lays its eggs in other birds' nests, are found along forest edges but not within interior forest areas.[56,60]

Edge Effects

Road corridors can create an abrupt change in habitat where the edge of the forest meets an opening. Openings change microclimate variables from those found in interior-forest areas, including changes to light and temperature, leaf-litter depth and moisture, and also provide favorable habitat for invasive species.[3,7,61-63] Research has shown measurable impacts from edge effects extending 330 feet into adjacent forest habitat.[61,64-67] Some animal and plant species are more sensitive to these changes than others.[64,68]

Similar to other environmental impacts, impacts from edge effects vary depending on many factors. Generally, the wider the corridor (which usually means more traffic, as well), the more severe the effects.[64] For example, one study found that salamanders were impacted by edge effects along a 12-meter-wide road, but not along a narrower, 5- meter-wide road.[22]

Barriers to Movement and Corridors for Invasion

Road corridors can restrict the movement of wildlife, isolate and reduce habitat, and accelerate the spread of invasive species.[3] Isolated populations have reduced gene flow, are less likely to survive environmental change and natural disasters, and are more prone to extinction. For many species, roads significantly decrease landscape permeability (the ability of an individual to move across a landscape), making it more difficult to reach necessary habitat or resources.[6,7]

Mammals might change their movement patterns to avoid roads, as previously discussed, and are more sensitive to roads with high traffic volumes.[6,7,9,28-30] For example, a black bear shows less hesitation crossing an abandoned forest road than a road with traffic.[69]

Amphibian and reptile movement can be inhibited even by relatively narrow, unpaved roads.[70,71] A study showed that spotted salamanders, marbled salamanders, pickerel frogs redback salamanders, wood frogs, and red-spotted newts strongly avoided forest-road edges and had difficulty crossing roads, particularly when there were steep roadside edges.[70,71] The inability to move

Narrower roads that preserve canopy cover can have less impact than wider corridors. © Tamara Gagnolet, TNC

into habitats used for breeding and wintering might severely affect population dynamics.[7,15,70,72]

Invasive plant species can use road corridors to spread into naturally unreachable forested habitats.[5,73,74] Seeds of invasive species can be dispersed by vehicles, equipment and people, as well as by water associated with road runoff.[31,40,73] Aside from accelerating dispersal, invasive species thrive in disturbed areas like roadside habitats.[61,73,75,76] The limestone gravel typically applied to road surfaces can also promote the establishment of invasive species by increasing the pH of the surrounding soils through dust and runoff.[73,77] Moreover, past land use has been shown to affect the spread and establishment of invasive species, meaning that a previously developed forested area has a higher probability of having invasive plants than an area that has not been developed.[73]

Watershed Impacts

Road development can alter stream habitat, increase erosion, change runoff patterns and impact overall watershed health, particularly near headwaters.[12,17,20,21] Improperly designed and maintained stream crossings can be especially damaging.[78,79] Consequently, the distribution of some fish species, including brook trout, and declines in spawning have been linked to road- and stream-crossing densities.[19,80,81] Wetland and riparian habitats are also sensitive to changes in hydrology caused by development.[6]

Improperly designed, constructed and maintained roads are often the single-greatest source of sediment to streams in forested landscapes.[1,2] Sedimentation rates are highest during the first years after construction and are influenced by rainfall, road slope, drainage management, road surface, traffic levels, road-base stability, and soil characteristics.[2,3,12,82,83] Generally, aside from traffic volume, road width and slope are the best indicators of sediment production.[1,12]

Road construction can be a significant source of sediment to aquatic habitat. © Mark Godfrey, TNC

Aquatic species can be adversely impacted by road development through loss of habitat and reduced habitat quality, changes in stream flow, loss of spawning areas, sediment and chemical runoff, and road-crossing structures that impede movement.[2,3,7,84] Sedimentation can harm naturally occurring algae and bacteria, which can have cascading effects throughout the ecosystem and reduce populations of aquatic organisms through mortality, reduced physiological function and habitat avoidance.[85,86]

CONSERVATION PRACTICES AND SCIENTIFIC SUPPORT

Scientific literature supports practices that reduce new road development by using existing corridors and sharing infrastructure to lessen the overall impact of roads on fish and wildlife habitat. The following practices are derived from management and guidance documents developed by state agencies, scientific/conservation organizations, and industry groups.

Use Existing Corridors

Scientific literature suggests that siting roads within existing corridors or along existing forest edge can reduce fragmentation and associated impacts.[5,8,10,64,87-90] Proper planning can help reduce the number, width and length of corridors; decrease maintenance requirements; and limit visual and physical impacts to forested environments.[2]

Existing conservation practices include planning at the landscape level and coordinating early with all stakeholders to promote shared infrastructure. When sharing or using existing corridors, roads might need to be upgraded to meet expected traffic volumes.

Properly Site New Development

Scientific literature suggests that proper road placement (i.e. siting) is the first step in significantly reducing

Top Resources for Road Development:

CLICK Penn State Center for Dirt and Gravel Road Studies

CLICK Environmentally Sensitive Road Maintenance Practices for Dirt and Gravel Roads

Co-location is important in reducing fragmentation; however, placing a pipeline beside a road creates a wider opening and more severe edge effects (foreground of photo) than maintaining canopy cover with a forested buffer between the pipeline and road (background of photo). © Pennsylvania DCNR

environmental impacts by reducing the number, width and length of corridors; decreasing maintenance needs; and reducing ecological risks.[2] Roads located near breeding and foraging areas, or that intersect wildlife corridors, are more likely to have higher mortality rates.[6]

Minimizing stream crossings, using natural contours to allow for proper sheetflow, establishing appropriate buffers, and implementing erosion control methods have been shown to lessen watershed impacts.[1,2,4,8,91,92] Shorter roads constructed on steep slopes often cost more to construct, maintain and reclaim — and also have greater ecological risks — than longer roads constructed on flatter terrain.

Existing conservation practices include avoiding the creation of new corridors and development in/on the following sensitive areas: steep slopes with greater than 10 to 15 percent grade, wetlands, large forested areas, rare or unique habitats, ridgelines, riparian areas, floodplains, lakeshores, areas subject to severe erosion, and important wildlife areas. When co-locating roads and pipelines, place the pipeline under the road or in the ditchline if safety regulations allow. Where this is not possible, use a forested buffer between roads and pipelines to reduce the severity of edge effects (i.e. maintain canopy cover). Additional practices include following topographic contours to preserve natural drainage patterns and to reduce risks of erosion.

Design and Construct to Minimize Impacts

Scientific literature suggests that keeping corridors narrow and preserving canopy cover can reduce the amount of runoff produced, avoidance behaviors, barriers to movement, dust, occurrence of edge and invasive species, microclimate variables, and other edge effects.[22,60,64,90,93,94]

Designing roads and stream crossings to accommodate the movement of water, sediment and debris during large storm events, and implementing practices that reduce erosion and sedimentation risks associated with soil excavation, movement and compaction can help lessen impacts of sedimentation to aquatic habitats.[1-3,95] Road materials can influence the amount of dust released and alter roadside vegetation and soil chemistry. Considering future uses of the road and landscape components (soil type, slope, vegetation, storm events, nearby aquatic habitats) during the planning, design and construction phases can reduce overall ecological impacts and assist in future reclamation efforts.[2,6]

Existing conservation practices include keeping road widths to a minimum; designing roads to fit within the landscape, when possible, to minimize excessive cut-and-fill construction practices; revegetating cut-and-fill slopes to stabilize soils and reduce the likelihood of invasive species establishment; and to reinforce and surface roads to withstand the anticipated volume, weight and speed of vehicles.[96] Use materials less likely to produce dust and alter roadside conditions. Practices also recommend constructing proper road drainage and erosion control for all roads, reducing road drainage connectivity to streams and wetlands, and avoiding "boiler plate" designs. Employ site-specific design and maintenance practices for each road.

Implement Maintenance and Seasonal Limitations

Scientific literature suggests that maintaining closed canopy cover over roads and a shrub layer (i.e. a diversity of young trees and shrubs) along a forest edge can reduce some edge effects.[22,62,63,91] Minimizing roadside disturbance, conducting proper maintenance activities, cleaning equipment as needed, and using appropriate techniques (e.g., mowing or herbicide application) can reduce the dispersal and establishment of invasive plant species.[73]

Regular monitoring and maintenance activities, including maintenance of drainage features that can deteriorate from heavy traffic and storms, can reduce adverse effects on aquatic

Scarlet tanagers rely on interior forest areas and are sensitive to fragmentation caused by roads. © Jacob W. Dingel

habitat.[1,2,43,97] Limiting heavy hauling on roads during the spring thaw, especially on roads with weak subgrades and poor road strength, and on roads located in close proximity to aquatic habitat can also lessen impacts.

Seasonally limiting road access through road closures and gating can benefit wildlife species such as deer, turkey, elk, and black bears by reducing avoidance behavior, road mortality, and illegal hunting.[5,6,16,93,98] Speed limits and road closures can also drastically decrease mortality rates, particularly during dispersal and breeding seasons of amphibians.[6]

Existing conservation practices include gating and closing roads to the public to minimize traffic, particularly during times of the year sensitive to wildlife; maintaining some form of vegetative cover, including native trees and shrubs in addition to native wildflowers and grasses, avoiding chemical spraying or dust-suppression activities near aquatic habitats; and conducting regular maintenance activities. Maintenance activities usually include regular inspections, surface repairs, ditch and culvert cleaning, and invasive-species management. Reducing speeds, allowing sufficient time between trucks, applying water to the road surface and preserving roadside canopy cover for shade can help to control dust.

TNC Recommended Conservation Practices

Based on scientific literature and existing practices, The Nature Conservancy recommends the following practices:

- **Plan at the landscape level**, using existing corridors and forest edges and co-locating infrastructure, to minimize forest fragmentation.
  - Keep corridors narrow and preserve canopy cover to reduce edge effects and follow natural contours.
- When developing new roads, **avoid and minimize the placement of roads in and near ecologically important habitats and areas subject to severe erosion.**
  - In the Appalachians, these areas include large forest patches greater than 1,000 acres, cave entrances, rocky outcrops, scrub oak/pitch pine barrens, freshwater habitats, floodplains, wetland and vernal pool complexes, seeps, bogs, fens, and slopes greater than 10 percent.
  - Infrastructure should not be encroach on ecological buffers necessary to support watershed condition and key wildlife habitats.
- **Construct and maintain proper road drainage and erosion control** consistent with U.S. Forest Service Environmentally Sensitive Road Maintenance Practices for Dirt and Gravel Roads. Use materials less likely to produce dust and that will not alter roadside soil and stream chemistry.
- **Regularly inspect and maintain roads,** particularly after storm events, to repair surfaces, apply water to control dust, clean and repair ditches and stream-crossing structures, and conduct invasive-species management.
- **Minimize traffic** by restricting road access, particularly during times of the year when wildlife are most sensitive to road mortality and during wet periods to minimize damage to roads and risks of erosion.

These recommendations are part of a suite of recommended practices intended to avoid and reduce impacts of shale development on Appalachian habitats and wildlife. These practices might need to be adapted to incorporate new information, consider operational feasibility, and comply with more stringent regulatory requirements that might exist.

Visit nature.org/shale-practices-refs for a list of references used in this document

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The Nature Conservancy is a science-based organization working globally to protect ecologically important lands and waters for nature and people. The Conservancy has assessed the ecological impacts of energy development in the Appalachians and advanced strategies and tools that reduce those impacts. This collection of documents stems from research by The Nature Conservancy that evaluated the scientific support for existing management practices related to surface impacts of shale development. The Nature Conservancy gratefully acknowledges generous financial support from the Colcom Foundation and the Richard King Mellon Foundation.