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FRACKING AND BIODIVERSITY: Unaddressed Issues in the New York Debate

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condensed and adapted for *News from Hudsonia* by Kristen Bell Travis

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Eastern states from New York to West Virginia are undergoing large-scale development of natural gas resources from the Marcellus shale. Recently it became economically feasible to exploit this source of gas via technology called high volume horizontal hydraulic fracturing (HVHFF, also called "fracking"). While New York has not yet permitted gas extraction by HVHFF, gas development using this technology has proceeded rapidly in Pennsylvania and West Virginia during the past few years. The New York State government will soon make decisions about whether and where to permit HVHFF in New York. If New York decides to permit HVHFF, areas of southern New York west of the Hudson River and the Shawangunk Mountains would potentially be available for gas extraction from the Marcellus shale. As of 2009, New York had 6,628 active "shallow" gas wells in 18 counties that used technologies other than HVHFF.¹⁹ Shallow wells in the Marcellus region would potentially be available for conversion to HVHFF if that technology is permitted in New York.

The impacts of HVHFF on water supplies, human health, and safety have received much justifiable attention during the past two years, but scientific study of impacts on biological resources is just beginning. Because of the magnitude of potential physical and chemical environmental impacts of HVHFF across the Marcellus region, and the potential threats to many uncommon and rare species and habitats, we perceived a critical need for analysis of impacts to biodiversity. Here we discuss potential individual and cumulative effects on habitats and species resulting from different aspects of HVHFF, and then draw attention to species that may be the most vulnerable to these effects.

HVHFF AND ITS IMPACTS

The gas-bearing Marcellus shale of New York, Pennsylvania, Ohio, West Virginia, Maryland, and Virginia occurs beneath the Allegheny Plateau.

In New York the Marcellus shale extends approximately from the Hudson River and the Shawangunk Mountains westward, south of the Mohawk River, to the western end of New York. The Marcellus shale is a blackish, organic-rich, Devonian shale about 400 million years old, and it contains large amounts of methane (natural gas) derived from anaerobic decay of the organic matter. The gas is tightly bound in pores within the rock.

Recently the HVHFF technology was developed to economically mine natural gas from gas shales. This technology constitutes drilling vertically to a depth of a mile or more to reach the Marcellus, then drilling horizontally for a mile or more, and forcing a mixture of water, sand, and chemicals into the shale to fracture the rock and release the gas. Gas and some of the water are then pumped from the well and the gas is cleaned and compressed for pipeline transmission. The "frack water" that returns to the surface is polluted with the chemicals forced into the well and other toxic substances from the shale itself. Drilling companies use diverse mixtures of fracking chemicals that include many very toxic substances.²³ An individual fracking installation, with its drilling pad, access road, and other facilities, may occupy 5 acres or more (average of 8.8 acres in a Pennsylvania sample).⁷ Pipelines and compressor stations that move the gas from the drilling areas create additional disturbance in the surrounding landscape.

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Wastewater. Among the most troubling impacts of HVHFF are those caused by wastewater. Ten to forty percent of the water forced into the well to fracture the shale returns to the surface with the gas. This frack water contains portions of the fracking chemicals as well as salt, naturally occurring radioactive materials, and heavy metals from the shale. Salt levels of frack water are sometimes, perhaps often, high compared to local fresh water. In theory, the wastewater is treated to remove pollutants before being discharged to the environment. In Pennsylvania, however, fracking wastewater is commonly stored in pits or ponds at the fracking installations, or disposed of in sewage treatment plants, most or all not designed to handle large volumes of industrial wastewater that contains non-traditional chemicals, salt, and radioactive materials. "Production brine" (i.e., salty return water from gas wells) might be allowed to be spread on roads in New York depending on levels of radioactivity in the brine, and storage of "flowback water" might be allowed in surface impoundments at some sites.¹⁸ Wastewater ponds are likely to attract semi-aquatic animals, such as waterfowl and other water birds, muskrat, turtles, frogs, and aquatic insects. Some of these animals will be poisoned by toxic substances concentrating in the wastewater ponds as water evaporates. A mass mortality of ducks occurred at tar sands wastewater ponds in Alberta,⁴ which illustrates the potential for trouble where toxic substances accumulate in open ponds or pits.

Wastewater can be injected into deep underground disposal areas or re-used for fracking, but it is not known how practical, cost-effective, or safe these practices will be. Even though some substances can be removed by treating wastewater, one of the most important pollutants, salt, is very expensive and impractical to remove. Brackish (salty) wastewater is expected to pollute streams and wetlands, rendering them unsuitable for many salt-sensitive freshwater organisms including salamanders, frogs, many fishes, and many freshwater plants. Brackish wastewater spilled or leaked onto soil would render the habitat unsuitable for many common and rare woodland plants including some trees, as well as many soil invertebrates.

Little information is available on the potential impacts of other fracking chemicals on streams, wetlands, or upland soils. Because some of these chemicals are known to be endocrine disruptors or carcinogens, we expect that these substances would cause harm to many stream, wetland, and forest wildlife species. In the Monongahela National Forest in West Virginia, HVHFF operations were allowed to dispose of frack water by spraying on the ground, resulting in mortality of forest vegetation.¹ Riverkeeper¹³ documented a large number of accidents at existing gas drilling installations that resulted in contamination of drinking water supplies or other impacts to human health and safety (also see Helman⁶). Many accidents of these kinds would harm wildlife and plants as well as people.

Air emissions. HVHFF can be a significant source of air pollution. Air emissions are produced by drilling rigs, diesel-powered pumps that create pressure in the wells, venting of some natural gas, and vehicular traffic. Pollutant emissions from natural gas drilling activities in the Dallas–Fort Worth region approximately equaled emissions from all car and truck traffic in that region.³

Between 2005 and 2009, hydraulic fracturing companies used 595 substances including 24 different hazardous air pollutants, among them hydrogen fluoride, hydrogen chloride, methanol, formaldehyde, ethylene glycol, and lead.²³ Volatile organic compounds (VOCs) including benzene, toluene, ethylbenzene, and xylene are emitted from wastewater during concentration and storage, engine exhaust, and compressor operation. Benzene and toluene are known human carcinogens; toluene affects the reproductive and central nervous systems; and ethylbenzene and xylene may have respiratory and neurological effects. Other air pollutants emitted by drilling operations include heavy metals, particulate matter, sulfur dioxide, and two precursors to the formation of ozone: VOCs and nitrogen oxides. Polycyclic aromatic hydrocarbons from diesel exhaust and wastewater pits are probable carcinogens that have been shown to have reproductive effects in animals. HVHFF also brings low levels of naturally occurring radioactive materials to the surface, a portion of which may become airborne. Some of these air pollutants would be toxic to trees and other plants where concentrated near drilling pads, as well as toxic to wildlife.

Habitat fragmentation. Large portions of the Marcellus region support extensive forests, and

many animals (and some plants) require large areas of continuous forest habitat in order to support viable populations. A dirt road through a forest may not significantly degrade habitat for a white-tailed deer that can readily cross such a road and is not harmed by changes associated with the road. The same road, however, may fragment habitat for a wood thrush if the road attracts nest predators, or for a ground beetle that has difficulty crossing even a dirt road or may be exposed to predators while doing so.

Areas of intensive gas drilling show forests fragmented by roads built for exploration, drilling pads, access roads, pipelines, and other facilities. Johnson⁷ presented data for 242 drilling pads on the Marcellus shale of Pennsylvania, about half of which were in forested areas. An average of 8.8 acres of forest was cleared for each drilling pad with its roads and other infrastructure. Assuming an ecological edge effect of 330 feet extending into intact forest from cleared areas, each drilling installation affected 30 acres of forest.⁷ In some areas of Pennsylvania, HVHFF installations occurred at a density of 1 per 40 acres, representing a very high degree of fragmentation. Johnson⁷ predicted that area-sensitive forest birds such as the black-throated blue warbler and scarlet tanager would be adversely affected.

A study in western Canada found that territories of the ovenbird, a ground-nesting warbler, did not straddle 25 foot wide cleared seismic exploration lines but did straddle 10 foot wide seismic lines.⁴ The wider lines fragmented ovenbird habitat, sometimes leading to local population declines. There is accumulating evidence that many forest songbirds avoid roads, trails, pipelines, and human activities.⁴ Other organisms that can be negatively affected by forest fragmentation include woodland pool-breeding amphibians, forest floor wildflowers with ant-dispersed seeds, and plants whose pollinators or herbivores are affected. American ginseng, an economically valuable medicinal plant, may be affected by forest fragmentation because the seeds have difficulty dispersing from one fragment to another.⁵

The New York State Department of Environmental Conservation (NYSDEC)¹⁸ stated, "Significant adverse impacts to habitats, wildlife, and biodiversity from site disturbance associated with high-volume hydraulic fracturing in the area underlain by the Marcellus shale in New York will



Fortuna Energy site (tract 587) in Tioga State Forest, PA, illustrating degree of forest fragmentation of a single HVHFF installation. Photo: Dick Martin of www.PAForestCoalition.org.

be unavoidable. In particular, the most significant potential wildlife impact associated with high-volume hydraulic fracturing is fragmentation of rare interior forest and grassland habitats... " and "Human induced openings can influence breeding bird productivity several hundred feet from the edge of the forest through increased predation and increased nest parasitism."

Other impacts. A single fracking episode may take several months, and a well may need to be fracked repeatedly at intervals of a few years in order to continue yielding gas. Each fracking episode requires about one to several million gallons of water, usually taken from lakes and river. The large volumes of **surface water extraction** required for HVHFF could affect plants and animals that depend on certain minimum water levels and flows during particular stages of their life cycles. Minimum instream flows are especially important to trout, freshwater mussels, and many other economically important or rare aquatic animals. **Soil erosion and siltation** caused by clearing and grading for the construction of drilling pads, access roads, and pipelines would very likely have a significant negative impact on water quality and the species that depend upon clean water in streams and wetlands.¹ Little or no precipitation water can infiltrate into the soil through the **impervious surfaces** of drilling pads and access roads, potentially leading to less groundwater recharge, altered stream flows, and increased stream siltation. Heavy **truck traffic** (for establishment and maintenance of HVHFF installations, in some cases transportation of water for fracking, and removal of wastes) will result in animals killed

on the roads, which for some species can cause population declines.⁴ Wildlife that is especially vulnerable to road mortality includes most turtles, snakes, salamanders, and frogs; ruffed grouse, eastern screech-owl, and many kinds of songbirds; small and medium-sized mammals; and a variety of insects. Gas drilling access roads and pipeline maintenance roads are likely to give **all-terrain vehicles (ATVs)** access into areas of forests and other habitats not easily reached otherwise. ATVs cause air pollution, soil compaction, erosion, and siltation of waterways; create water-filled ruts conducive to mosquito breeding; and make noise that disturbs animals. HVHFF installations are likely to be brightly lit at night. **Artificial night lighting** has many deleterious impacts on wildlife,²⁰ including the attraction and killing of night-flying aquatic and terrestrial insects, which could deplete the prey of stream fishes and bats. Gas compressors produce **loud noise** 24 hours per day. Noise can disrupt the behavior of wildlife that communicates acoustically, including birds, bats, frogs, and singing insects such as katydids and crickets.

Cumulative impacts. Impacts that occur at multiple sites separated in space or time may have additive or synergistic effects on biological resources. Cumulative impacts may also involve interactions of different impacts, such as the interaction of HVHFF impacts with those of coal mining, residential development, or climate change. Cumulative effects from many separated drilling installations on branches of a stream system may result in large impacts downstream. Salinity or toxic substances from wastewater,

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sediment from soil erosion, increased runoff from impervious surfaces, and spills and leaks of fracking chemicals would cause cumulative impacts on streams or wetlands.

IMPLICATIONS FOR THE BIOTA

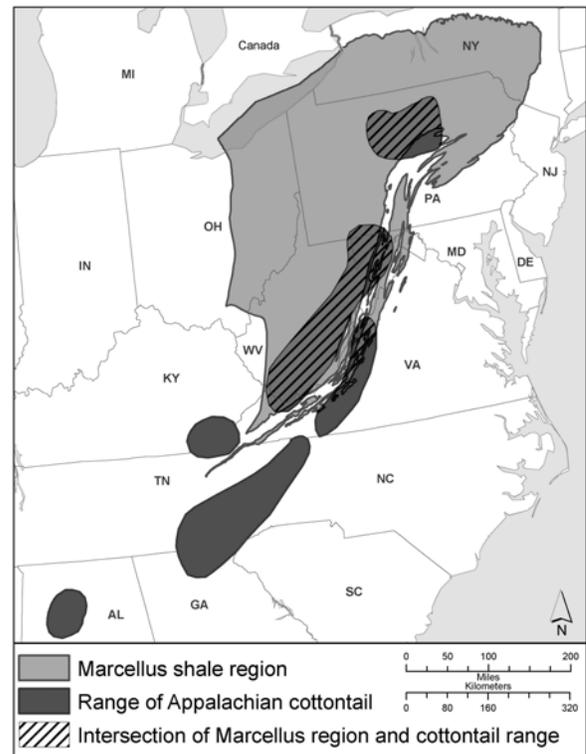
Streams would be among the habitats most vulnerable to the impacts of HVHFF, putting many rare, endangered, and “resource species” that depend on streams with good water quality at risk. Resource species include those organisms that people use directly for food or other purposes. Trout fishing, for example, is a widespread and economically important form of recreation on the Allegheny Plateau. Trout, and the native **brook trout** in particular, require high quality streams with cool water, high dissolved oxygen levels, adequate flow even in droughts, areas of suitable gravelly substrate for spawning, and otherwise good water quality. Removal of forest cover for drilling installations and their infrastructure would raise stream water temperatures. Higher temperatures and any additions of sediment from disturbed soils would reduce dissolved oxygen and degrade spawning habitats. Salt from frack water would kill many of the **freshwater aquatic insects** of the trout diet.

Other rare species would also be threatened by the degradation of stream quality associated with HVHFF development. The **eastern hellbender** (*Cryptobranchus alleggheniensis*) is North America’s largest aquatic salamander. In New York, it occurs only in the Marcellus region, in the Susquehanna and Allegheny river systems.¹⁷ This species evidently requires high levels of dissolved oxygen and is believed to be vulnerable to habitat degradation from siltation. In New York, four species of darters (small fishes in the family Percidae) are apparently confined to the Marcellus region: the **bluebreast darter** (*Etheostoma camurum*), **spotted darter** (*E. maculatum*), **banded darter** (*E. zonale*), and **variegate darter** (*E. variatum*).²¹ These are all species of flowing streams where they are likely to be sensitive to pollution by salt and sediment. **Freshwater mussels** (many species) are among the most endangered of American wildlife.²² Many of these animals are also among the most sensitive to water quality and hydrological conditions, and they can be affected by salinization, sediment inputs, and reduction of flows during dry periods. Portions of several major river systems in the Marcellus region support important populations of rare freshwater mussels. **Riverweed** (*Podostemum ceratophyllum*), a Threatened species in New York, is a small plant that grows on rocks in running water of good quality.¹⁵ Four of the seven New York counties in which it occurs²⁴ are partly or entirely in the Marcellus region. A preliminary study of stream chemistry and wildlife in Pennsylvania revealed elevated water conductivity and fewer species of salamanders and sensitive aquatic insects in small watersheds with HVHFF installations compared to watersheds without HVHFF installations.² As yet, because information on fracking chemicals is essentially limited to a list, it is hard to predict toxicological impacts of HVHFF on wildlife. A few species that are particularly sensitive to toxic contaminants may be assumed to be in danger, including **American mink**, **river otter**, **common muskrat**, **great blue heron**, **osprey**, and **bald eagle**.

Organisms that are restricted to the Marcellus region, or substantially so, will be under a higher level of threat from HVHFF. **Wehrle’s salamander** (*Plethodon wehrlei*) has most of its global range in the Marcellus region.

The endangered **Chittenango ambersnail** (*Novisuccinea chittenangoensis*) is apparently limited to a single locality in New York.¹⁴ This locality may be over the Marcellus shale or subject to downstream impacts from gas drilling in the Marcellus. The **West Virginia white** (*Pieris virginiensis*) in New York occurs only in the Marcellus region. This butterfly lives in forests in and near wet areas, and is not readily able to cross nonforested areas.¹⁶ The federally listed plant **monk’s-hood** (*Aconitum noveboracense*) in New York occurs primarily in the Marcellus region.

Bats, snakes, frogs, salamanders, land snails (exclusive of slugs), freshwater mussels, crayfish, aquatic insects, xystodesmid millipedes, submergent aquatic plants, orchids, true sedges (*Carex*), fern allies, stoneworts, liverworts, and peat mosses (*Sphagnum*), as well as the fauna of freshwater streams, may be especially vulnerable to HVHFF. These are some of the taxonomic groups found to be absent or low in diversity at a heavily urbanized and industrialized site, the New Jersey Meadowlands.^{8,9,10,11} Many of the impacts to the Meadowlands environment, including deforestation,



The Appalachian cottontail (*Sylvilagus obscurus*) is an atypical small rabbit that lives in high elevation forests and eats conifer needles. This animal was only recently recognized as a species distinct from the more northeasterly New England cottontail of shrublands east of the Hudson River. Photo © Carly Lesser & Art Drauglis



industrialization, fragmentation of the landscape, hydrological alteration, salinization, and chemical contamination, are analogous to those predicted to occur around HVHFF installations.

Although there might be an occasional rare native plant or animal—e.g., **Schweinitz flatsedge** (*Cyperus schweinitzii*)—that is able to exploit the industrial environment around an HVHFF installation, we think the noise, night lighting, activity of people and machines, salt, and toxic contamination would inhibit most uncommon or rare native species. The result, as is often the case in intensely industrial habitats, would be an assemblage of mostly common nonnative and native species. The compacted or eroded soils around new roads, drilling pads, and pipelines would be good environments for the establishment of weedy native plants, and nonnative plants such as **common reed** (*Phragmites australis* ssp. *australis*), **Japanese knotweed** (*Fallopia japonica*), and **stiltgrass** (*Microstegium vimineum*). Salinized soils around HVHFF installations would inhibit the growth of many typical native plants, and allow more competitive salt-tolerant species such as common reed to thrive. Warming and pollution of streams and other waterbodies by sediment, frack water, and removal of forest cover may well create more favorable conditions for nonnative fishes such as **common carp**, **green sunfish**, **snakehead**, and **weatherfish**. The common propensity of nonnative plants and animals to spread from intensely disturbed habitats into more natural habitats is cause for serious concern.

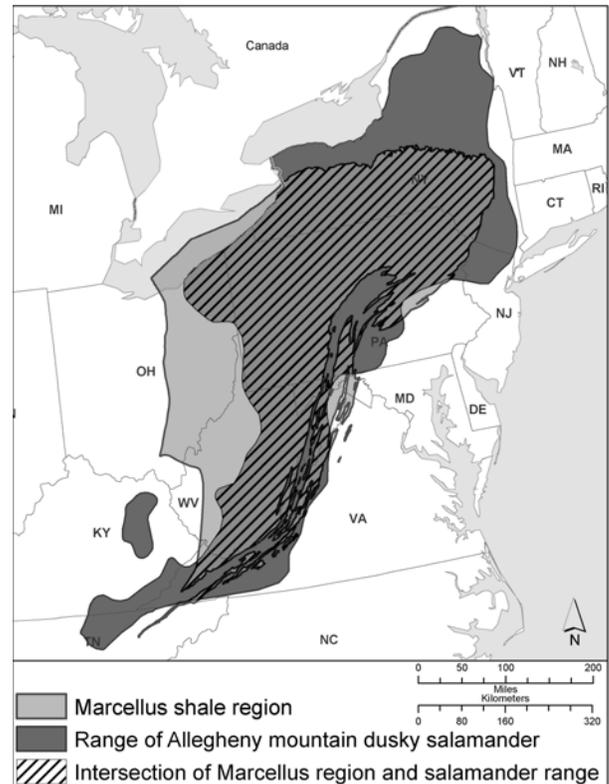
The Environmental Impact Statement on hydrofracking¹⁸ called for construction equipment and vehicles to be pressure-washed with hot water prior to delivery to sites where HVHFF wells are to be established, with the goal of preventing the arrival of nonnative species at the sites. However, HVHFF installations will host a steady stream of vehicles and equipment after well establishment and, in addition, nonnative plants can disperse along roads, pipelines, and electric rights-of-way without the help of trucks. In 2011, for example, we found many nonnative plants at sites of recent intensive disturbance, such as surface mines and logging areas, in the Catskill Mountain region.¹² Some of the less-common species that have not yet spread widely seem to be dispersing from disturbance to disturbance via roadways, heavy equipment, or vehicles, and we think that HVHFF installations would be effective “incubators” for incipient populations of some of these plants.

CONCLUSIONS

HVHFF as it is currently occurring in Pennsylvania is a very large scale and intensive industrial activity and land use with potentially severe impacts on wildlife and plants. In the Marcellus region, where natural gas resources are being intensively exploited by HVHFF, the impacts could be as great as those of the historic deforestation of the eastern states that took place in the 1700s and early 1800s.

Some of the impacts of HVHFF on biological resources can potentially be reduced or mitigated. Siting installations in already-altered areas rather than high quality habitats; reducing the width, length, and numbers of access roads and pipelines and the size of well pads; redesigning the chemical constituents of fracking fluids to use less toxic materials; treating some of the contaminants in wastewater; and strengthening legislative and regulatory controls on acceptable levels of contamination would all lessen impacts. The Environmental Impact Statement¹⁸ proposes some steps in that direction. It is unclear, however, what level of environmental review each permit appli-

The Allegheny mountain salamander (mountain dusky salamander, *Desmognathus ochrophaeus*) inhabits stream margins and riparian seeps. It superficially resembles the northern dusky salamander and both are sensitive to hydrological and chemical changes in their streamside habitats.
Photo © John MacGregor



cation for an individual well site will receive, and whether wetlands, streams, and rare species will be accorded appropriate consideration. Nonetheless, HVHFF is an activity that at best is very likely to have severe impacts on biological resources in the Marcellus region. In practical terms, HVHFF impacts are unlikely to be effectively controlled for financial, political, and regulatory reasons. The proposed additions to NYSDEC staff will help but in reality someone would probably have to monitor each HVHFF installation 24 hours per day to acceptably reduce the risk of spills, leaks, and other violations. One of the most important impacts, fragmentation of extensive forest habitats, may be impossible to control because HVHFF is by necessity a highly dispersed activity. Another very important impact, salinization from salt in frack waters, will be expensive and challenging to avoid, and drilling companies will probably not want to pay for this.

Our observations during many years in the Marcellus region, and our review of information on both shallow drilling and HVHFF in the Marcellus region and elsewhere, indicate strongly that many elements of biodiversity

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would be vulnerable to the impacts of HVHFF. These biological resources include not only economically important animals and plants such as trout, and a long list of other species of conservation concern, but also habitats including forests and wetlands that play crucial roles in maintenance of water quality and many other environmental services provided essentially free to human society. Avoiding or mitigating serious impacts to biodiversity and environmental services may cost more than industry, governments, and the public are willing to pay. ■

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JOAN EHRENFELD

Gone too soon

Joan Ehrenfeld, a professor of ecology at Rutgers University for many years, and a member of Hudsonia's Advisory Board, died in June 2011. She and her students conducted research across New Jersey, from the Pine Barrens to the Highlands to the Meadowlands. I had been in touch with her husband David from time to time due to a mutual interest in turtles, but did not work with Joan until 2001 when she provided very helpful comments on a draft of the long first paper about Meadowlands biodiversity that I wrote with colleague and then Rutgers graduate student Kristi MacDonald-Beyers. I discovered that Joan's interests and expertise were as wide-ranging as our attempt to treat the subject comprehensively. She was a pioneer in the study of urban wetlands, and had strong research interests in non-native plants, vegetation ecology, and biogeochemistry. I always enjoyed a conversation with her and I deeply regret there will be no more such discussions. Hudsonia has lost a good advisor and supporter, and the world of conservation science has lost a keen practitioner.

—Erik Kiviat

Donations in Joan's memory may be made to the New York – New Jersey Trail Conference (www.nynjtc.org/donatenow).