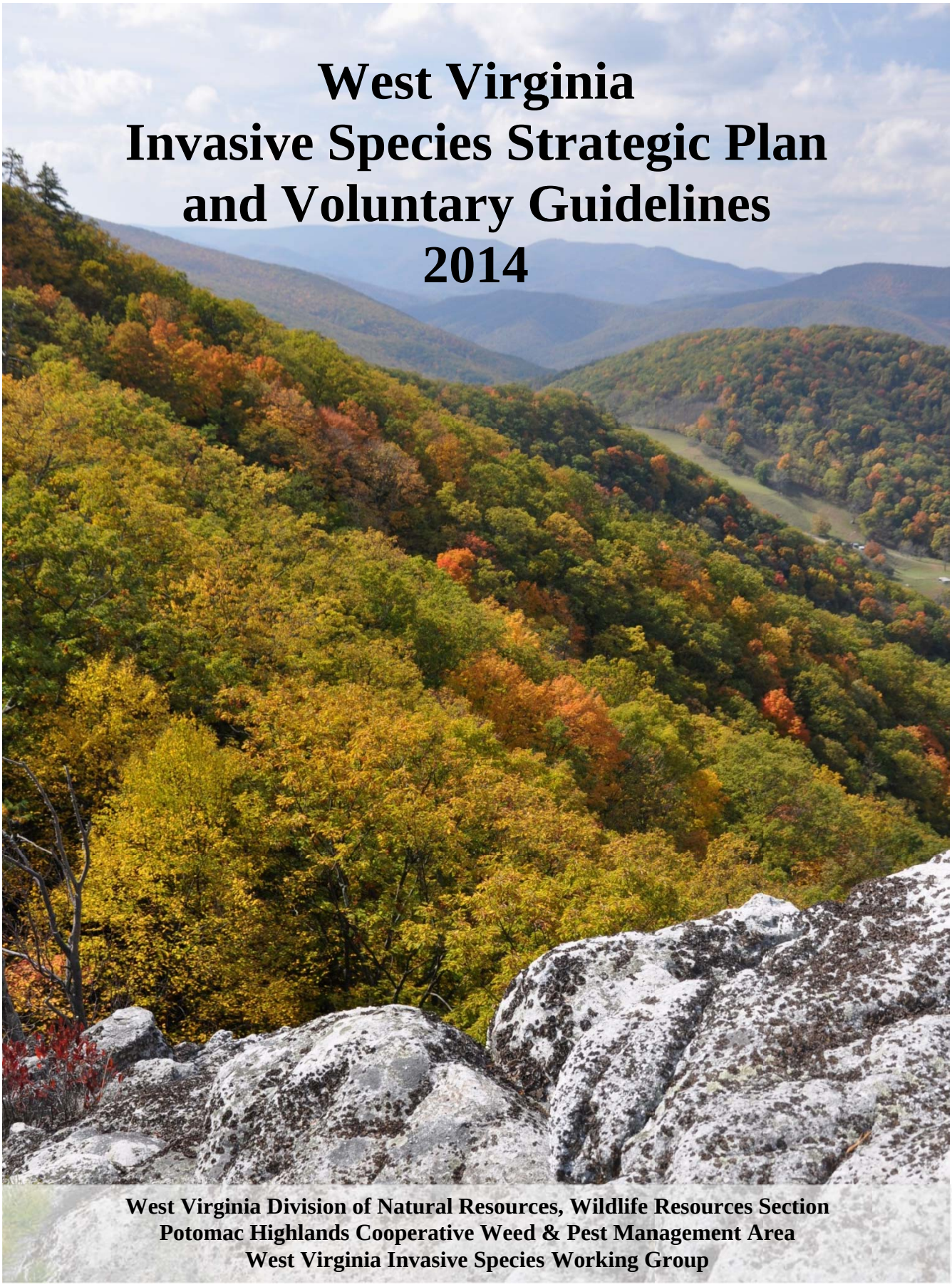
West Virginia
Invasive Species Strategic Plan
and Voluntary Guidelines
2014



West Virginia Division of Natural Resources, Wildlife Resources Section
Potomac Highlands Cooperative Weed & Pest Management Area
West Virginia Invasive Species Working Group

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EXECUTIVE SUMMARY

"Each federal agency whose actions may affect the status of invasive species shall, to the extent practicable and permitted by law…not authorize, fund, or carry out actions that it believes are likely to cause or promote the introduction or spread of invasive species in the United States or elsewhere unless, pursuant to guidelines that it has prescribed, the agency has determined and made public its determination that the benefits of such actions clearly outweigh the potential harm caused by invasive species; and that all feasible and prudent measures to minimize risk of harm will be taken in conjunction with the actions."

–Presidential Executive Order 13112, February 3, 1999

People have been moving plants and animals around the globe for thousands of years, but the ease of travel and scale of international commerce over the last century has facilitated the spread of non-native plant and animal species at an unprecedented scale. A small but significant percentage of these species are proliferating in their new environments and causing significant damage to ecosystems, economies, and human health. These are referred to as invasive species.

Presidential Executive Order 13112 defines an invasive species as, "an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health" (EO 13112, 1999). To be considered an invasive species for policy purposes, the negative effects that the organism causes or is likely to cause must outweigh any benefits it may provide (ISAC 2006).

Invasive species cost the world economy over one trillion dollars every year. Annual losses due to invasive species in the U.S. alone have been estimated at over $127 billion (Pimentel, 2011).

Every year, invasive species cost West Virginia millions of dollars. They threaten our natural resources, agricultural industry, outdoor recreation industry, human health, and overall economy. To reduce economic losses and maximize control effectiveness and efficiency, West Virginia's professional natural resource community has developed science-based administrative and management recommendations tailored to our state's situation and needs. These are described in Section III and summarized in Appendix A.

Recommended management goals in this strategic plan include all aspects of integrated pest management:

- Coordination
- Prevention
- Early Detection
- Rapid Response
- Control and Management
- Research and Risk Assessment, and
- Education and Outreach

Invasive species do not spread according to jurisdictional boundaries, and are most effectively dealt with on a regional or landscape scale. Management efforts are most effective when aligned with federal, regional, and state priorities. This plan incorporates landscape-scale priorities into state-specific recommendations, and provides consistent strategic direction across a wide variety of organizational and agency practices. It is intended to enable West Virginia and all entities operating within its borders to address the threats posed by all terrestrial and aquatic invasive species, including pathogens, which occur or may occur, in the state.

The guidelines contained within this plan are meant to be applied only as practicable, in whole or in part, and within the context of all pre-existing obligations, mandates, constraints, and enabling legislation. It is the hope of the authors that this will enable West Virginia to better address the threats and negative impacts of invasive species throughout the state, for the benefit of all those who live, work, and play in Wild, Wonderful West Virginia.

I. INTRODUCTION

WHAT ARE INVASIVE SPECIES, AND WHY ARE THEY A PROBLEM?

The National Invasive Species Management Plan (NISMP) defines an invasive species as, "a species that is non-native to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health" (NISC, 2008).

Plant and animal communities naturally shift in distribution and composition over geological time, but human activity and climate change have dramatically increased the rate at which new species are introduced to landscapes and watersheds. The past century has been marked by increasingly rapid and varied movement of goods around the globe, which has facilitated both intentional and accidental introductions of plants, animals, and pathogens to new environments (Elton, 1958; Pimental, 2000).

Many introduced species are benign or beneficial to humans, and most do not survive or reproduce successfully outside of human care. Some become naturalized (i.e., reproduce and persist) but do not spread significantly or impair native ecosystems.

However, some introduced species possess or develop characteristics that enable them to aggressively and quickly colonize large areas of their new surroundings (Rejmanek, 1996). These traits include rapid growth to maturity, prolific reproduction, being able to reproduce multiple times within a year, and high tolerance for disturbed and varied habitats (Allendorf, 2003). Rapid adaptation to changing conditions (Colautti and Barrett, 2013), novel weapons such as allelopathy (Van Kleunen, 2010), and lack of local predators and pathogens (the enemy release hypothesis (Keane and Crawley, 2002)) also contribute to their success. This suite of traits and their effects on invasives' competitive ability is termed Evolution of Increased Competitivity hypothesis (Blossey, 1995; Uesugi, 2013).

Assessing the potential impacts of newly-introduced or newly-established non-native species can be challenging for policy makers and land managers, and there is still scientific debate regarding the circumstances under which an established non-native species should be considered invasive rather than just naturalized (Hegar et al., 2013).

When species expand to such a degree that they impair native ecosystems and compromise the economic and societal benefits those ecosystems provide, they are generally considered invasive.

A non-regulatory, policy-oriented explanation of the term "invasive species" is available from the Invasive Species Definition Clarification and Guidance White Paper, written by the Invasive Species Advisory Committee (2006) for the National Invasive Species Advisory Council: www.invasivespeciesinfo.gov/docs/council/isacdef.pdf.

Invasive species have had devastating impacts on native flora and fauna, agricultural productivity, recreational opportunities, commercial and urban forest resources, human health, and ultimately local economies in the eastern United States (Moser et al., 2009). Annual damage and control costs associated with management of invasives in the U. S. have been estimated to exceed $127 billion a year (Pimentel, 2011).

West Virginia's economy is heavily reliant on natural resource-based industries such as forest products, agriculture, extractive industries, and outdoor recreation and tourism. The wood products industry in West Virginia exceeds $2.5 billion annually and accounts for nearly 11,000 jobs (PHCWPMA, 2013). The Outdoor Industry Association calculates that in West Virginia alone, outdoor recreation creates an additional $7.6 billion in consumer spending every year, $2.0 billion in wages and salaries, 82,000 jobs, and $532 million in state and local tax revenue (outdoorindustry.org/advocacy/recreation/economy.html). Invasive species cost these industries and the state millions of dollars every year in decreased productivity, lost revenue, monitoring, control, staff time, and resources (Sherrie Hutchinson, personal communication 10/8/13; John Perez, personal communications, 4/26/13 and 7/11/13; Quentin Sayers, personal communication, 11/17/13).

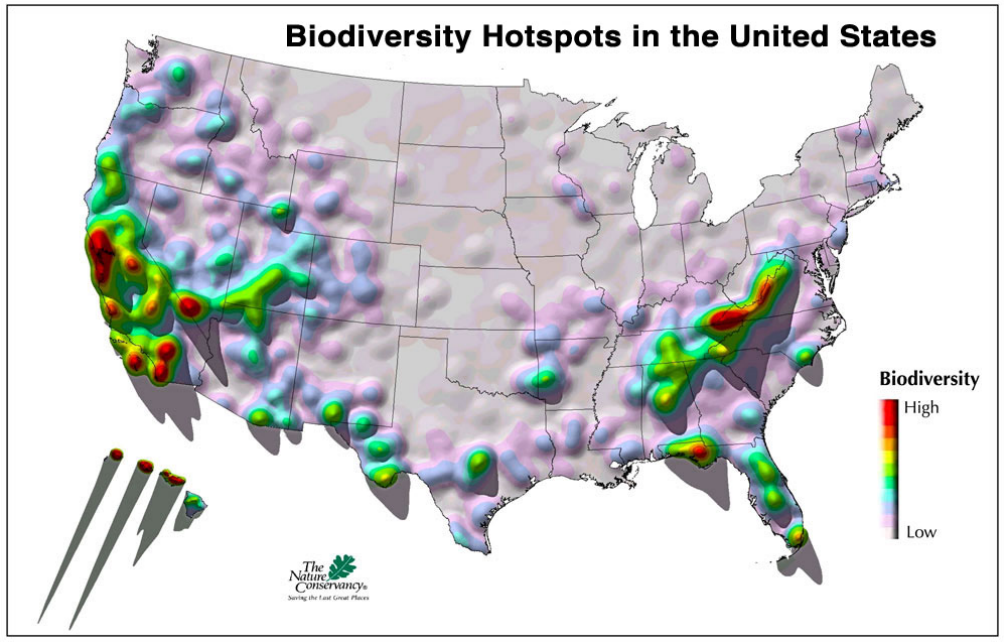
West Virginia forests contribute to quality of life in the region through a variety of ecosystem services. They absorb pollution, protect watersheds from erosion and sedimentation, and provide for long-term carbon sequestration. Invasive species damage forest health and impair their ability to serve these vital functions (IUCN, 2008).

West Virginia's rivers and streams are part of a network that hosts the highest number of endemic freshwater fauna in North America (worldwildlife.org). Some of the premier trout fishing streams in the eastern half of the country are found in the state's eastern highlands. Aquatic invasive plants and animals threaten recreation and biodiversity in many of these waterways.

As shown in Figure 1, The Nature Conservancy has designated the Central and Southern Appalachians as one of six biodiversity "hotspots" in the nation (TNC, 2000). West Virginia's rare ecosystems such as wetlands, limestone and shale barrens, prairies, glades, and karst are home to many rare, threatened, endangered, and endemic species. Widespread habitats such as northern hardwoods, oak-hickory, and cove forests also host a variety of economically and biologically important species. West Virginia hosts some of the greatest ecological diversity in the United States, and is one of the most critical areas in the nation for preserving biodiversity in context of a changing climate.

As climate change progresses, West Virginia's natural areas will serve as essential corridors and climate change strongholds for many species. West Virginia's flora, fauna, and economy, now and in the future, depend on these areas being healthy and productive. Invasive species are one of the leading causes of global biodiversity loss (Pimentel et al., 2005, Lowe et al., 2000, Stein and Flack, 1996), and threaten every component of these critical ecosystems.

Figure 1: Biodiversity Hotspots in the United States



The Nature Conservancy, 2000

DEVELOPMENT OF THE STRATEGIC PLAN: LEGISLATIVE CONTEXT, HISTORY, AND PARTICIPANTS

Federal and state governments have recognized the threat of invasive species for decades. The federal government passed the Federal Noxious Weed Act in 1974, and the West Virginia Legislature passed its Noxious Weed Act in 1976. This legislation incorporates by reference the entire Federal Noxious Weed list, and is intended to deal primarily with species harmful to agriculture and silviculture, though it does include a few other well-known invasive plants such as Japanese knotweed (*Fallopia japonica*) and multiflora rose (*Rosa multiflora*). West Virginia also implemented a white pine blister rust quarantine in 1967.

The 1980s saw little policy movement on invasive species, but in 1990, the federal government passed the Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA), which established a Federal Aquatic Nuisance Species Task Force (ANSTF). The Federal Interagency Committee for the Management of Noxious & Exotic Weeds (FICMNEW) was established by a Memorandum of Understanding among various federal agencies in 1994, and the National Invasive Species Act (NISA) (a reauthorization and amendment of NANPCA) followed shortly thereafter in 1996. The NISA provided authorization and guidance for states to develop invasive species management plans. During that decade, the West Virginia Department of Agriculture also implemented additional quarantines for pathogens (barberry and black stem rusts) and animals (non-native plant-feeding snails and gypsy moths), and state botanists also began to raise the alarm about invasive plants (Harmon, 1995).

On February 3rd, 1999, President Clinton signed Federal Executive Order (EO) 13112, which defines invasive species as, "alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health". The purpose of the order is to "prevent the introduction of invasive species and provide for their control and to minimize the economic, ecological, and human health impacts that invasive species cause." The Order directs federal agencies to prevent, detect, respond to, monitor, and research invasive species; conduct restoration and education; and not cause introduction or spread of invasive species. Executive Order 13112 also created the National Invasive Species Council (NISC) and the Invasive Species Advisory Committee, and directed the NISC to work with the FICMNEW.

The federal legislation passed during that decade demonstrated that invasive species were recognized as a national problem, and that states had a critical role in addressing the issue. In October 2001, the WVDA Plant Industries Division convened the first meeting of the Invasive Species Working Group (WVISWG), with a focus on education and information-sharing. To address concerns raised by The West Virginia B.A.S.S. Federation about largemouth bass virus, the West Virginia legislature enacted a bill in 2003 which gave regulatory authority to the West Virginia Division of Natural Resources (WVDNR) over certain stocking practices (Jernecjec, 2004). Six years later, in 2007, the state enacted the Plant Pest Act.

In 2009, recognizing the need for more coordinated action at the state level, the WVISWG formed a sub-committee to draft a state strategic plan. The sub-committee included representatives of state and federal natural resource agencies, agriculture, transportation, academic researchers, and non-profit conservation organizations. In 2013, a full-time staff person was hired to coordinate the final drafting of the plan, through a grant funded by ANSTF, the WVDNR, and West Virginia University.

Invasive species management is a dynamic and growing field. This strategic plan is meant to be an evolving document that will be revised and updated every three to five years, guided by progress, accomplishments, and new discoveries.

SCOPE, PURPOSE, AND GOALS

This plan is intended to enable West Virginia and all entities operating within its borders to address the threats posed by all terrestrial and aquatic invasive species, including pathogens, which occur or may occur, in West Virginia.

Since invasive species do not follow jurisdictional boundaries, they are most effectively dealt with on a regional or landscape scale. Operational, species, land management, and site construction plans that deal with invasive species will therefore be most effective if aligned with federal, regional, and state invasive management priorities. This plan makes that possible by incorporating landscape-scale priorities into state-specific recommendations.

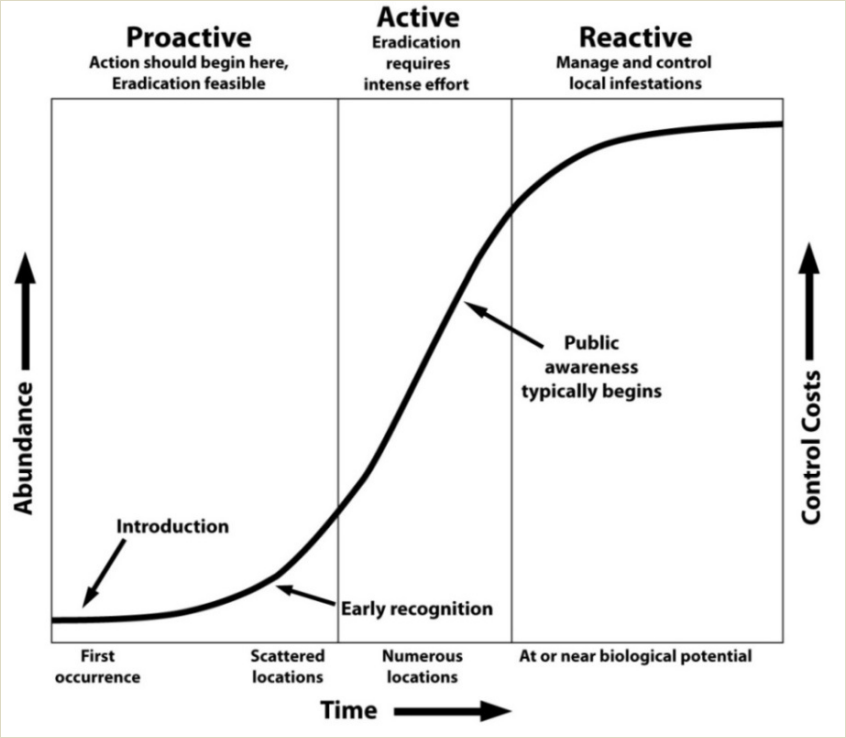
This plan is designed to serve as a guidance document, to be incorporated in whole or in part and as practicable, into relevant organizational and agency practices.

Administrative goals will support the plan's management goals, which include:

- Coordination
- Prevention
- Early Detection
- Rapid Response
- Control and Management
- Research and Risk Assessment, and
- Education and Outreach

Figure 2 illustrates the process of invasive species awareness and control. The goal of this plan is to maximize the effectiveness and efficiency of all stages of invasive species management efforts that occur wholly or partially within the state of West Virginia.

Figure 2: Phases of Invasive Species Invasion and Control



Center for Invasive Species and Ecosystem Health, University of Georgia. www.eddmaps.org/about/pictures/9.jpg

II. Invasive Species in West Virginia

Types of Invasive Species in WV

Standard taxonomic divisions are applicable but insufficient for a holistic discussion of invasive species. The very designation of "invasive" implies ecological threats and management requirements, so in categorizing them it is sometimes useful to consider how they are managed, as well as their taxonomic rank. For example, insects and pathogens have disproportionately large economic impacts compared to most other animals, and are the target of numerous federal and state eradication and control programs. Therefore, in the discussion below, they are described separately from other animals. Aquatic animals and plants are discussed together because aquatic habitats come with unique management challenges, regardless of species. The following discussion reflects this management-oriented approach. For lists of invasive species currently known to exist in West Virginia, please refer to Appendix B.

Terrestrial plants

Out of over 800 non-native plant species established in West Virginia, nearly 500 are considered invasive in some area of the United States (www.eddmaps.org/tools/stateplants.cfm?id=us_wv). Over 270 have been documented as being invasive in West Virginia, and approximately 36 percent of these are ranked as posing moderate to high threats (WVDNR, 2009). These are listed in Appendix B. Invasive plants affect nearly every habitat in West Virginia, from the common oak-hickory forest to rare limestone glades. They easily become established and spread near roads, trails, developments, and other disturbed areas. They can also be transported to remote wilderness and undeveloped areas by human activity and natural seed dispersers such as animals, wind, and water. Pyšek and Chytrý (2013), in a review of large vegetation datasets, found that the habitats most likely to be invaded are characterized by fluctuating availability of resources, especially nutrients, and most of these habitats are frequently or strongly disturbed.

Many, such as multiflora rose, kudzu (*Pueraria spp.*), Japanese knotweed, tree-of-heaven (*Ailanthus altissima*), and autumn olive (*Elaeagnus umbellata* var. *parvifolia*) were initially introduced to the U.S. in the 19th and 20th centuries for ornamental, agricultural, or even restoration purposes (Bergmann and Swearingen, a, b, c, nps.gov; Fryer, 2010; Munger, 2003). Others, such as Japanese stiltgrass (*Microstegium vimineum),* were introduced accidentally (www.nps.gov/plants/alien/pubs/midatlantic/mivi.htm).

Asiatic tearthumb and garlic mustard. Clark Owen.

Terrestrial animals

Invasive terrestrial animals in West Virginia include rodents, birds, feral cats, and feral hogs.

Hundreds of millions of European starlings (*Sturnus vulgaris)* occupy urban and agricultural habitats across the United States. English sparrows (*Passer domesticus*) and brown-headed cowbirds (*Molothrus ater*, brood parasites native to prairie ecosystems), are also significant competitors with native songbirds (Rich Bailey and Jim Fregonara, personal communications, 9/11/13 and 10/15/13).

Feral cats (*Felis catus*) are listed by the Global Invasive Species Database as one of the top 100 worst invasive species globally (www.issg.org). Every year, cats kill over 1 billion birds in the U.S. alone, and several billion small mammals (The Wildlife Society, 2009).

Destructive and aggressive feral hogs are a growing problem in southern West Virginia, with some populations approaching one hundred individuals (Jeff Hajenga, personal communication 9/22/14).

Insects

More than 450 non-native insect pests are known in the United States, and dozens of these affect West Virginia's forests, agriculture, parks, and residential and business properties. Several of the more well-known include gypsy moth (*Lymantria dispar*), emerald ash borer (*Agrilus planipennis*), hemlock woolly adelgid (*Adelges tsugae*), and brown marmorated stink bug (*Halyomorpha halys*). Balsam woolly adelgid and Asiatic ladybug beetles are also having significant impacts.

Gypsy moths, introduced in Massachusetts in 1869 for silk production, were first found in West Virginia in the early 1980s and now occur in half the state. They eat the leaves of many hardwoods, reducing forest functionality and aesthetics, and can cause rashes and irritation of the eyes or respiratory tract after exposure to caterpillars (USDA, 2012).

Emerald ash borer and tunnels.

Image courtesy of VA Cooperative Extension, VA Tech, and Virginia State University.

The emerald ash borer was first detected in June of 2002 in south-eastern Michigan. The beetle eats the cambium of the tree, girdling and killing it within 2-3 years of infestation. It is estimated that emerald ash borer has killed between 50 and 100 million trees in the U.S. since 2002, and threatens all 7.5 billion ash trees on the continent. It is currently considered "the most destructive forest pest ever seen in North America" (McCollough and Usborne, 2013). First found in West Virginia in Fayette County in 2007, emerald ash borers have spread to 35 counties as of 2014 (Eric Ewing, personal communication, 8/5/14).

The hemlock woolly adelgid is a sap feeder that is deadly to hemlock trees. The loss of hemlocks dramatically changes forest composition, decreases breeding habitat for birds, and exposes high elevation cold water trout streams to increased sunlight and sedimentation. As of this writing, hemlock woolly adelgid is found in 48 (out of 55) counties in West Virginia (Quentin "Butch" Sayers, personal communication, 8/4/14), and is expected to extirpate most of the eastern hemlock trees in its range.

The brown marmorated stink bug is an agricultural pest that arrived in eastern Pennsylvania in the late 1990s. It feeds on at least 170 kinds of ornamental and horticultural crops and has quickly become a severe pest. It is also a household nuisance, eating house plants and overwintering in large numbers in some residences. First detected in West Virginia in 2004, it has caused severe crop losses for stone fruit and pome fruit growers (Leskey, 2010).

Pathogens

Introduced pathogens have wrought significant ecological changes in West Virginia. The chestnut blight, first described in the U.S. in 1905 by mycologist William Murrill, virtually eliminated a dominant tree species throughout its range by 1940. Within one human generation, the world economy lost a valuable timber tree; deer, squirrel, and turkey lost a primary mast source; and Appalachian hardwood forest communities were transformed forever (Rogerson and Samuels, 1996). Today's forests are under threat from pathogens such as beech bark disease, white pine blister rust, and caliciopsis canker.

Animal pathogens wreak havoc on ecological communities. Since 2006, a European fungus that leads to white-nose syndrome has killed over 5.7 million bats in over 20 states in eastern North America, often causing 90-100% mortality in affected hibernacula (whitenose syndrome.org). Amphibians worldwide are being decimated by strains of chytrid fungus and rana virus (Whittaker and Vredenburg, 2011 and Green, 2012), and it is theorized that movements of amphibians for the food and pet industry have contributed to their spread (www.amphibianark.org/the-crisis/chytrid-fungus).

Viral hemorrhagic septicemia, or VHS, is a highly contagious fish pathogen that was discovered in the Great Lakes in 2002 (www.invasivespeciesinfo.gov/microbes/vhs.shtml). It affects at least 28 species of both freshwater and saltwater fish, and causes catastrophic fish kills (www.dec.ny.gov/animals/25328.html).

Aquatic Species

Invasive plants and animals pose a significant threat to West Virginia's aquatic ecosystems.

Hydrilla (*Hydrilla verticillata*) grows thickly and interferes with boating and swimming. Yellow iris (*Iris pseudacorus*) alters local hydrology in rare limestone wetlands, disrupting these delicate habitats (Sarver et al, 2008). Didymo (*Didymosphenia geminata*), a type of single-celled algae, smothers native brook trout breeding sites and deprives eggs of oxygen, decreasing reproductive success (sites.duke.edu/aquaticinvasives/tag/didymo/).

Zebra mussels (*Dreissena polymorpha*) were first observed in the Ohio River system in West Virginia in the early 1990s, and spread rapidly. After an unexplained population crash in 2000, they remain widespread and locally impactful in the Monongahela, Kanawha, Ohio, and Little Kanawha rivers (Patricia Morrison, personal communication, 10/21/13).

Rusty and virile crayfish (*Orconectes rusticus* and *O. virilis*) out-compete native species and reduce biodiversity (Lodge et al., 2000).

Silver carp (*Hypophthalmichthys molitrix*), notorious for leaping out of the water and injuring boaters and recreationists, are spreading through the Ohio River drainage. In coordination with other Ohio River Basin states, West Virginia is developing an Asian carp action plan and is participating in monitoring efforts to better understand carp movement and develop control measures (wvdnr.gov/Fishing/Asian_Carp.shtm).

Biologists anticipate that snakehead fish (*Channa argus*) will also soon be found in West Virginia waterways (Chris O'Bara, personal communication 11/5/13).

Left: Zebra mussels growing on federally endangered fanshell mussel, *Cyprogenia stegaria.*
Right: native snail completely smothered by zebra mussels.
Photos: Janet Clayton, WVDNR

ECONOMIC IMPACTS OF INVASIVE SPECIES

Annual losses due to invasive species in the U.S. have been estimated at over $127 billion (Pimentel, 2011). This amount includes damage to crops and pasture, forest losses, damage from insect and other invertebrate pests, human diseases, control costs, and even loss of residential value (Aukema et al., 2011). Annual damage to agricultural and livestock production in the U.S. totals $65 billion every year (Pimentel, 2011). Control measures cost the U.S. $14 billion a year (Pimentel, 2011).

West Virginia spends millions of dollars every year to mitigate the impacts of invasive species on forestry, agriculture, natural resources, and recreation (John Perez, personal communications, 4/26/13 and 7/11/13; Sherrie Hutchinson, personal communication 10/8/13; Walt Kordek, personal communication, 10/9/13; Quentin Sayers, personal communication, 11/17/13). As costly as it is, preventing invasion is far more cost efficient than trying to control established infestations: the Oregon Department of Agriculture found that weed management programs yield a 34:1 benefit to cost ratio (ODA, 2000).

Agricultural and Forest Resources

Agriculture contributes over $710 million to West Virginia's economy every year (www.crop insuranceinamerica.org/wpcontent/uploads/ westvirginia1.pdf). The forestry and wood products industry is second only to coal in economic impact to West Virginia, contributing over $4 billion annually as of 2005 (WVDOF, 2005). Every year non-native insect pests take a significant toll on production and revenue in both these industries.

The West Virginia Division of Agriculture collaborates with the West Virginia Division of Forestry (WVDOF), the United States Forest Service (USFS), and other agencies on programs targeting high priority species such as gypsy moth, emerald ash borer, hemlock woolly adelgid, and brown marmorated stink bugs.

Other programs survey for species not established in the state, such as the Asian longhorned beetle (*Anoplophora glabripennis*) (which has been found just 50 miles from the WV border—Cindy Sandeno, personal communication, 1/22/14), fire ants (*Solenopsis invicta*), and Africanized honey bee (*Apis mellifera scutellata*) (Paul Poling, personal communication 10/23/13). From 2009 to 2012, survey and control efforts cost WVDA over $3.6 million (Sherrie Hutchinson, personal communication, 10/8/13).

Gypsy moth defoliation. M.E. Robinson, USGS.

The gypsy moth is one of the most well-known forest defoliators in the state. From 2000 to 2003 alone, gypsy moths damaged over $18 million worth of sawtimber and pulpwood, (Haynes et al., 2005). At the peak of gypsy moth infestation, mortality was averaging 138 million board feet per year (Bross-Fregonara, 2004). From 1985 to 2013, it is estimated that gypsy moths have defoliated over 2.4 million acres, and caused over $42 million in damage (Quentin Sayers, personal communication, 11/17/13).

The federal government has disbursed hundreds of thousands of dollars in grant money to WVDA for emerald ash borer survey, trapping, and suppression since 2007 (Susan Kuhn, personal communication, 9/23/13; Donna Murphy and Amy Hill, personal communication, 1/27/14; Tim Tomon, personal communication, 1/30/14). The National Park Service is spending approximately $70,000 to treat for emerald ash borer (John Perez, personal communication, 4/26/13).

A federal emerald ash borer quarantine imposed in 2009 restricts "the movement of ash nursery stock, unprocessed (green) ash lumber, and any other ash material, including logs, stumps, roots and branches out of the state without Federal certification" (www.wvagriculture.org/images/Plant_Industries/ EAB.html), including all hardwood firewood. This

imposes certification and opportunity costs on every park, campground, and individual wishing to produce or sell firewood in the state.

Though borers and defoliators cause significantly more economic and physical damage to timber species than sap feeders such as hemlock woolly adelgid (Aukema et al., 2011), sap-feeding species still cause significant damage and are expensive to control. The WVDA has been treating trees for hemlock woolly adelgid since 1992, with annual survey and treatment costs approaching $100,000 (Sherrie Hutchinson, personal communication, 10/8/13).

The USDA FS Northeastern Area State and Private Forestry (NA S&PF) Forest Health program has been a primary source of funding for HWA control. Since survey and treatment efforts began, they have disbursed over $973,000 in Forest Health grants to WVDA and the Monongahela National Forest (Amy Hill, personal communication, 1/27/14). In 2011, they also awarded $30,000 to the Potomac Highlands CWPMA to fund the field crew and Integrated Pest Management (IPM) treatments.

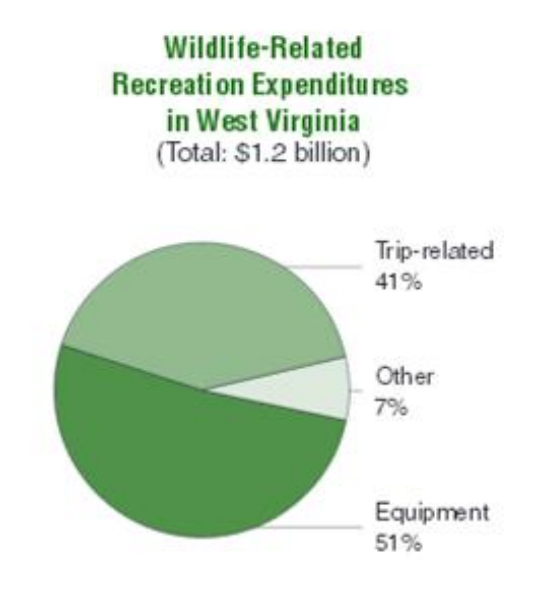
Recreational

In 2011, over 1.2 million people participated in hunting, fishing, and wildlife watching in West Virginia, contributing over $1.2 billion to the state's economy (USDOI, 2013). (Figure 3)

However, invasive species degrade consumers' experiences. Invasives cover historic structures, block trails and boat access points, clog waterways, and reduce the species diversity that many people travel long distances to experience. As a result, visitors come less often, invest less money in visits, spend less locally, invest in different forms of recreation, and eventually travel elsewhere altogether. In 2006, Eisworth et al. estimated that invasive species cost states six to twelve million dollars every year in lost recreational revenue.

Parks and businesses are taking proactive steps to prevent revenue loss from invasive species. In historic sites across West Virginia, kudzu control costs National Park Service $15,000 to $17,000 per acre (John Perez, personal communication, 4/26/13. Between 2006 and 2013, the National Park Service spent $404,000 to treat over 13,000 hemlock trees for hemlock woolly adelgid at an approximate cost of $30 per tree (John Perez, personal communications, 4/26/13 and 11/4/13). The Tree Tops Canopy Tour company in Fayetteville is directing a portion of its ticket prices towards hemlock woolly adelgid treatment in an effort to preserve the hemlock forest on which it depends (www.riverman.com/blog/entry/hemlock-woolly-adelgid).

Figure 3: Wildlife-Related Recreation Expenditures in West Virginia



USDOI 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation—West Virginia

Human Health

In addition to their impacts on forest and agricultural resources and recreation, some invasive species are harmful to human health. This creates another category of economic burden in terms of insurance costs and lost worker productivity.

Asian tiger mosquitos (*Aedes albopictus)* spread diseases such as West Nile virus (www.invasive speciesinfo.gov/animals/asiantigmos.shtml),which nationwide creates over $630 million a year in public health costs (Pimentel et al., 2005).

Fire ant stings have caused human death in six states, and nationwide fire ants cause an estimated $2 billion in death and damage to livestock, crops, and machinery (they are attracted to electricity and chew on wires, causing short-circuits and other

malfunctions) (www.tn.gov/agriculture/regulatory/importedfireants.shtml).

Silver carp pose one of the most direct threats to human well-being of any species in or near West Virginia's borders. These fish grow up to sixty pounds and respond to noise disturbance (such as from a fast-moving boat) by leaping up to 10 feet out of the water (www.fws.gov/midwest/fisheries/library/fact-asiancarp.pdf).

Jumping Asian carp.
Photo: Great Lakes Fishery Commission.

A University of Illinois survey of recreational boaters near Havana, IL reported that forty-seven percent of boaters in 2010 and 2011 had been hit by an airborne carp, and one third had suffered boat damage (Paynter, 2012). As well as being a physical hazard, this has a dramatic economic impact. When Asian carp invaded Kentucky Lake, recreational use dropped sixty percent (Chris O'Bara, personal communication, 9/4/13).

Even plants can be a threat to human health. Bennett et al. (2013) found that tree-of-heaven sap can cause severe skin irritation, headaches, nausea, and possibly heart problems.

The sap of giant hogweed (*Heracleum mantegazzianum*) causes severe chemical burns (see www.dec.ny.gov/animals/72556.html for health hazards and safety information). Hogweed has only been found in Brooke County in West Virginia (Patricia Morrison, personal communication, 10/21/13) but is present in Ohio, Pennsylvania, and Maryland, and is easily confused with the less toxic cow parsnip.

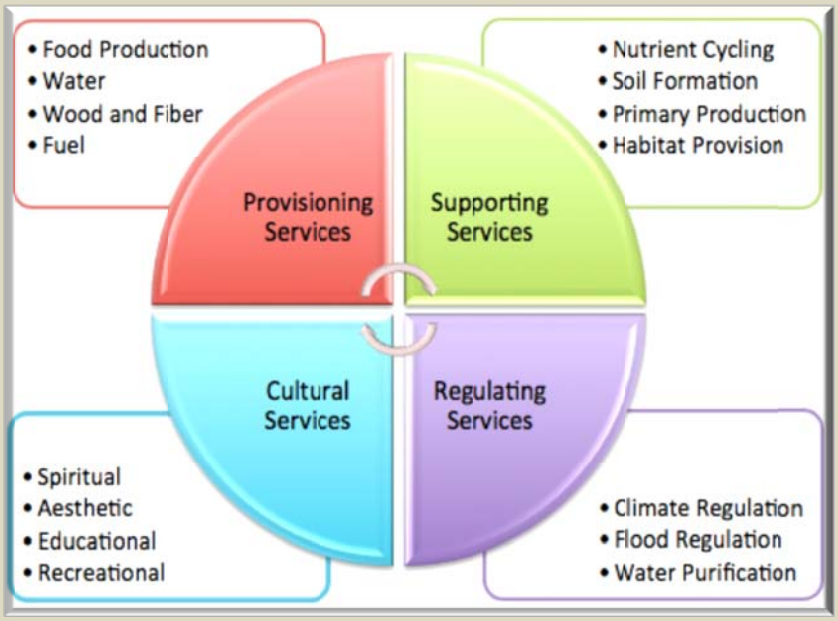
Giant Hogweed and worker in protective suit.
Photo: Credit Valley Conservation

Ecological Services and the Cost of No Action

People depend on healthy ecosystems for easily quantifiable goods such as food, fuel, and building materials, but also for less tangible values such as air purification, water filtration and flow regulation, erosion control, natural pest control, pollination, and nutrient absorption (Charles and Dukes, 2007).

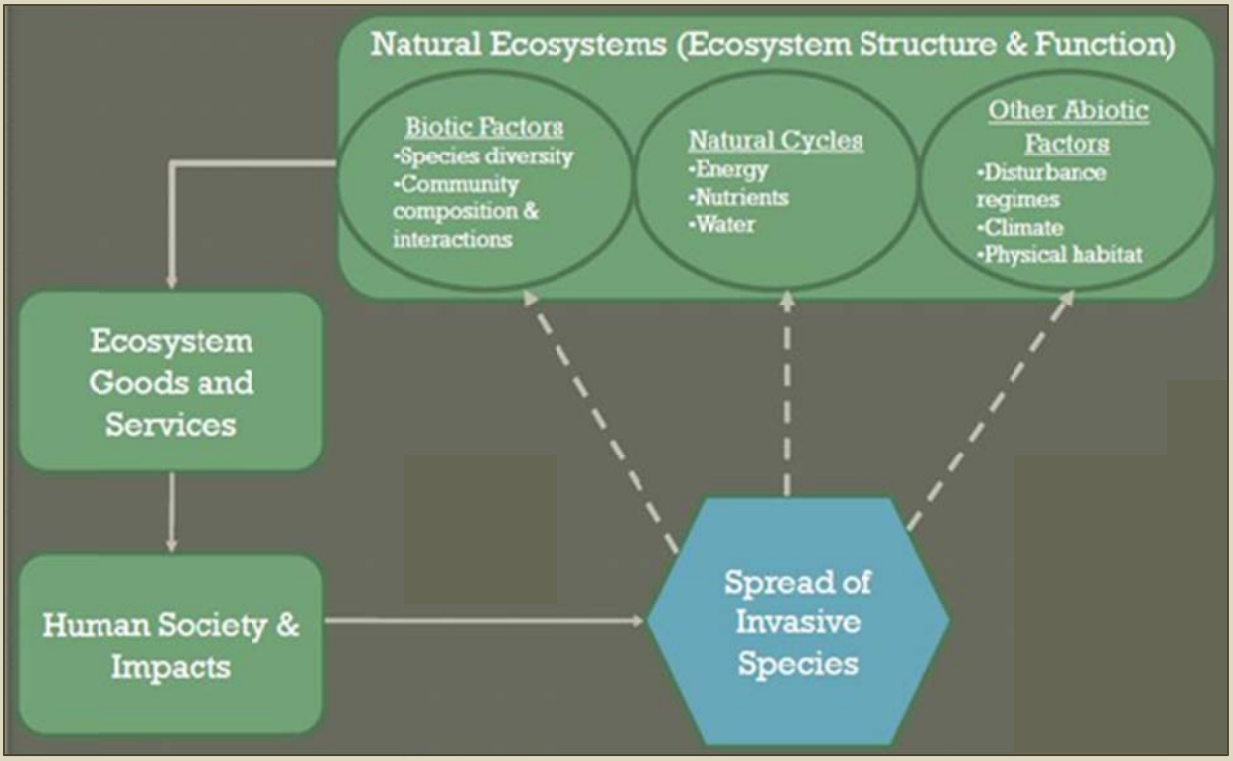
Collectively, these products are often referred to as ecological or ecosystem services (Figure 4), and their global value is estimated at $44 trillion, nearly twice the global GNP of approximately $24 trillion (Holzman, 2012; Costanza, 1997). Invasive species affect all these services (Charles and Dukes, 2007) (Figure 5).

Figure 4: Types of Ecological Services



Source: Millenium Ecosystem Assessment 2005

Figure 5: Mechanism of Invasive Species Impacts on Ecosystem Services



Source: Charles and Duke, 2007

Ecosystem services can provide immense value both globally and locally. The U.S. Environmental Protection Agency determined that restoring the Catskills watershed to reduce water pollution, at a cost of $1-1.5 billion, would be six to eight times cheaper than building and maintaining a water pollution treatment plant (estimated at $6-8 billion plus $300-500 million/year in operating costs) (Perrot-Maître and Davis, 2001).

Just as the value of ecological services can be calculated, so can the ecological cost of invasive species. In economic terms, invasive species are considered a "hidden tax," "negative externality," or "market failure"—an item or situation that negatively affects people who did not choose to incur that cost. Invasive species are shown to have a negative impact on ecosystem services both locally and at a landscape scale (Charles and Dukes, 2007).

Invasive species are associated with decreased species diversity, which in turn is associated with reduced overall productivity (Cadotte, 2013). Invasive plants may decrease the quality and quantity of all goods and services that healthy ecosystems provide (Pejchar and Mooney, 2009). This means less food, fuel, fiber, timber, pharmaceutical chemicals, and other natural products that people use every day. In West Virginia's natural resource based economy, this could have significant impacts.

Wild-gathered edible and medicinal plants are an integral part of West Virginia culture and economy. Ramps, morels, goldenseal, blue cohosh, ginseng, and others are gathered for personal use, and bring in both tourists and dollars. The annual ginseng (*Panax quinquefolia*) harvest brings in several million dollars to the state economy every year, yet studies show that populations invaded by garlic mustard (*Alliaria petiolata*) have reduced seedling recruitment (Wixted and McGraw, 2010) and potentially reduced future productivity.

Native vegetation around farms is also economically important for agricultural production. Fifteen to thirty percent of U.S. food production depends on bee pollination, and if sufficient habitat exists, wild bees can perform much of that service. Native bee populations are threatened by degradation of native plant communities and invasive mites, which in turn threaten crop yields (Donna Murphy, personal communication 1/27/14; Kremen, 2005).

Wild bats also provide critical services for agriculture in the form of pest control. They pollinate plants, spread seeds, and are vital sources of nutrients for rare and sensitive cave ecosystems (Jones and Dale 2010). However, bat populations are plummeting due to white-nose syndrome.

Little brown bat showing characteristic symptoms of white nose syndrome. Photo: Craig Stihler.

Every year, the West Virginia Division of Natural Resources spends approximately $50,000 (Walt Kordek, personal communication, 10/9/13), and the Monongahela National Forest spends approximately $100,000 (Cindy Sandeno, personal communication, 1/14/13) to track white-nose syndrome. Millions of dollars in federal grants for research and control have been disbursed since the fungus was discovered (whitenosesyndrome.org/news).

Despite these efforts, researchers estimate that agricultural losses due to bat declines from white-nose syndrome will exceed $3.7 billion in the coming years (Boyles, 2011).

It is essential to identify and prioritize threatened systems, and assign resources strategically to best protect our most important resources. The collective cost of not protecting these and other ecosystem goods and services is far greater.

BIOLOGICAL IMPACTS OF INVASIVE SPECIES

Biodiversity

Invasive species threaten overall ecosystem diversity and stability in a number of ways (Vila et al., 2011). Along with habitat destruction, invasives are one of the leading threats to biodiversity, (Pimentel et al., 2005, Lowe et al., 2000, Stein and Flack, 1996). Physical or chemical alterations, and/or changes in species diversity, have ripple effects throughout the ecosystem (Pyšek et al., 2012).

Invasive plants decrease native plant populations through competition, exclusion, interactions with herbivores, and habitat alteration (Ehrenfeld and Scott, 2001; Wixted and McGraw 2008). Invasives out-compete natives for space and resources by shading and smothering, alter soil structure through root exudates, and exude chemicals into the soil that inhibit other plants from germinating (Weidenhamer and Callaway, 2010). Native plants that successfully compete with invasives are preferentially browsed by herbivores, and compete far better against invasives when relieved of white-tailed deer grazing pressure (McShea et al., 2008).

Invasive insects damage or kill native plants by defoliation, girdling, or by acting as vectors for pathogens such as beech bark disease. Their effects can be devastating. It is expected that the New River Gorge National River will lose all of its ash trees by 2016 except for approximately 500 trees that have received insecticide treatment, and that the National Park Service will lose up to 90 percent of the hemlocks on its West Virginia lands (John Perez, personal communications, 4/26/13 and 7/11/13).

Native animals' reproductive success declines when invasive plants replace or coexist with native plants. Songbirds who nest in multiflora rose and bush honeysuckles suffer increased nest predation (Borgmann and Rodewald, 2004; Schmidt and Whelan, 1999). Garlic mustard is toxic to the eggs of the West Virginia White Butterfly (*Pieris virginiensis*), but they mistake it for their caterpillars' native food source and lay their eggs on it. The eggs never hatch. Even when not lethal, invasive plants provide inferior forage, and insects tend to be smaller in areas of dense invasive infestation (Heleno et al., 2009). Decreased insect biomass means less food is available for native nesting and migrating birds.

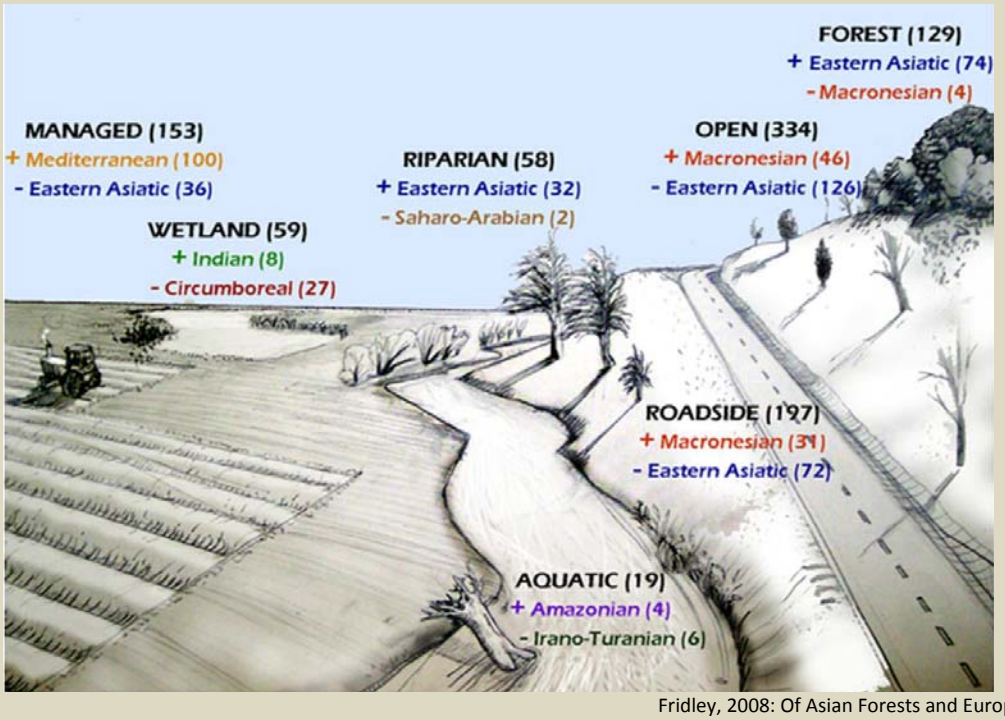
Native birds also face competition from invaders. European starlings and house sparrows aggressively displace cavity nesters like woodpeckers, eastern bluebirds, tree swallows, purple martins, and other species. House finches, native to the U.S. southwest but introduced here, carry diseases such as *Mycoplasma gallisepticum* (Mike Welch, personal communication, 10/11/13).

The brown-headed cowbird, native to the Midwest but spread through human-induced land use change, has had the greatest negative impact of any alien bird species on eastern song birds (Rich Bailey, personal communication, 9/11/13). Cowbirds have been documented parasitizing over 200 species of birds and can lay more than forty eggs in a breeding season (Jim Fregonara, personal communication, 10/15/13). Midwestern birds have evolved coping strategies against cowbirds, but eastern birds have not, and are suffering population declines as a result (Robinson et al., 1993).

Cowbird chick being fed by a chipping sparrow.
Photo: Al Mueller, muddyriverphotography.com.

Invasives can also have disproportionate ecological impacts depending on where they establish. In the New River Gorge National River, sixty-five percent of the plant species are found in riparian zones, which make up only two percent of the park's land area (Vanderhorst et al., 2007). Because of high nutrient availability, riparian and limestone habitats are particularly vulnerable to colonization by invasions of exotic plants (Jim Vanderhorst, personal communication, 9/19/13). See Figure 6.

Figure 6: Floristic signatures of Eastern U.S. Plant Invasions by Habitat Type



Fridley, 2008: Of Asian Forests and European Fields: Eastern U.S. Plant Invasions in a Global Floristic Context

Dr. Jason Fridley studied the origins of 449 invasive plants found in the eastern U.S. He found that naturalized alien plants tend to be native to Europe, those that have become invasive tend to come from East Asia. He says, "East Asian invaders are mostly woody (56%, compared to just 23% of the total alien flora) and are significantly more likely to invade intact forests and riparian areas than European species, which dominate managed or disturbed ecosystems."

In the above image, "seven habitat types are illustrated with the total number of species described as "invasive" listed in bold parentheses. Floristic regions most positively and negatively associated with each habitat were determined by the most extreme positive and negative standardized residual values from a Pearson chi-square test of a contingency table of all floristic regions and habitat types. The number of invaders contributed to each habitat by each listed region are noted in parentheses. Drawing by Eric Fridley."

Nutrient-poor habitats such as shale barrens and the specialist plants that depend on them are threatened by nitrogen fixing invaders like autumn olive and crown vetch (P.J. Harmon, personal communication, 9/16/13). As these plants spread and increase soil fertility, they enable a different ensemble of more generalist plants to establish and dominate which out-compete the specialists (Weidenhamer and Callaway, 2010).

Rare, threatened, and endangered (RTE) plants tend to exist in isolated patches which are easily extirpated by aggressive invaders. Local species diversity declines in rare plant communities when invasives establish (Powell et al., 2011). Forty-two percent of RTE species in the U.S. are threatened by invasive species (Stein and Flack, 1996), and most RTE plants in West Virginia are threatened by invasives (P.J. Harmon, personal communication, 9/16/13).

Invasive species control efforts can potentially have negative impacts on native flora and fauna if done improperly. Herbicide ingredients are often toxic to amphibians and native plants, and chemicals used in gypsy moth and adelgid control also affect native insects (Jim Vanderhorst, personal communication, (11/14/13).

High priority natural areas

West Virginia's national parks, forests, and wildlife refuges, designated Wilderness areas, state parks and wildlife management areas, NGO-managed nature preserves, and unique private lands protect many rare species, habitats, and natural communities.

Bear rocks in Dolly Sods Wilderness. Photo: David Ede.

Unusual and rare habitats such as shale barrens, limestone glades, and cave ecosystems are particularly important to protect from a biodiversity perspective. Protected areas with unique ecology such as Cranberry Glades, Cranesville Swamp, Ice Mountain, the red spruce ecosystem in the Monongahela National Forest, Kanawha State Forest, lands owned and managed by The Nature Conservancy, and the Ohio River Islands National Wildlife Refuge attract tourists and offer unique recreational and educational opportunities. A sampling of these important ecological areas is shown in Figure 7.

Wetlands comprise less than one half percent of the state's land area (Vanderhorst, 2010). Their rarity alone would make them important conservation targets, but high elevation wetlands also contain exceptional biodiversity and are of particular conservation value (Byers et al., 2007; WVDEP & WVDNR 2011). West Virginia's wetlands are home to approximately 40 percent of the plants and 20 percent of the vertebrates considered rare by WVDNR's Natural Heritage Program (Vanderhorst, 2010). Wetlands are highly susceptible to invasion, and of the world's worst invasive plants, 24 percent are wetland species (Zedler and Kercher, 2004).

Greenbottom Swamp, Cabell County. Elizabeth Byers.

The Potomac Highlands Cooperative Weed and Pest Management Area (PHCWPMA) manages an area that is home to over 120 rare animals, plants, and natural communities (Cindy Sandeno, personal communication 6/26/13). West Virginia is also home to the Monongahela National Forest, one of the most ecologically diverse forests in the National Forest system. Containing only about 6 percent of the land in West Virginia, it is home to 13 percent of the rare plant and animal species in the state (Cindy Sandeno, personal communication 6/26/13).

Figure 7: Sample of Ecologically Significant Areas

Alicia Mein, WVDNR

PATHWAYS AND VECTORS OF INTRODUCTION AND SPREAD

National and international exchange of materials facilitates the spread of invasive species. Invasives spread through almost every means conceivable. Plant seeds, plant fragments, and invasive insects are carried in packing material and agricultural products, and hitch rides on animals, people, and contaminated machinery. Pathogens spread through infected agricultural products, nursery stock, wildlife movement, the pet trade, and contaminated clothing and equipment. Invasive aquatic species are inadvertently dispersed on and in contaminated fishing equipment, boats, ballast water, and personal gear. Several major dispersal vectors are described in more detail below.

Commercial distribution: Horticulture, Food markets, and Pet and Bait trades

Before awareness of invasive species, plants and animals were deliberately distributed across the globe by collectors and various natural resource industries. This still occurs where species are not banned and where there is a market. Invasive plants such as English ivy (*Hedera helix*), Japanese barberry (*Berberis thunbergii*), silvergrass (*Miscanthus sinensis*), Japanese spirea (*Spiraea japonica*), and burning bush (*Euonymous alatus*) are still sold by many nurseries, as are cultivars such as "sterile purple loosestrife" which are in fact highly fertile (Swearingen, 2005). Nationwide there is growing industry awareness about the issue (Niemiera and Von Halle, 2011), but individual operators' levels of awareness and concern vary. Snakehead fish originally entered the U.S. via live fish markets, and escaped when people dumped them into local waterways (Fuller et al., 2013). The aquarium trade is a likely source for many hydrilla infestations (www.invasiveplantatlas.org/subject.html?sub=3028) and anglers and bait suppliers are unintentional vectors for aquatic and terrestrial invasive species (Kilian et al., 2012).

Disturbance

Disturbed areas are vulnerable to invasive plant establishment. A disturbance is any event that dramatically alters the microclimatic conditions of a site, such as light and moisture regimes, vegetation structure and composition, soil exposure, and topography. Natural disturbances include tree falls, native disease outbreaks, habitat modification such as tree cutting and flooding from beavers, and damage from storms, fire, etc. (Hobbs and Huenneke, 2002).

Human disturbances include development, road and trail building, timber harvesting, mining, and other activities that remove native vegetation, disturb the soil, or dramatically alter light and moisture conditions. Air, water, and soil pollution are less visible but equally harmful anthropogenic stressors that make ecosystems more vulnerable to invasive species.

Viper's bugloss (*Echium vulgare*) on a Pendleton County construction site. Whitney Bailey.

Even climate change can be considered a large-scale disturbance, in that it alters local growing conditions beyond the range to which native species are adapted, and favors a new suite of more generalist species. While natural disturbances (such as fire) are integral to many ecosystems' normal functioning, the scale and variety of anthropogenic disturbances that species experience today is unprecedented.

Natural Resource Utilization and Management

Construction, transportation infrastructure, and maintenance activities are prime vectors for invasive plant spread (Cal-IPC, 2012). Timber harvesting operations, gas and oil pads, and wind farms all require significant disturbance and construction, including new facilities, access roads, and distribution lines. These cause forest fragmentation and early successional habitat where invasives are likely to colonize (Lake and Leishman, 2004).

Contaminated mulch, seed mixes, gravel, and fill dirt introduces seeds and fragments of Japanese stilt-grass, garlic mustard, Japanese honeysuckle (*Lonicera japonica*), Japanese knotweed, and others. These species are then spread further by unwashed mowing and construction equipment (Transportation Research Board, 2006).

Many invasive plants were intentionally introduced to the U.S. decades ago for site restoration and wildlife habitat manipulation. For example, multiflora rose was initially introduced to the U.S. in the late 1800s in the nursery trade, then was promoted by the U.S. Soil Conservation Service for soil stabilization and as a living fence (Bergmann and Swearingen (a), nps.gov). Tree-of-heaven (*Ailanthus altissima*) was first introduced as an ornamental in 1784 (Fryer, 2010), then was planted in reforestation projects. Autumn olive (*Elaeagnus umbellata var. parvifolia*) has been planted for wildlife food in many states (Munger, 2003) and also as a restoration plant due to its nitrogen fixing ability (Donna Murphy, personal communication, 1/27/14). Confusing regulations sometimes result from this dual-use history. Kudzu (*Pueraria spp.*) was initially introduced to the U.S. in the late 1800s as an ornamental (Bergmann and Swearingen, (b, c), nps.gov). Even though it is currently listed as a federal noxious weed, a permit can still be issued for its cultivation in West Virginia because of its potential to serve as a forage crop (www.fs.fed.us/database/feis/plants/vine/puemonl/all.html).

Mining restoration guidelines recommend plantings of fast-growing, dense groundcovers such as grasses and legumes, and permit use of non-native species if those species comply with applicable laws, (WV DEP, 2011). However, in West Virginia, the only current legislation regulating invasive species is the Noxious Weed Act. While including several common invasive plants, it is limited in scope to the species named.

Transfer of large volumes of water is a potential vector for aquatic invasives. A mostly underground pipeline that transports water from the Ohio River to sites in the Marcellus and Utica formations could introduce invasive aquatic organisms from the Ohio River to local streams and rivers if it broke (Chris O'Bara, personal communication, 10/30/13). Water management plans including invasive species control methods are required, however (Mark C. Collins, personal communication, 10/8/14).

Transportation

Highways, railroads, and rivers are all pathways for species to travel far in excess of their natural dispersal abilities, (Cal-IPC, 2012; Ruiz and Carlton, 2003). Seeds and plant fragments can easily go unnoticed in packing and construction material, and on vehicles, equipment, animals, and clothing. Plants and animals can hitchhike on boats, vehicles, and other equipment. Agricultural products and livestock can host pathogens (Ruiz and Carlton, 2003).

As mentioned above, plants are frequently introduced and spread along roads, both during initial construction and subsequently by mowing while plants are in seed. Others are planted for erosion control or aesthetics.

Hydrilla. Don Schmitz, FWC.

Waterways are also a significant vector for the inadvertent transportation of invasive species, both on boats and in material being shipped (Ruiz and Carlton, 2003). West Virginia is connected by navigable waters to the Ohio River, the largest tributary of the Mississippi and a major interstate shipping route. Other commercially navigable rivers include the Kanawha and Monongahela. All of these waterways are affected by, and serve as vectors for, aquatic and terrestrial invasive plants and animals.

Agriculture, Forest Products, and Aquaculture

Invasive species are often introduced accidentally in shipments of plant material. Nursery stock, feed, bedding, mulch, untreated wood, and packing and shipping materials have all been vectors for invasive species introductions (Ruiz and Carlton, 2003). For example, fire ants were found in a 1999 hay shipment from the south. (Sherrie Hutchinson, personal communication, 5/30/13). Contaminated hay had been distributed to sixteen sites statewide by the time the ants were discovered. Surveys found ants at four of the sites, which were all treated, and follow-up surveys in 2001 found no ants at any of the sites.

The importation of wooden items from abroad – everything from cargo pallets to clothespins – have been identified as a major pathway for hitchhiking insects and microbial pathogens (USDA-MRP-APHIS, 2003). It is suspected that Asian long-horned beetle, first detected in 1996, arrived in wooden packing material from Asia (asian-longhorned-beetle.com). While not yet found in West Virginia, WVDA surveys for it annually.

Movement of firewood is another high-risk pathway for spreading non-native and native forest pests in the United States. Up to 20% of all firewood is contaminated with insects or pathogens (USDA-APHIS, 2010), and during the initial spread of the emerald ash borer in the northeast, 75 percent of new infestations were found in campgrounds or parks, including campgrounds in Ohio and West Virginia (Buck, 2008).

Although plant material is subject to state inspection, pests may still hitchhike in. Fast-growing, hardy ornamental plants sometimes escape cultivation and become invasive. Tree-of-heaven, Japanese barberry, bush honeysuckles (*Lonicera spp.),* purple loosestrife (*Lythrum salicaria*), and Japanese knotweed were all introduced originally as ornamentals, but now dominate thousands of acres of forests, riparian zones, and wetlands.

Trade for the aquaculture industry is a potential vector not only for fish and invertebrate species, but also for invasive pathogens such as viral hemorrhagic septicemia (VHS) and largemouth bass virus (LMBV) (NAAHTF, 2008). Since the detection of these pathogens in the Great Lakes, trade with surrounding states has dropped dramatically, and disinfecting protocols have been implemented for boats and stocking equipment (Frank Jernejcic, personal communication 10/25/13).

Recreation

Outdoor recreation is a significant vector for spreading invasive species. Cars, trucks, campers, off-road vehicles, boats, hikers, animals, and all recreation equipment and clothing can potentially carry seeds, insects, pathogens, and/or aquatic species deep into West Virginia's natural areas (Pickering and Mount, 2010; Rooney, 2005; Johnson et al., 2001; Tim Tomon, personal communication 1/30/14). The Potomac, Cheat, New, and Gauley Rivers all receive heavy recreational use by visitors from all over the world, and along with the Ohio, are potential vectors for both aquatic and terrestrial invasive species to spread (www.anstaskforce.gov).

Fisherman. Kent Mason, TNC.

The Monongahela National Forest alone contains more than 500 miles of hiking trails and receives over 214 million visits every year (Cindy Sandeno, personal communication 6/26/13). Some of the fastest growing outdoor recreation activities include hiking, backpacking, birding, camping, off-road driving, snowmobiling, downhill skiing, and walking (USFS 2006). Maintaining the forest's biological integrity is critical to its continued attractiveness as a recreation destination.

The frequency, timing, and type of use; the number of access points; and the trail's proximity to invasive populations along similar trails all influence the likelihood that a given trail will become a vector for invasive species spread (Rooney, 2005). It is essential that land managers and outdoor recreation businesses participate in educating the public about how to clean gear between outdoor excursions. Leave No Trace guidelines include, "Avoid introducing or transporting non-native species" (www.lnt.org/learn/7-principles). There is still a great need for education and awareness to facilitate behavioral changes among outdoor enthusiasts.

Climate change

Increasing international commerce is not the only factor exacerbating the spread of invasive species. Global climate change may alter conditions globally, nationally, and in West Virginia in ways that may allow formerly benign non-native species to become problematic and allow species currently restricted to warmer climates to become potential invaders (Hellmann et al., 2008; Ruiz and Carlton, 2003;

Mooney and Hobbs, 2000; Dukes and Mooney, 1999). It is estimated that global warming will allow 48 percent of currently established invasive plants and animals to expand their northern distributions (Ziska and George, 2004). For example, species such as didymo and giant hogweed have recently begun expanding their range and becoming aggressive invaders for reasons as yet unexplained (Gucker, 2009; MDDEP-MRNF, 2007; Spaulding and Elwell, 2007). (For definitions and more information about global climate change and global warming, see www.epa.gov/climatechange/basics, www.iea.org/topics/climatechange, and climate.nasa.gov/evidence, among others.)

Ecosystems' resilience to climate change is challenged by stressors such as invasive species (Burgiel and Muir, 2010). Higher average temperatures may enable invasive species to take advantage of weakened ecosystems and out-compete native species. Invasive insects such as hemlock woolly adelgid and balsam adelgid are two such examples (Paradis et al., 2007).

Climate change not only stresses native ecosystems and expands the range for potential invaders; rising atmospheric carbon dioxide (CO_2) levels also produce physiological changes in plants which affect their invasive and/or harmful potential. Common agricultural weeds like Canada thistle (*Cirsium arvense*) are more resistant to herbicides when grown in higher CO_2 concentrations, making them harder to control (Ziska and George, 2004). Climate change also affects native plants, sometimes to the detriment of people and possibly native ecosystems. Ragweed (*Ambrosia spp*.) grown at elevated CO_2 levels produces twice as much pollen as plants grown at lower levels of CO_2 (NWF, 2012). Poison ivy (*Toxicodendron radicans*) grows more vigorously at higher levels of CO_2 and produces a more virulent form of urushiol oil, the substance that causes contact dermatitis in most people (Mohan et al., 2006). Though poison ivy has high wildlife value, it is invasive in Europe, a nuisance for most people, and hazardous for those who are highly sensitive.

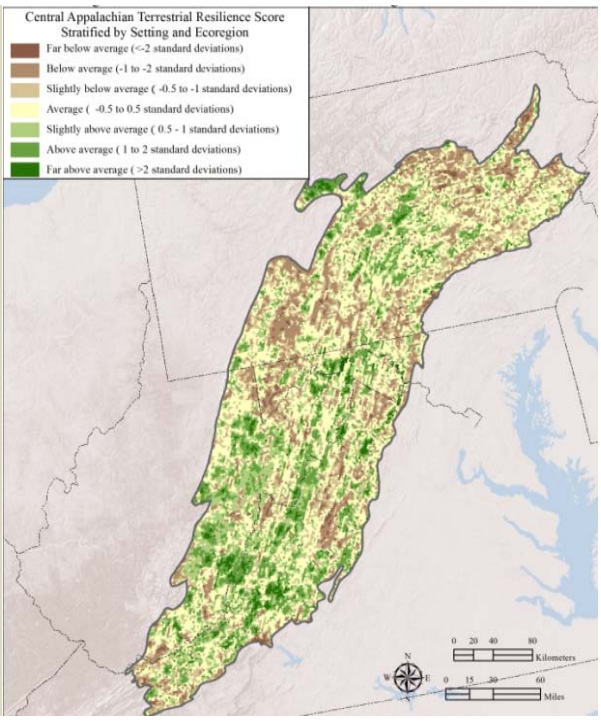
It is clear that plant community compositions and species distributions are shifting, sometimes in unpredictable ways and with unpredictable effects. Current science suggests that preserving biodiversity in natural communities is critical to preserving ecosystem functionality (Hooper et al., 2005), in that it contributes to ecosystem resilience. (See figure 8 below.) Controlling the spread of aggressive invasive species is a key strategy for preserving biodiversity.

Figure 8: Areas of High Ecological Resilience in the Central Appalachians

The Nature Conservancy's 2012 report, "Resilient Sites for Terrestrial Conservation in the Northeast and Mid-Atlantic Region", describes the Central Appalachian Ecoregion, including a large area of eastern West Virginia, thus: "The region forms a critical connecting link between the Northern and Southern Appalachians, and it is a global center of endemism in its own right. Of all the ecoregions in the Northeast and Mid-Atlantic, the Central Appalachians support the highest diversity of species…"

This map illustrates areas of high ecological resilience in the face of climate change, with green indicating the highest scores. Invasive species reduce biodiversity and threaten ecosystem resilience. Mapping efforts like this can help prioritize invasive species control work.

-Anderson et al, 2012.



CURRENT MANAGEMENT: ENTITIES AND EFFORTS

Many entities are involved in managing invasive species in West Virginia, including federal and state government agencies, as well as national, regional, state, and local organizations. (See Appendix D for more detail.)

Federal agencies working on invasives in West Virginia include the U. S. Department of Agriculture (USDA) and Department of the Interior (USDOI).

State agencies include the West Virginia Department of Agriculture (WVDA), Division of Natural Resources (WVDNR), Division of Forestry (WVDOF), Division of Highways (WVDOH) and Department of Environmental Protection (WVDEP).

Federal

USDA agencies working on invasives in West Virginia include the Animal and Plant Health Inspection Service (APHIS) and Plant Protection and Quarantine (PPQ), the United States Forest Service (USFS), and the Natural Resource Conservation Service (NRCS). USDA APHIS-PPQ conducts inspections, surveys, and treatments for federally regulated pests. The USDA Forest Service conducts ongoing inventory, control, and monitoring of high priority invasive species within the boundaries of the Monongahela and George Washington-Jefferson National Forests, and the USFS Northern Research station conducts research on invasive insects, pathogens, and their interactions. West Virginia's gypsy moth program is a combined effort of WVDA, WVDOF, NPS, USFS, and private landowners.

The National Park Service (NPS) and the U.S. Fish and Wildlife Service (USFWS) operate offices and oversee thousands of acres of protected land in West Virginia. The National Park Service monitors and treats for invasives on their protected lands, as does the U.S. Fish and Wildlife Service on public and private lands. The USFWS Partners for Fish and Wildlife program has been treating invasives with a private contractor since before 2008 (Keith Krantz, personal communication, 9/27/13) and partnering with the Potomac Highlands Cooperative Weed and Pest Management Area since its inception in 2009. The U.S. Army Corps of Engineers and U.S. Navy also conduct invasive species monitoring and removal on their properties.

State

The West Virginia Department of Agriculture is the only agency in the state with a legislative mandate to control invasives. The WVDA Pesticide Regulatory Programs Unit regulates the production, use, sale and disposal of all pesticides in West Virginia.

The WVDA and West Virginia Division of Forestry conduct state-wide monitoring, reporting, and some control on agricultural and forest insect pests. The Divisions of Natural Resources and Forestry are involved with monitoring and managing state forests, state parks, Wildlife Management Areas, and biological resources.

The WV Division of Natural Resources is working to address the impending threat of aquatic invasive species such as Asian carp. Through partnerships with regional organizations such as the Aquatic Nuisance Species Task Force's Mississippi River Basin Panel, the Mississippi Interstate Cooperative Resource Association, and the Ohio River Fisheries Management Team, WVDNR is leveraging regional expertise to address carp along its Ohio River boundary and prevent introductions elsewhere. Programs like Fishing the Edge, eDNA Surveillance and Asian Carp Telemetry have expanded public awareness and institutional knowledge. In 2014, the legislature passed a bill to prohibit the importation or release of several carp species into West Virginia. The WVDNR also creates and distributes educational materials about aquatic and terrestrial invasive species, monitors wildlife-impacting pathogens, and notes and treats invasive plants during timber management activities where possible.

The Department of Environmental Protection oversees mine reclamation and restoration projects, and regulates oil, gas, and water resource development, all of which require consideration of invasive species.

The West Virginia Division of Highways (WVDOH) manages 35,000 miles of state roads and associated rights-of-ways. In 2013 WVDOH began partnering with the PHCWPMA to conduct targeted invasive control along roadside rights-of-way and—with advance permission from landowners—on adjacent private lands.

Non-governmental organizations and businesses

Several other organizations contribute significant time and expertise to invasive species management in the state.

The West Virginia Invasive Species Working Group (WVISWG) and the Potomac Highlands Cooperative Weed and Pest Management Area (PHCWPMA) are two of the largest and most active collaborations working on invasive species issues in the state. The WVISWG is an educational collaborative of professionals from a wide range of agencies and organizations. The PHCWPMA conducts monitoring and treatment within its boundaries for a wide range of invasive plants, and conducts education and outreach.

The Nature Conservancy (TNC) has been a lead organization for furthering invasive species issues in West Virginia and at the federal level. TNC is currently the lead fiscal agent for the PHCWPMA, and leads all of their treatment and stewardship activities on both private and public work sites. TNC has also played an active role in working with partners to expand the "Don't Move Firewood" campaign across the state, raising awareness of forests pests and pathogens.

Cheat-Potomac District Ranger Jason Reed cuts the ribbon on a new STOMP grant invasive species display. Cindy Sandeno.

Other entities actively combating invasives in West Virginia include the Hemlock Conservation Working Group, Trout Unlimited, and the Appalachian Forest Heritage Area (AFHA).

The Nature Conservancy and the AFHA have been integral in facilitating collaborative non-governmental invasive species projects in West Virginia. One of these is the recently completed STOMP Project (Slowing the Onward Movement of Pests) which helped erect educational billboards statewide along travel routes to popular natural and recreational areas.

Mayor Van T. Broughton of Elkins and the Monongahela Deputy Forest Supervisor DeVela J. Clark pose with two young artists at the 2013 Invasive Species Awareness Day in Elkins, WV. Photo: Cindy Sandeno.

West Virginia University Extension Service (WVUES) collaborates with all these agencies and organizations, and provides support through research and education.

Several invasive species control businesses and native plant nurseries service the state's restoration projects. Many other entities deal tangentially with invasive species. These include watershed associations, environmental non-profits and working groups, citizen volunteer and interest groups, industry and recreation associations, and others. Local organizations also team up with the PHCWPMA to run educational events involving local school children, such as Kid's Day during National Invasive Species Awareness Week.

Given the many critical economic and natural resources threatened by invasive species, and the complex nature of the problems, it is clear that greater coordination among all these entities will increase their effectiveness and efficiency. Proposed Administrative and Management Goals for this purpose are described in the following section.

III. Recommendations for Implementation

The following goals are intended to serve as recommended guidelines to enable West Virginia and all entities operating within its borders to address the threats posed by all terrestrial and aquatic invasive species, including pathogens, which occur or may occur, in the state. **These goals are meant to be implemented voluntarily and as practicable, within the context of pre-existing and/or updated obligations, regulations, and mandates.** All recommendations are to be interpreted according to current legislation and scientific understanding, and subject to revision according to same.

Administrative Goals

The West Virginia Invasive Species Strategic Plan (WVISSP) will need administrative support and actions from the conservation community to ensure its usefulness and relevance. While agencies and organizations around the state work to implement the Management Goals described below, Partner signatories to the WVISSP MOU will also be supporting it through working towards these Administrative Goals. More detail is provided in Appendix A.

1: Build Support: Develop Public, Executive, and Legislative support, and assist in seeking financial support, for managing invasive species in West Virginia.

2: Establish Memoranda of Understanding: Obtain Memoranda of Understanding with various agencies to implement WVISSP guidelines as appropriate.

3: Coordinate Management Plans: Provide a framework for aligning operational, species, regional, agency, etc. land management and site construction plans with federal, regional, and state invasives plans.

4: Coordinate and Promote Science-Based Policy: Provide a coordinated, science-based voice on invasive species policy so legislative actions and management plans at all levels complement national, regional, and state guidance.

5: Support Regional Collaboration: Encourage long-term collaborative management for widespread invasive species, and for priority regions.

6: Practice Adaptive Management: Regularly assess progress towards implementation and revise WVISSP as necessary.

Management Goals

All agencies, organizations, and individuals in West Virginia are encouraged to support progress towards one or more of the following Management Goals that together form a comprehensive set of guidelines for invasive species management. Background information and recommended Management Strategies are described in greater detail in the following section and Appendix A.

1: Coordination: Coordinate with WVISSP and with other agencies and organizations to maximize efficiency and ensure alignment with federal, regional, and state priorities and programs.

2: Prevention: Prevent the introduction and spread of known or potential invasive species.

3: Early Detection: Detect, report, and monitor new populations of invasive species in West Virginia efficiently, effectively, and appropriately.

4: Rapid Response: Develop and implement cooperative, multi-agency teams and protocols to rapidly, efficiently, and effectively respond to newly discovered infestations.

5: Control and Management: Prioritize, manage, and monitor known populations of invasive species in West Virginia efficiently, effectively, and appropriately.

6: Research and Assessment: Identify and support research and assessment needs, conduct research, and share results. Regularly review current scientific findings and update practices as needed.

7: Education and Outreach: Conduct invasive species education and outreach in a variety of formats with a wide range of stakeholders and interest groups.

MANAGEMENT GOALS

MANAGEMENT GOAL 1: COORDINATION

Coordinate with the West Virginia Invasive Species Strategic Plan and with other agencies and organizations to maximize efficiency and ensure alignment with federal, regional, and state priorities and programs.

Successful invasive species prevention and control requires coordination, leadership, procedures to align local projects with large-scale efforts, increased non-governmental participation, memorandums of understanding among federal and state agencies, and consistent enforcement of control measures.

Most agencies and organizations who work on invasive species control in West Virginia coordinate or partner with each other to some degree, and there are a number of programs available to help private landowners with invasive species. However, organizational coordination is currently voluntary and subject to budgetary and other constraints.

There is no legislative mandate or funding for inter-agency coordination or cooperation. There is no state-wide program to monitor or manage invasive plants, except for the few species on the noxious weed list. This creates potential for unnecessary duplication of effort, excessive attention to particular species or locations, and neglect of other important species and locations.

There is a need for greater regional coordination of invasive species programs and establishment of additional or expanded Cooperative Weed and Pest Management Areas, which have been shown to be one of the more effective tools for addressing invasive species issues (MIPN.org, 2011).

All agencies and organizations are potential vectors for spread, and all can contribute to prevention and control through implementation of Best Management Practices such as those listed at www.invasive speciesinfo.gov/toolkit/preventionbmp.shtml.

Dialog among diverse agencies and organizations is essential to identify problem areas, educate as needed, and create solutions that work for all involved.

Management Strategy 1.1: Consult WVISSP to ensure that land and water management, development, and other such plans and activities are congruent with the content and/or intent of WVISSP guidelines.

Management Strategy 1.2: Partner with other agencies to maximize efficient use of resources.

Management Strategy 1.3: Identify and/or develop, and share, Best Management Practices for invasive species prevention and control.

> **Management Action 1.3.1:** Incorporate Best Management Practices for invasive species prevention and control into state and federal permits and plans.

Management Strategy 1.4: Develop and/or implement online resources to share information and to capture statewide survey, monitoring, and treatment data.

> **Management Action 1.4.1:** Encourage managers to enter invasive species data into EDDMapS.org, iMapInvasives, the USGS NAS database, and/or other database.
>
> **Management Action 1.4.2:** Implement or develop a statewide GIS-based invasive species mapping system in order to track range expansion/reductions of target species, and develop and prioritize treatment strategies.

Management Strategy 1.5: Designate a single point of contact for each participating agency and group.

MANAGEMENT GOAL 2: PREVENTION

Prevent the introduction and spread of known or potential invasive species.

Vague and confusing regulations along with limited funding and staffing currently contribute to enforcement difficulties. State and federal jurisdictional authority exists, but current capacity is insufficient to adequately survey, quarantine, eradicate, and otherwise manage most invasive species. There is no agency mandated to manage invasive species other than agricultural or forest pests. Limited funding is available for the strategies and improvements outlined in this plan.

Greater funding and staffing, improved regulatory incentives and disincentives, and legislative support are needed to address these issues.

Don't Move Firewood billboard erected with STOMP funding. Photo: Cindy Sandeno.

Management Strategy 2.1: Identify priority areas in the state for invasive species prevention, eradication, control, and management. Review regularly and revise as necessary.

Management Action 2.1.1: Delineate biodiversity refugia (remnant natural areas with high biodiversity significance) that are critical to the maintenance of West Virginia's flora, fauna, and ecosystem services.

Management Action 2.1.2: Identify geographic areas with institutional or community capacity to serve as pilot action areas.

Management Strategy 2.2: Coordinate with surrounding states and other agencies and organizations to minimize the spread of invasives both in state and across state lines.

Management Action 2.2.1: Create and annually update a "watch list" of high-priority invasive species not yet present but with a high probability of being introduced or establishing in West Virginia.

Management Action 2.2.2: Track species movements, identify leading edges and outlier infestations, and share information to prioritize prevention efforts.

Management Strategy 2.3: Develop, maintain, and share lists of invasive plants, insects, animals, and pathogens currently present in West Virginia, ranked according to threat.

Management Action 2.3.1: Support legislation to control all invasive species in West Virginia with the highest threat ranking.

Management Strategy 2.4: Seek support for, develop, and implement, policies and legislation to regulate or cease trade in or spread of species identified as high priority invasives.

Management Strategy 2.5: Develop sources of funding and support to ensure agencies have the capacity to enforce laws and uphold policies pertaining to invasive species.

Management Strategy 2.6: Develop and distribute educational materials on prevention to all stakeholder groups, including outdoor recreation, transportation, development, natural resource extraction, utilities, etc.

Management Strategy 2.7: Develop and/or implement Best Management Practices to reduce the likelihood of spreading invasive species during all land management activities.

MANAGEMENT GOAL 3: EARLY DETECTION

Detect, report, and monitor new populations of invasive species in West Virginia efficiently, effectively, and appropriately.

When new populations of invasive species establish in West Virginia, early detection and appropriate response is critical to prevent their spread. Regular invasive species surveys need to be conducted around introduction pathways, protected areas, and urban and agricultural ecosystems, and new occurrences of invasive species should be reported to a regularly updated database with at least statewide coverage. Taxonomic confirmation, eradication efforts, and follow-up monitoring are all essential for high priority invasive species. Map-based monitoring and reporting illustrates invasion patterns and the performance of prevention and eradication programs. Such data is essential to inform future management decisions.

Given the many vectors by which invasive species enter the state, current detection, monitoring, and reporting efforts are insufficient, as are funds to support these critical activities. To better allocate limited resources, a prioritized list of public and natural areas needs to be developed, as well as a watch list of all identified and emerging invasive taxa ranked by threat level. High priority natural areas need to be assigned to organizations which assume responsibility for conducting regular surveys.

Public and private landowners need to be proactive in invasive species detection, reporting, and control. Training is needed for agency staff and private citizens on identification, reporting, control, and monitoring. Monitoring programs need at the minimum to cover all landscapes and invasive species identified as being high priority, and invasive species presence should be at least documented on all public lands to enable fully informed decision-making.

Several national and regional internet mapping web sites exist that include West Virginia, and PHCWPMA maintains mapping and management data for their coverage area, but there is no central repository for all West Virginia invasive species mapping and management data. Monitoring and management efforts would benefit from a WV-specific GIS and management database, or a process for coordinating annual monitoring and management programs among agencies and organizations using existing technologies such as EDDMapS, iMapInvasives, or the USGS NAS database (nas.er.usgs.gov).

Management Strategy 3.1: Monitor at least high priority sites, identify new occurrences of invasive species, and report them to a database as described in MA 1.4.1.

Management Action 3.1.1: Formalize a network of stakeholders responsible for conducting surveys.

Management Action 3.2: Improve early detection capacity in the state.

Management Action 3.2.1: Identify and evaluate ongoing early detection programs, networks, and other avenues through which invasive occurrences are detected, reported, and monitored in West Virginia.

Management Action 3.2.2: Identify geographic, procedural, infrastructural, and funding gaps, and develop and implement recommendations and programs to enhance capacity. Support refinement and growth of high-functioning programs.

Management Strategy 3.3: Establish a network of participating taxonomic experts to enable rapid identification of unknown species and to differentiate between native and non-native species, subspecies, and varieties.

Management Strategy 3.4: Develop or implement a citizen science program to teach volunteers and stakeholders how to identify high priority invasive species and native lookalikes, and how to enter data into EDDMapS.org, iMapInvasives.org, or similar database.

MANAGEMENT GOAL 4: RAPID RESPONSE

Develop and implement cooperative, multi-agency teams and protocols to rapidly, efficiently, and effectively respond to newly discovered infestations.

When new infestations of high priority invasive species are detected, it is imperative to quickly eradicate or contain them before the species can spread. For high priority invasive species already present in the state, newly discovered infestations in important biological areas should be prioritized.

A "watch list" of high priority species which are not yet known in West Virginia, but which present a risk of being imported or establishing themselves, needs to be developed. Eradication and control plans need to be prepared prior to in-state detection for these species. These plans need to identify the people, resources, and equipment necessary to deal with an early infestation, and provide agencies the authority and funding to deploy and direct resources as needed. The Potomac Highlands CWPMA and National Park Service treatment teams are good examples of this process in action and can serve as models for rapid response teams across the state.

Management Strategy 4.1: Develop rapid response plans to enable rapid deployment of personnel, equipment, and funds to eradicate and control new occurrences of "watch list" species (see MA 2.2.1) in West Virginia.

Management Strategy 4.2: Identify which agencies would need to be involved for various types of pests, seek their support, and establish cooperative agreements among such agencies, organizations, and private entities.

Management Strategy 4.3: Establish a network of rapid response teams responsible for implementing rapid response plans. Individuals and/or agencies on the team must have authority to quickly:

- access funding, personnel, and equipment,
- deploy and direct the use of those resources,
- restrict movement of materials or species, and
- act according to cooperative agreements established for this purpose.

Note: All applicators of any pesticide who are operating under the employment of a government, business or even those volunteering for an agency or non-profit must either be a Certified Commercial Applicator, Certified Public Applicator or a Registered Technician operating under the supervision of a Certified Commercial Applicator or Certified Public Applicator. For more information, consult the WVDA's Pesticide Regulatory Programs Unit within the Regulatory and Environmental Affairs Division (READ) (personal communication, Philip Smith, 9/23/14).

MANAGEMENT GOAL 5: CONTROL AND MANAGEMENT

Prioritize, manage, and monitor known populations of invasive species in West Virginia efficiently, effectively, and appropriately.

Established invasive species require control through eradication, containment, or other management strategies to minimize environmental and economic impacts. Management objectives may include eradication within an area, population suppression, limiting spread, and reducing impacts.

Management activities should be prioritized based on the value of the resource being threatened, the degree of threat the invasive species poses, the extent of establishment, other local control efforts, and the availability of resources (see Figure 9). Cost-benefit analyses can help structure management decisions by taking into account species risk assessments, habitat vulnerability analyses, species distribution, and required control methods.

In managed ecosystems, restoration of both habitat and ecosystem processes (including ecological processes such as succession) is essential to prevent establishment of new, or re-invasion of eradicated, invasive species (D'Antonio and Chambers, 2006). Adequate funding, public awareness, and management expertise are critical to success. Invasive species control methods (including mechanical, chemical, biological, or some combination thereof such as IPM) can evoke stakeholder opposition, necessitating education for the public and flexibility by managers.

Businesses, individuals, and families are essential partners in the invasive management effort. Cooperative Weed and Pest Management Areas have had great success conducting outreach and providing treatment on private lands, but currently only one is active in West Virginia. Establishing a state-wide network of CWPMAs or weed management districts, similar to New York's PRISM program (www.nyis.info), would be a significant step towards effective landscape-scale invasive management and organizational collaboration.

Management Strategy 5.1: Develop and implement management plans to eradicate, control, contain, manage, monitor, and/or report on management actions taken on known, prioritized invasive species infestations. Plans should:

- include baseline site conditions,
- identify desired outcomes based on measurable parameters,
- provide for monitoring parameters of success,
- provide means to adjust treatments and goals as needed, and
- include reporting requirements to a centralized database to enhance regional/statewide efforts

Management Strategy 5.2: Develop and implement restoration plans concurrent with invasive management activities.

Management Strategy 5.3: Develop a state-wide network of Cooperative Weed and Pest Management Areas.

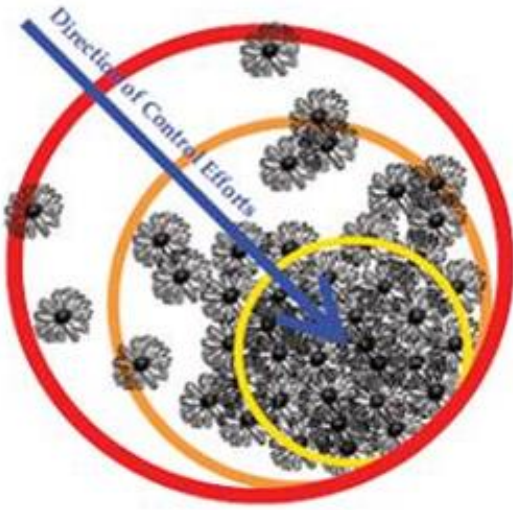
Management Strategy 5.4: Develop and/or implement Best Management Practices in management plans to control invasives.

Management Strategy 5.5: Maintain and enhance capacity and training for management activities.

Management Strategy 5.6: Pursue sufficient funding for invasive species control on public and private lands and waters.

Management Strategy 5.7: Develop new, and align with existing, programs and incentives to assist private landowners in implementing invasive species prevention and control, and habitat restoration activities.

Figure 9: Prioritizing Control Efforts for a Single Species by Density of Infestation



Outliers – Highest priority

- Lowest density of infestation
- Goal = eliminate small, isolated infestations
- Prevent the reproduction and survival of outliers
- Monitor annually beyond the known infestation for new outliers
- Lowest level of commitment, resources, and effort needed.

Advancing Front – Moderate priority

- Goal = control the advancing front and perimeter of core infestations
- Prevent the expansion of the core infestation

Core – Lower priority

- Highest density of infestation
- Goal = suppress the interior of core infestations
- Highest level of commitment, resources, and effort needed

Note: Effective control may require the use of multiple control methods. Control efforts must be followed up by monitoring for new plants, regrowth, and flowering, generally within the same growing season. Monitoring should be done annually.

Adapted from work by Fred Clark, Clark Forestry Inc. and Wisconsin DNR-Urban Forestry

PHCWPMA treatment crews cut knotweed along Kimsey Run as part of a collaborative pilot project with WV DOH that began in summer 2013. PHCWPMA is providing mapping, technical advice, and volunteers and staff to do hand-cutting, while WV DOH provides mowing equipment, herbicide, and contacts with adjacent landowners. WV DOH benefits because knotweed blocks sight lines and can grow through concrete, causing structural damage. PHCWPMA benefits because greater access to land and equipment makes its control efforts more effective.

Photo: Cindy Sandeno

MANAGEMENT GOAL 6: RESEARCH AND ASSESSMENT

Identify and support research and assessment needs, conduct research, and share results. Regularly review current scientific findings and update practices as needed.

The information needs of the professional invasive species community differ somewhat from the research that is being conducted (Figure 10). Along with the rest of the scientific community, West Virginia should support research to meet this information gap. Research needs include both basic and applied, both long term and short term.

Specific research needs include cost/benefit analyses and effectiveness of current prevention and control measures, a systematic ranking procedure to evaluate invasive species threats, and more information on life histories, limiting factors, pathways, and vectors for high-threat species. Information is also needed on economic and ecological impacts of invasive species in West Virginia, effective educational materials and marketing tools, and economic incentives for private invasive control. Professionals in the state need to share information on new technologies being developed for invasive species detection, control, and eradication, and new findings in invasion science and ecosystem resilience.

Risk and vulnerability assessments attempt to combine what is known about invasive species and priority ecosystems with current distribution and movement patterns. This enables managers to identify and predict trends in current invasive species population growth, and the potential for future invasions by new species and in new areas. Risk assessments also enable managers to assess how significantly invasive species might impact forestry, outdoor recreation, agriculture, cultural sites, ecosystems, natural communities, and rare, threatened, and endangered species. Such predictions would enable a more efficient and deliberate response to new outbreaks and new invasive species. Risk assessments, while costly to implement, are shown to produce positive net economic benefits (Keller et al., 2006).

Without access to current research, however, science-based management decisions and risk assessments are impossible. West Virginia needs to ensure its professionals have access to major peer-reviewed journals.

Management Strategy 6.1: Collaborate with state, regional, and federal researchers and taxonomists.

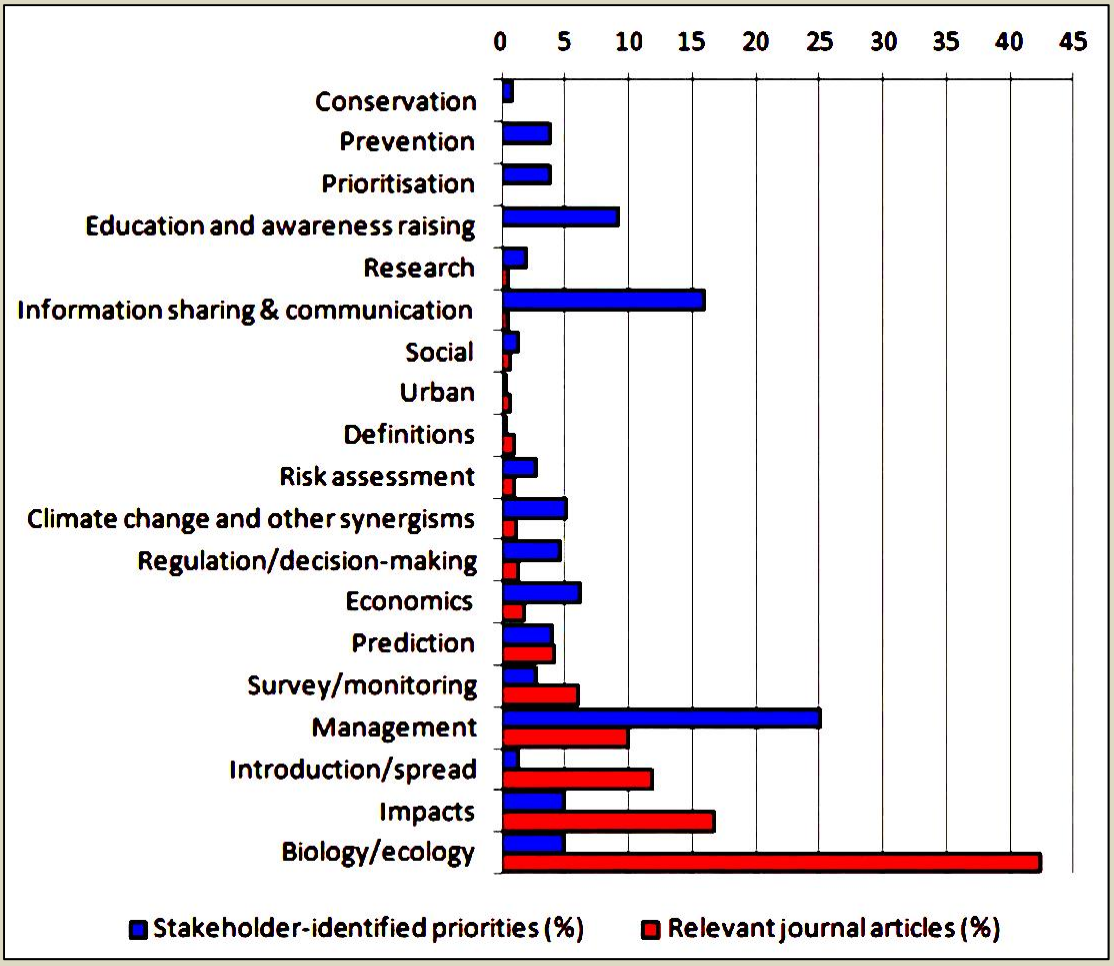
Management Strategy 6.2: Improve access to current invasive species research and share findings statewide and regionally.

Management Strategy 6.3: Identify research priorities for WV and its surrounding region, and develop and conduct relevant projects. See Appendix E.

Management Strategy 6.4: Develop invasive species risk assessments and natural community vulnerability assessments in West Virginia to better prioritize invasive species management efforts.

- **Management Action 6.4.1:** Collect and share existing risk assessments for invasive species that are present in or approaching WV.
- **Management Action 6.4.2:** Collect and share existing vulnerability assessments for natural areas in West Virginia.
- **Management Action 6.4.3:** Identify and task agencies with the responsibility for conducting risk and vulnerability assessments in West Virginia, and develop additional assessments as needed.
- **Management Action 6.4.4:** Increase capacity for invasive species and risk assessment research in terms of funding, personnel, facilities, equipment and software, data, and training.

Figure 10: A perceived gap between invasive species research and stakeholder priorities.



Bayliss et al., 2013

Note for black & white printers:
Stakeholder identified priorities are shown by the top bar for each category, and relevant journal articles are shown by the bottom bar.

MANAGEMENT GOAL 7: EDUCATION AND OUTREACH

Conduct invasive species education and outreach in a variety of formats with a wide range of stakeholders and interest groups.

West Virginia needs a professionally developed and marketed broad-based education and information campaign directed toward preventing introductions and spread of invasive species. The audience needs to include the general public, elected officials, agency staff, landowners, business owners, and volunteers. Many outdoor recreationists and sportsmen/women are inadequately aware of the invasive species problem and do not employ measures to prevent their spread. Likewise, owners and staff of plant nurseries, pet stores, and landscaping and construction companies may be unaware of invasive species problems, and may take insufficient steps to educate their customers. Private landowners would benefit from technical assistance to manage invasive species. Outreach partnerships need to be developed or expanded with educational institutions and industry groups, such as horticulturalists, the aquarium trade, bait trade, shipping firms, marina operators, and natural resource industries. Invasive species education needs to be integrated into curricula for grade, middle, and high school students, and opportunities for experiential learning need to be expanded.

Management Strategy 7.1: Support existing community, non-profit, and educational projects and programs focused on invasive removal, habitat restoration, environmental education, and citizen science.

Management Strategy 7.2: Research current awareness and interest among stakeholder groups and the general public in WV about invasive species.

Management Strategy 7.3: Develop and distribute a variety of educational presentations and materials on a variety of aspects of invasive species for diverse audiences. See Appendix F.

Aquatic invasive species sign developed by TNC and installed by partners at high visibility public recreation sites in West Virginia in the summer of 2013. Photo: Amy Cimarolli

IV. APPENDICES

APPENDIX A: SUMMARY TABLES FOR GUIDELINES

NOTE: Costs listed (recent and estimated future) are for Aquatic Invasive Species activities ONLY.
Funding for all projects will be provided by grants and government programs.

ADMINISTRATIVE GOALS, STRATEGIES, AND ACTIONS SUMMARY TABLE

AG: Administrative Goal; AS: Administrative Strategy; AA: Administrative Action

TASK ID	TASK	FUNDING SOURCE	LEAD AGENCY OR ORGANIZATION	COOPERATING AGENCIES AND ORGANIZATIONS	TIME FRAME	RECENT COSTS OF AIS EFFORTS (~2011-2014)	EST. FUTURE COSTS OF AIS EFFORTS (2015-6)
AG 1	**BUILD SUPPORT** **Develop Public, Executive, and Legislative support, and assist in seeking financial support, for managing invasive species in West Virginia.**						
AS 1.1	Raise public awareness of the issue of invasive species through leadership, collaboration, and education.		WVISSP MOU Partners	WVISWG, WVDNR, WVDA, USFS, USFWS, TNC, NRCS, NPS, WVDOF, WVU, PHCWPMA	Ongoing		$1000
AA 1.1.1	Develop and implement West Virginia Invasive Species Strategic Plan.		WVDNR	PHCWPMA, TNC, WVU	In process	$9189	$9000
AA 1.1.2	Develop and implement a Strategic Education and Outreach Plan that identifies key issues, audiences, and mechanisms for spreading the word about the threat of invasive species and how to slow or stop their spread.		PHCWPMA	WVISWG, WVDNR, WVDA, USFS, USFWS, TNC, NRCS, NPS, WVDOF, WVU	Ongoing		$500
AA 1.1.3	Develop public education materials focused on specific target audiences such as public and private land managers, agency leadership and legislative decision makers, outdoor recreationists, industry groups, K-12 students, and others as identified.		PHCWPMA	WVISWG, WVDNR, WVDA, USFS, USFWS, TNC, NRCS, NPS, WVDOF, WVU	Ongoing		$500
AA 1.1.4	Develop and provide annual workshops for public and private landowners, cooperators, gardeners, highway personnel, plant industry personnel, and others on identifying and reporting high priority invasive pests.		PHCWPMA	WVISWG, WVDNR, WVDA, USFS, USFWS, TNC, NRCS, NPS, WVDOF, WVU	Ongoing		$300
AS 1.2	Review existing legislation and municipal plans for: • ID geographic & taxonomic coverage gaps. • Develop recommendations for the West		WVISSP MOU Partners	WVISWG, WVDNR, WVDA, TNC, DOF	Ongoing		$500

	Virginia General Assembly and municipalities. • Promote regulatory exclusion as the first line of defense against invasive species.						
AS 1.3	Seek an executive order from the governor to agencies to direct funds and resources, as they become available and as appropriate, to eradicate and prevent establishment of invasive species as per WVISSP guidelines. This will empower state government agencies to: • Follow WVISSP guidance in developing and implementing programs • Support the WVISSP by publicizing and enforcing invasive species policies • Allocate funding to further WVISSP Strategies and objectives		TNC	WVISWG, WVDA, WV DNR	2014		$1500
AS 1.4	Support WV agencies and organizations in seeking grants and other funding to implement WVISSP goals.		WVISSP MOU Partners	WVISWG, WVDNR, WVDA, USFWS, TNC, NRCS, NPS, WVU, WVDEP, WVDOF, PHCWPMA	Ongoing		$500
AS 1.5	Recommend continuation of and increased support for the West Virginia Invasive Species Working Group.		TNC	WVISWG, WVDA, WVDNR	2014		$500
AS 1.6	Recommend creation of a full-time statewide Invasive Species Coordinator position.		TNC	WVISWG, WVDA, WVDNR	2014		$1000
AG 2	**ESTABLISH MEMORANDA OF UNDERSTANDING** **Obtain Memoranda of Understanding with various agencies to implement WVISSP guidelines as appropriate.**						
AS 2.1	Develop relationships with and among key departmental leadership positions.		WVISSP MOU Partners	WVISWG, WVDNR, WVDA, USFS, USFWS, TNC, NRCS, NPS, WVDOF, WVU, PHCWPMA	Ongoing		$300
AA 2.1.1	Provide copies of this plan and supplemental educational materials to decision-makers.		WVISSP MOU Partners				$1000
AS 2.2	Identify agencies and organizations willing to sign as WVISSP MOU partners and draft MOU language.		WVDNR, PHCWPMA	WVISWG, WVDA, USFS, USFWS, TNC, NRCS, NPS, WVU, WVDEP, WVDOF	2013-2014		$100

AS 2.3	Secure WVISSP MOUs among partners.		WVDNR, PHCWPMA	WVISWG, WVDA, USFS, USFWS, TNC, NRCS, NPS, WVU, WVDEP, WVDOF	2014		$100
AA 2.3.1	Secure WVISSP MOUs among supporters (natural area managers, the outdoor recreation community, creators of linear transmission vectors such as highways and energy corridors, and others.)		WVISSP MOU Partners	WVDA, WVDNR, USFS, USFWS, TNC, NRCS, NPS, WVU, WVDEP, WVDOF, PHCWPMA	Ongoing		$200
AG 3	**COORDINATE MANAGEMENT PLANS** **Provide a framework for aligning operational, species, regional, agency, etc. land management and site construction plans with federal, regional, and state invasives plans.**						
AS 3.1	Distribute the WVISSP to decision-makers and management plan developers, encourage its use, and provide guidance for implementation.		WVDNR	WVISWG, WVDA, WVDOF	2014		$500
AS 3.2	Develop a prioritized list of areas in the state for invasive species prevention and management.		WVISSP MOU Partners	WVISWG, WVDA, WVDNR, USFS, USFWS, TNC, NPS, WVDOF, PHCWPMA	2014		$200
AS 3.3	Review management plans and make recommendations: • To increase alignment with recommended management goals • To reduce overlap of invasive species management actions • To increase interaction and cooperation among stakeholder groups		WVISSP MOU Partners	WVISWG, WVDA, PHCWPMA	Ongoing		$100
AS 3.4	Serve as clearinghouse for resources on control methods, state agency management plans, etc.		WVDA	WVISWG, PHCWPMA, WVDNR	Ongoing		$500
AS 3.5	Develop and/or collect, share, Best Management Practices for controlling invasive species.		USFS, PHCWPMA	WVISWG, WVDA, WVDNR	Begin in 2014		$200
AS 3.6	Develop, distribute, and annually update a “watch-list” of known invasive species that are either rapidly approaching and/or likely to establish in WV.		WVDA, WVDNR	WVISWG, USFS, USFWS, TNC, NPS, WVDOF, PHCWPMA	Begin in 2014		$100
AS 3.7	Support the development of agency and statewide management rules, regulations, and programs consistent with state, regional, and federal priorities and guidance, including this plan.		WVDA, WVDNR	WVISWG, USFS, USFWS, TNC, NPS, WVDOF, PHCWPMA	Ongoing		$200

AG 4	**COORDINATE AND PROMOTE SCIENCE-BASED POLICY** **Provide a coordinated, science-based voice on invasive species policy so legislative actions and management plans at all levels complement national, regional, and state guidance.**						
AS 4.1	Maintain and spread awareness about current research and management directives at the federal and regional levels, and surrounding states.		WVISSP MOU Partners	WVISWG, WVDA, WVU, USFS, WVDNR, TNC, USFWS, WVDOF	Ongoing		$300
AS 4.2	Consult with experts, provide commentary on proposed policy and legislation, and submit policy and legislative recommendations.		TNC	WVISWG, WVDA, WVDNR, WVU, WVDOF	Ongoing	$3880	
AG 5	**SUPPORT REGIONAL COLLABORATION** **Encourage long-term collaborative management for widespread invasive species, and for priority regions.**						
AS 5.1	Support species-specific working groups both within WV and in collaboration with other states as needed and as practicable.		USFS, USFWS	WVISWG, WVDA, WVDNR, TNC, WVU, WVDOF	Ongoing		$2500
AS 5.2	Support formation of CWPMAs, within WV and in collaboration with other states, as needed and as practicable.		PHCWPMA	WVISWG, WVDNR, WVDA, USFS, USFWS, NRCS, NPS, TNC, WVDOF, WVU	Full state coverage by 2025		$200
AG 6	**PRACTICE ADAPTIVE MANAGEMENT** **Regularly assess progress towards implementation and revise WVISSP as necessary.**						
AS 6.1	Assess progress towards Administrative Goals and Management Goals annually.		WVISSP MOU Partners		Annually		$200
AA 6.1.1	Publicize accomplishments and identify reasons for success. Replicate where possible.		WVISSP MOU Partners		Annually		$300
AA 6.1.2	Identify shortfalls, reasons for shortfalls, and develop strategies to address those reasons.		WVISSP MOU Partners		Annually		$500
AS 6.2	Revise WVISSP annually.		WVISSP MOU Partners		Annually		$500

MANAGEMENT GOALS, STRATEGIES, AND ACTIONS SUMMARY TABLE

MG: Management Goal; MS: Management Strategy; MA: Management Action

TASK ID	TASK	FUNDING SOURCE	LEAD AGENCY OR ORGANIZATION	COOPERATING AGENCIES AND ORGANIZATIONS	TIME FRAME	RECENT COSTS OF AIS EFFORTS (~2011-2014)	EST. FUTURE COSTS OF AIS EFFORTS (2015-6)
MG 1	**COORDINATION** **Coordinate with the West Virginia Invasive Species Strategic Plan and with other agencies and organizations to maximize efficiency and ensure alignment with federal, regional, and state priorities and programs.**						
MS 1.1	Consult WVISSP to ensure that land and water management, development, and other such plans and activities are congruent with the content and/or intent of WVISSP guidelines.		WVISSP MOU Partners	WVISWG, WVDNR, WVDA, USFS, USFWS, NRCS, NPS, TNC, WVDOF, WVU, PHCWPMA, WVDOH	Ongoing		$200
MS 1.2	Partner with other agencies to maximize efficient use of resources.		WVISSP MOU Partners	WVISWG, WVDNR, WVDA, USFS, USFWS, NRCS, NPS, TNC, WVDOF, WVU, PHCWPMA, WVDOH	Ongoing	$4835	$5000
MS 1.3	Identify and/or develop, and share, Best Management Practices for invasive species prevention and control.		USFS, PHCWPMA	WVISWG, WVDA, WVDNR	2014		$200
MA 1.3.1	Incorporate Best Management Practices for invasive species prevention and control into state and federal permits and plans.		WVISSP MOU Partners	WVDNR, WVDA, USFS, USFWS, NRCS, NPS, WVDOF, PHCWPMA, WVDOH	Ongoing	$3880	$4000
MS 1.4	Develop and/or implement online resources to share information and to capture statewide survey, monitoring, and treatment data.		PHCWPMA, WVDNR, TNC	USFS, USFWS, WVDA	Ongoing	$1800	$200
MA 1.4.1	Encourage managers to enter invasive species data into EDDMapS.org, iMapInvasives, the USGS NAS database, and/or other database.		WVISSP MOU Partners		Ongoing		$300
MA 1.4.2	Implement or develop a statewide GIS-based invasive species mapping system in order to track range expansion/reductions of target species, and develop and prioritize treatment strategies.		PHCWPMA	WVDA, WVDNR, TNC, USFS, USFWS	2014		$1000
MS 1.5	Designate a single point of contact for each participating agency and group.		WVISSP MOU Partners		2014		$300

MG 2	**PREVENTION** **Prevent the introduction and spread of known or potential invasive species.**						
MS 2.1	Identify priority areas in the state for invasive species prevention, eradication, control, and management. Review regularly and revise as necessary.		WVDA, WVDNR	USFS, USFWS, TNC, NPS, PHCWPMA	2015	$370	$300
MA 2.1.1	Delineate biodiversity refugia (remnant natural areas with high biodiversity significance) that are critical to the maintenance of West Virginia's flora, fauna, and ecosystem services.		TNC, WVNDR		2015	$370	$300
MA 2.1.2	Identify geographic areas with institutional or community capacity to serve as pilot action areas.		PHCWPMA	NPS, NRCS, USFS, USFWS, WVDOF, TNC	2015	$370	$300
MS 2.2	Coordinate with surrounding states and other agencies and organizations to minimize the spread of invasives both in state and across state lines.		WVDA, WVDNR	WVISWG, USFS, USFWS, TNC, NPS, WVDOF, PHCWPMA	Ongoing	$5308	$5000
MA 2.2.1	Create and annually update a "watch list" of high-priority invasive species not yet present but with a high probability of being introduced or establishing in West Virginia.		WVDA, WVDNR	WVISWG, USFS, USFWS, TNC, NPS, WVDOF, PHCWPMA	Ongoing	$370	$300
MA 2.2.2	Track species movements, identify leading edges and outlier infestations, and share information to prioritize prevention efforts.		WVDA, WVDNR	WVISWG, USFS, USFWS, TNC, NPS, WVDOF, PHCWPMA	Ongoing	$20,855	$18500
MS 2.3	Develop, maintain, and share lists of invasive plants, insects, animals, and pathogens currently present in West Virginia, ranked according to threat.		WVDNR	WVDA, USFS, TNC, WVU	Ongoing	$370	$300
MA 2.3.1	Support legislation to control all invasive species in West Virginia with the highest threat ranking.		TNC	WVDNR, WVDA			$500
MS 2.4	Seek support for, develop, and implement, policies and legislation to regulate or cease trade in or spread of species identified as high priority invasives.		TNC	WVDNR, WVDA, WVDOF	Ongoing	$3880	$500
MS 2.5	Develop sources of funding and support to ensure agencies have the capacity to enforce laws and uphold policies pertaining to invasive species.		WVISSP MOU Partners				$500
MS 2.6	Develop and distribute educational materials on prevention to all stakeholder groups, including outdoor recreation, transportation, development, natural resource extraction, utilities, etc.		PHCWPMA	WVISWG, WVDNR, WVDA, USFS, USFWS, TNC, NRCS, NPS, WVDOF, WVU	Ongoing	$8140	$7,000

MS 2.7	Develop and/or implement Best Management Practices to reduce the likelihood of spreading invasive species during all land management activities.		USFS, WVDOF, PHCWPMA	WVISWG, WVDA, WVDNR, WVDOH	Ongoing	$3780	$4000
MG 3	**EARLY DETECTION** **Detect, report, and monitor new populations of invasive species in West Virginia efficiently, effectively, and appropriately.**						
MS 3.1	Monitor at least high priority sites, identify new occurrences of invasive species, and report them to a database as described in MA 1.4.1.		WVDNR, USFS	PHCWPMA, WVISWG, TNC, NPS	2015	$10,275	$7,000
MA 3.1.1	Formalize a network of stakeholders responsible for conducting surveys.		WVISSP MOU Partners	WVDNR			$1000
MS 3.2	Improve early detection capacity in the state.		WVISSP MOU Partners	WVDNR, WVDA, PHCWPMA, NPS	Ongoing		$300
MA 3.2.1	Identify and evaluate ongoing early detection programs, networks, and other avenues through which invasive occurrences are detected, reported, and monitored in West Virginia.		WVISSP MOU Partners		2016		$200
MA 3.2.2	Identify geographic, procedural, infrastructural, and funding gaps, and develop and implement recommendations and programs to enhance capacity. Support refinement and growth of high-functioning programs.		WVISSP MOU Partners		2016		$200
MS 3.3	Establish a network of participating taxonomic experts to enable rapid identification of unknown species and to differentiate between native and non-native species, subspecies, and varieties.		WVDNR, WVDA	WVU, USFS	Ongoing		$500
MS 3.4	Develop or implement a citizen science program to teach volunteers and stakeholders how to identify high priority invasive species and native lookalikes, and how to enter data into EDDMapS.org, iMapInvasives.org, or similar database.		PHCWPMA	WVDNR, USFS, USFWS, TNC	2015		$300
MG 4	**RAPID RESPONSE** **Develop and implement cooperative, multi-agency teams and protocols to rapidly, efficiently, and effectively respond to newly discovered infestations.**						
MS 4.1	Develop rapid response plans to enable rapid deployment of personnel, equipment, and funds to eradicate and control new WV occurrences of "watch list" species (see MA 2.2.1) in West Virginia.		WVISSP MOU Partners		2016		$500

MS 4.2	Identify which agencies would need to be involved for various types of pests, seek their support, and establish cooperative agreements among such agencies, organizations, and private entities.		WVISSP MOU Partners		2016		$500
MS 4.3	Establish a network of rapid response teams responsible for implementing rapid response plans. Individuals and/or agencies on the team must have authority to quickly: • access funding, personnel, and equipment, • deploy and direct the use of those resources, • restrict movement of materials or species, and • act according to cooperative agreements established for this purpose.		WVISSP MOU Partners	PHCWPMA, WVDNR, WVDA, USFS, USFWS, TNC, NPS, WVDOH	2016		$1000
MG 5	**CONTROL AND MANAGEMENT** **Prioritize, manage, and monitor known populations of invasive species in West Virginia efficiently, effectively, and appropriately.**						
MS 5.1	Develop and implement management plans to eradicate, control, contain, manage, monitor, and/or report on management actions taken on known, prioritized invasive species infestations. Plans should: • include baseline site conditions, • identify desired outcomes based on measurable parameters, • provide for monitoring parameters of success, • provide means to adjust treatments and goals as needed, and • include reporting requirements to a centralized database to enhance regional/statewide efforts.			WVDNR, WVDA, USFS, USFWS, TNC, NRCS, NPS, WVDOF, PHCWPMA, WVDOH	Ongoing	$20268	$15000
MS 5.2	Develop and implement restoration plans concurrent with invasive management activities.			WVDNR, WVDA, USFS, USFWS, TNC, NRCS, NPS, WVDOF, PHCWPMA, WVDOH	Ongoing		$500
MS 5.3	Develop a state-wide network of Cooperative Weed and Pest Management Areas.		PHCWPMA	WVISSP MOU Partners	2025		$200
MS 5.4	Develop and/or implement Best Management Practices in management plans to control invasives.		USFS, PHCWPMA	WVISSP MOU Partners	Ongoing	$500	$1500
MS 5.5	Maintain and enhance capacity and training for management activities.			WVDNR, WVDOH, USFWS, TNC, NRCS, NPS, WVDOF, WVDA	Ongoing	$2587	$2500

MS 5.6	Pursue sufficient funding for invasive species control on public and private lands and waters.		WVISSP MOU Partners		Ongoing		$200
MS 5.7	Develop new, and align with existing, programs and incentives to assist private landowners in implementing invasive species prevention and control, and habitat restoration activities.			NRCS, WVDOF, WVDA, TNC	Ongoing		$500
MG 6	**RESEARCH AND ASSESSMENT** **Identify and support research and assessment needs, and share results. Regularly review current scientific findings and update practices as needed.**						
MS 6.1	Collaborate with state, regional, and federal researchers and taxonomists.		WVISSP MOU Partners	WVDA, USFS, TNC, WVU	Ongoing		$300
MS 6.2	Improve access to current invasive species research and share findings statewide and regionally.		WVISSP MOU Partners	WVDNR, WVDA, WVU	Ongoing		$200
MS 6.3	Identify research priorities for WV and its surrounding region, and develop and conduct relevant projects. See Appendix E.		WVU, USFS	WVDNR, WVISWG	Ongoing	$14,550	$15000
MS 6.4	Develop invasive species risk assessments and natural community vulnerability assessments in West Virginia to better prioritize invasive species management efforts.		WVDNR, WVDA	USFS, USFWS, WVU, TNC, PHCWPMA	Ongoing		$1000
MA 6.4.1	Collect and share existing risk assessments for invasive species that are present in or approaching West Virginia.		WVDNR, WVDA	USFS, USFWS, WVU, TNC, PHCWPMA	Ongoing		$1000
MA 6.4.2	Collect and share existing vulnerability assessments for natural areas in West Virginia.		WVDNR	USFS, USFWS, NPS, WVU, TNC, PHCWPMA	Ongoing		$300
MA 6.4.3	Identify and task agencies with the responsibility for conducting risk and vulnerability assessments in West Virginia, and develop additional assessments as needed.		WVISSP MOU Partners	WVDNR, TNC	Ongoing		$500
MA 6.4.4	Increase capacity for invasive species and risk assessment research in terms of funding, personnel, facilities, equipment and software, data, and training.		WVISSP MOU Partners	WVDNR, TNC	Ongoing	$4850	$4000

MG 7	**EDUCATION AND OUTREACH** **Conduct invasive species education and outreach in a variety of formats with a wide range of stakeholders and interest groups.**						
MS 7.1	Support existing community, non-profit, and educational projects and programs focused on invasive removal, habitat restoration, environmental education, and citizen science.		WVISSP MOU Partners	PHCWPMA, WVDNR, USFS, USFWS, TNC, NPS	Ongoing	$4895	$1500
MS 7.2	Research current awareness and interest among stakeholder groups and the general public in WV about invasive species.		WVISSP MOU Partners		2015		$200
MS 7.3	Develop and distribute a variety of educational presentations and materials on a variety of aspects of invasive species for diverse audiences.		WVISSP MOU Partners	PHCWPMA, WVDNR, USFS, USFWS, TNC, NPS	Ongoing	$14,355	$15000

	RECENT COSTS OF AIS EFFORTS (~2011-2014)	**EST. FUTURE COSTS OF AIS EFFORTS (2015-6)**
Totals	**$139,677**	**$142,900**

APPENDIX B: INVASIVE SPECIES IN WEST VIRGINIA

What follows is a substantial but not comprehensive listing of invasive species known to be established in West Virginia, developed by state experts from various agencies. A few listed are not yet present in the state but are considered a concern due to proximity or likelihood of invasion; these are marked with an asterisk. Some agencies and organizations may consider additional or different species to be invasive, and actual site-specific impacts may vary depending on site conditions. Animal, microbe, and some aquatic species have not had a threat ranking assessed or assigned. Non-native game species whose populations are artificially maintained for recreation are not included.

Species are divided into the following categories for ease of reference:

- Terrestrial and Aquatic Invasive Plants
- Terrestrial and Aquatic Invasive Animals, including Insects
- Microbes (Fungi, Bacteria, Viruses, Protists)

1. Terrestrial and Aquatic Invasive Plants

There are nearly 500 documented species of invasive plant species in West Virginia. WVDNR staff have ranked them on a threat scale from 1-4 from most to least threat. Only those ranked 1 (high) and 2 (moderate) are included here. This list was compiled primarily by WVDNR botanists, with special thanks to Elizabeth Byers, P. J. Harmon, and Jim Vanderhorst (WVDNR, 2009.) Species are arranged alphabetically by common name.

Threat Ranking	Common Name	Scientific Name
1	Amur Honeysuckle	*Lonicera maackii*
1	Asian Bittersweet	*Celastrus orbiculata*
1	Asiatic Tearthumb (Mile-a-minute)	*Polygonum perfoliatum*
1	Autumn Olive	*Elaeagnus umbellata var. parvifolia*
1	Bradford Pear	*Pyrus calleryana*
1	Cheatgrass	*Bromus tectorum*
1	Chinese Bushclover	*Lespedeza cuneata*
1	Chinese Yam	*Dioscorea oppositifolia*
1	Common Reed	*Phragmites australis*
1	Cork Tree	*Phellodendron japonicum* Maxim
1	European Privet	*Ligustrum vulgare*
1	Garlic Mustard	*Alliaria petiolata*
1	Hydrilla	*Hydrilla verticillata*
1	Japanese Barberry	*Berberis thunbergii*
1	Japanese Honeysuckle	*Lonicera japonica*
1	Japanese Knotweed	*Fallopia japonica*
1	Japanese Stiltgrass	*Microstegium vimineum*
1	Johnson Grass	*Sorghum halepense*
1	Kudzu	*Pueraria montana var. lobata*
1	Lesser Periwinkle	*Vinca minor*
1	Meadow Fescue	*Schedonorus pratensis*
1	Morrow's Honeysuckle	*Lonicera morrowii*
1	Multiflora Rose	*Rosa multiflora*
1	Norway Maple	*Acer platanoides*
1	Purple Crown-Vetch	*Coronilla varia*
1	Purple Loosestrife	*Lythrum salicaria*
1	Reed Canarygrass	*Phalaris arundinacea*
1	Small Carpgrass	*Arthraxon hispidus*

1	Spotted Knapweed	*Centaurea stoebe ssp. micranthos*
1	Tall Fescue	*Schedonorus phoenix*
1	Tatarian Honeysuckle	*Lonicera tatarica*
1	Tree-Of-Heaven	*Ailanthus altissima*
1	Wine Raspberry	*Rubus phoenicolasius*
1	Winged Euonymus	*Euonymus alata*
1	Winter Creeper	*Euonymus fortunei*
1	Yellow Iris	*Iris pseudacorus*
2	Amur Peppervine or Porcelainberry	*Ampelopsis brevipedunculata*
2	Beefsteak Plant	*Perilla frutescens*
2	Bell's Honeysuckle	*Lonicera ×bella*
2	Bishop's Goutweed	*Aegopodium podagraria*
2	Border privet	*Ligustrum obtusifolium*
2	Bull Thistle	*Cirsium vulgare*
2	Butter-And-Eggs	*Linaria vulgaris*
2	Canada Bluegrass	*Poa compressa*
2	Canada Thistle	*Cirsium arvense*
2	Celandine	*Chelidonium majus var. majus*
2	Common Buckthorn	*Rhamnus cathartica*
2	Common Chickweed	*Stellaria media ssp. media*
2	Common Chickweed	*Stellaria media ssp. pallida*
2	Common Chickweed	*Stellaria media*
2	Common Sheep Sorrel	*Rumex acetosella*
2	Common St. John's-Wort	*Hypericum perforatum*
2	Common Velvetgrass	*Holcus lanatus*
2	Creeping Jenny	*Lysimachia nummularia*
2	Curly Pondweed	*Potamogeton crispus*
2	Drooping Star Of Bethlehem	*Ornithogalum nutans*
2	Eurasian Water-Milfoil	*Myriophyllum spicatum*
2	Fiveleaf Akebia	*Akebia quinata*
2	Fuller's Teasel	*Dipsacus fullonum*
2	Garden Yellow-Rocket	*Barbarea vulgaris*
2	Giant Knotweed	*Fallopia sachalinense*
2	Glossy False Buckthorn	*Frangula alnus*
2	Great Mullein	*Verbascum thapsus*
2	Ground-Ivy	*Glechoma hederacea*
2	Gypsy-Flower	*Cynoglossum officinale*
2	Hairy Cat's-Ear	*Hypochaeris radicata*
2	Indian-Strawberry	*Duchesnea indica*
2	Japanese Brome	*Bromus japonicus*
2	Japanese Bushclover	*Lespedeza bicolor*
2	Japanese Spiraea	*Spiraea japonica var. fortunei*
2	Kentucky Bluegrass	*Poa pratensis ssp. pratensis*
2	Laciniate Wild Teasel	*Dipsacus laciniatus*
2	Lesser Burdock	*Arctium minus*
2	Lesser Celandine	*Ranunculus ficaria var. bulbifera*
2	Meadow Brome	*Bromus commutatus*
2	Meadow Hawkweed	*Hieracium caespitosum*
2	Mother-Of-The-Evening	*Hesperis matronalis*
2	Nodding Plumeless-Thistle	*Carduus nutans ssp. macrolepis*

2	Oriental Lady's-Thumb	*Polygonum caespitosum var. longisetum*
2	Oxeye Daisy	*Leucanthemum vulgare*
2	Parrot's-Feather	*Myriophyllum aquaticum*
2	Parsnip	*Pastinaca sativa*
2	Perennial Ryegrass	*Lolium perenne ssp. multiflorum*
2	Poison-Hemlock	*Conium maculatum*
2	Poverty Brome	*Bromus sterilis*
2	Princess-Tree	*Paulownia tomentosa*
2	Queen Anne's-Lace	*Daucus carota*
2	Rough Bluegrass	*Poa trivialis*
2	Russian-Olive	*Elaeagnus angustifolia*
2	Rye Brome	*Bromus secalinus*
2	Siberian Elm	*Ulmus pumila*
2	Smooth Bromegrass	*Bromus inermis ssp. inermis var. inermis*
2	Standish's Honeysuckle	*Lonicera standishii*
2	Star Of Bethlehem	*Ornithogalum umbellatum*
2	Stonecrop	*Sedum sarmentosum*
2	Sweetclover	*Melilotus officinalis*
2	Viper's Bugloss	*Echium vulgare*
2	Watercress	*Rorippa nasturtium-aquaticum*
2	Wocheiner Knapweed	*Centaurea nigrescens*
(Unranked*)	Didymo	*Didymosphenia geminata*
(Unranked*)	Golden Algae	*Prymnesium parvum*

*Golden algae and didymo, both in the kingdom *Chromista* (diatoms and some algae), have not been ranked in comparison with plant species at this time, but are both considered significant threats.
Note: This list is an evolving document due to the nature of invasion biology and research. As of this writing, candidates for addition include Bohemian knotweed (*Fallopia x bohemica*), Japanese hops (*Humulus japonicas*), Chinese silvergrass (*Miscanthus sinensis*), and others.

2. Invasive Animals

List compiled and reviewed primarily by WVDNR and WVDA staff, with special thanks for their comments and critical review to Rich Bailey, Dan Cincotta, and Walt Kordek of WVDNR; Rachel Braud, Laura Miller, and Tim Tomon of WVDA; Kent Karriker and Patricia Morrison of USFS; and all TNC Elkins office staff. These species have not been assigned threat rankings at this time. Species are arranged alphabetically by common name within taxon.

Taxon	**Common Name**	**Latin Name**
Birds	Brown-headed cowbird	*Molothrus ater*
Birds	House sparrow	*Passer domesticus*
Birds	European starling	*Sturnus vulgaris*
Crustaceans	Rusty crayfish	*Orconectes rusticus*
Crustaceans	Virile crayfish	*Orconectes virilis*
Fishes	Bighead carp	*Hypophthalmichthys nobilis*
Fishes	Goldfish	*Carassius auratus*
Fishes	Grass carp	*Ctenopharyngodon idella*
Fishes	Mosquitofish	*Gambusia affinis*
Fishes	Northern snakehead*	*Channa argus**
Fishes	Silver carp	*Hypophthalmichthys molitrix*

Insects	Alfalfa weevil	*Hypera postica*
Insects	Ambrosia/Bark beetle species	*Anisandrus maiche*
Insects	Ambrosia/Bark beetle species	*Xyleborus pelliculosus*
Insects	Ambrosia/Bark beetle species	*Xyleborus californicus*
Insects	Ambrosia/Bark beetle species	*Ambrosiophilus atratus*
Insects	Ambrosia/Bark beetle species	*Euwallacea validus*
Insects	Asian Lady beetle	*Harmonia axyridis*
Insects	Asian long-horned beetle*	*Anoplophora glabripennis**
Insects	Asian bush mosquito	*Aedes japonicus*
Insects	Asian tiger mosquito	*Aedes albopictus*
Insects	Balsam Woolly Adelgid	*Adelges piceae*
Insects	Banded Elm Bark Beetle	*Scolytus schevyrewi*
Insects	Beech Scale	*Cryptococcus fagisuga*
Insects	Blueberry Maggot	*Rhagoletis mendax*
Insects	Brown Marmorated Stink Bug	*Halyomorpha halys*
Insects	Cabbage White	*Pieris rapae*
Insects	Elongate Hemlock Scale	*Fiorina externa*
Insects	Emerald Ash Borer	*Agrilus planipennis*
Insects	Euonymus scale	*Unaspis euonymi*
Insects	European Corn Borer	*Ostrinia nubilalis*
Insects	European Elm Bark Beetle	*Scolytus multistriatus*
Insects	European hornet	*Vespa crabro*
Insects	European Paper Wasp	*Polistes dominula*
Insects	German Yellow Jacket	*Vespula germanica*
Insects	Granulate Ambosia Beetle	*Xylosandrous crassiusculus*
Insects	Gypsy Moth	*Lymantria dispar*
Insects	Hemlock Woolly Adelgid	*Adelges tsugae*
Insects	Japanese Beetle	*Popillia japonica*
Insects	Large yellow underwing	*Noctus pronuba*
Insects	Mexican Bean Beetle	*Epilachna varivestis*
Insects	Pine Shoot Beetle	*Tomicus piniperda*
Insects	Soybean Aphid	*Aphis glycines*
Insects	Spotted Wing Drosophila	*Drosophila suzukii*
Insects	Walnut twig beetle*	*Pityophthorus juglandis**
Insects	White Fringed Beetle	*Naupactus leucoloma*
Insects	Yellow-fever mosquito*	*Aedes aegypti**
Mammals	Feral cat	*Felis catus*
Mollusks-Gastropods	Chinese mystery snail	*Cipangopaludina chinensis malleata*
Mollusks-Bivalves	Asian Clam	*Corbicula fluminea*
Mollusks-Bivalves	Zebra mussel	*Dreissena polymorpha*

**species not yet detected in WV but likely to be here, or considered a significant imminent threat*

3. Invasive Microbes or Pathogens (Fungi, Bacteria, Viruses, Protists, etc.)

Listing invasive microbes for a given region is complicated by several issues. Determining the origin, and therefore exoticness, of a microbe is much more difficult than with a plant or animal. Some well-known pathogens such as rabies and Hantavirus are present in West Virginia as native strains. Some pathogens primarily affect agricultural crops or livestock. Agricultural diseases are beyond the scope of this document, but information is available at www.wvagriculture.org/images/Plant_Industries/PlantPathologyResources.html. Finally, some exotic pathogens such as HIV sicken primarily people. For policy and regulatory purposes these tend to be dealt with more like diseases than invasive species (though if they are carried on a zoonotic vector, control measures may be similar to those employed for invasive species, regardless of whether the vector is exotic or native). A treatment and listing of such diseases in West Virginia is obviously beyond the scope of this document, but information is available at www.cdc.gov/ncezid/ and www.dhhr.wv.gov/oeps/disease/Zoonosis/Pages/default.aspx.

The list that follows, therefore, is a conservative compilation of the most well-known and impactful exotic pathogens known to be present and/or actively surveyed for in West Virginia, which affect native plants and animals. It is based on lists maintained at www.invasive.org/gist/products/gallery/regionlist.html and www.dontmovefirewood.org/gallery-of-pests. The list was further customized to West Virginia based on reviewers' comments, with special thanks to Jim Crum of WVDNR, Kent Karriker of USFS, and Tim Tomon of WVDA.

These species have not been assigned threat rankings. Species are arranged alphabetically by common name.

Common Name	**Infectious agent**	**Species or taxon affected**
Beech bark fungus	*Nectria coccinea var faginata*	Beech trees
Butternut canker	*Sirococcus clavigignenti-juglandacearum*	Butternut trees
Chestnut blight	*Cryphonectria parasitica*	Chestnut trees
Chronic wasting disease (CWD)†	*prion—no name**	White-tail deer
Dogwood anthracnose	*Discula destructiva*	Dogwood trees
Dutch Elm Disease	*Ophiostoma ulmi*	Elm trees
Phytophthora root rot	*Phytophthera cinnamomi*	American chestnut and Allegheny chinkapin
Sudden Oak Death**	*Phytophthera ramorum***	Oaks and other hardwoods
Thousand Cankers Disease**	*Geosmithia morbida***	Black walnut trees
Viral Hemorrhagic Septicemia (VHS)	*Novirhabovirus*	Over 50 species of freshwater & marine fish
West Nile Virus	*Flavivirus*	Primarily birds, but also humans, horses, and many other mammals
Whirling Disease	*Myxobolus cerebralis*	Trout
White Pine Blister Rust	*Cronurtium ribicola*	White Pines
White-nose syndrome	*Pseudogymnoascus destructans*	Bats hibernating in caves and mines

**CWD is caused by a mis-folded protein called a prion; all mammalion prions are mutated versions of the protein referred to as PrP^{Sc} (Krull and Nunnally, 2004). Its geographic origin is not known at this time, but it seems to have spread from the American west.*

***species not yet detected in WV but considered a significant imminent threat*

APPENDIX C: WEST VIRGINIA ADMINISTRATIVE CODES AND STATUTES RELATING TO INVASIVE SPECIES

See www.invasivespeciesinfo.gov/laws/wv.shtml for links to the full text of each of the following:

- **West Virginia Code -** State Laws (www.legis.state.wv.us/WVCODE/Code.cfm)
    - Agriculture (Chapter 19)
        - Insect Pests, Plant Diseases, and Noxious Weeds (Article 12)
            - Quarantines (19-12-6)
            - Permit required to sell, transport, etc., plant pests or noxious weeds (19-12-14)
        - Interstate Compact on Pest Control (Article 19-12B)
        - West Virginia Noxious Weed Act (Article 19-12D)
            - Multiflora rose (19-12D-5)
            - Quarantines (19-12D-6)
            - Importation or sale of multiflora rose unlawful (19-12D-12)
    - Natural Resources (Chapter 20)
        - Natural Resources (Article 2)
            - Release of aquatic organisms prohibited without DNR stocking permit (20-2-64)
        - Forests and Wildlife Areas (Article 3)
            - Protection of forests against destructive insects and diseases (20-3-19)
- **Code of State Rules -** State Regulations (apps.sos.wv.gov/adlaw/csr)
    - Agriculture (Title 61)
        - West Virginia Plant Pest Act Rule (61-14) (DOC | 138 KB)
        - Rules and Regulations Dealing with Noxious Weeds (61-14A) (DOC | 57 KB)

For a recently compiled list of all Federal laws applicable to invasive species, see “Invasive Species: Major Laws and the Role of Selected Federal Agencies” (Corn and Johnson, 2013).

APPENDIX D: CONTRIBUTING AGENCIES AND ORGANIZATIONS, AND CURRENT INVASIVES PROGRAMS

Note: this only includes agencies that deal with invasives as part of their mission, not those who deal with invasives tangential to their mission or in the course of carrying out another primary mission.

FEDERAL GOVERNMENT

DEPARTMENT OF AGRICULTURE

Animal and Plant Health Inspection Service/Plant Protection and Quarantine (APHIS-PPQ) (www.aphis.usda.gov/)
The Animal and Plant Health Inspection Service is a multi-faceted federal agency with a broad mission that includes, among many other things, protecting U.S. agricultural health and managing wildlife damage. These efforts support the overall mission of USDA, which is to protect and promote food, agriculture, natural resources and related issues. APHIS works to defend America's animal and plant resources from agricultural pests and diseases, such as Asian longhorned beetle. When a pest or disease of concern is detected, APHIS implements emergency protocols and partners with affected states to quickly manage or eradicate the outbreak. APHIS develops and advances science-based standards with trading partners and protects natural resources that are vulnerable to invasive pests and pathogens.

Forest Service (USFS) (www.fs.fed.us/invasivespecies)
The Forest Service is dedicated to the sustained management of natural resources on National Forest System lands for multiple uses of these resources for current and future generations. Managing the resources of the Nation's forests and grasslands requires the complex integration of resource assessments, management actions, and cooperative partnerships. By working with partners, the Forest Service expands its capability to participate in conservation through stewardship, research, and education/outreach. The Forest Service uses the best available science-based methods to prevent and reduce the impacts of invasive species and thereby sustain the integrity and resilience of the Nation's forest and grassland ecosystems. The Invasive Species Program is integrated across all deputy areas of the agency. The Forest Service has identified invasive species as one of the four critical threats to our Nation's ecosystems. The Forest Service is a leading federal agency in forest research, forest health, and Federal resource management. In West Virginia, USFS staff from the George Washington, Jefferson, and Monongahela National Forests, Northeastern Area State and Private Forestry, and the Northern Research Station are actively involved in many aspects of invasive species management, including regional partnerships, removal, control, education, funding, and research.

Natural Resources Conservation Service (NRCS) (www.nrcs.usda.gov)
NRCS works with landowners through conservation planning, education/outreach and technical and financial assistance designed to benefit the soil, water, air, plants, and animals that together create productive lands and healthy ecosystems. The presence of noxious and/or invasive plants is a resource concern that NRCS staff evaluate during the planning process. All NRCS conservation plans include an inventory of invasive species, a map outlining the affected areas, identification of control/restoration strategies, and an analysis of their impacts. NRCS provides financial assistance for the control of some invasive species as program guidelines and funding allow. NRCS succeeds through its partnerships, working closely with individual farmers, landowners, local conservation districts, government agencies, volunteers and others that care about the quality of natural resources.

DEPARTMENT OF THE INTERIOR

National Park Service (NPS) (www.nps.gov)
The National Park Service maintains three significant natural areas contained entirely within West Virginia: the New River Gorge National River, Bluestone National Scenic River, and Gauley River National Recreation Area. The Appalachian Trail, Chesapeake & Ohio Canal, and Harper's Ferry National Historic Park are other NPS-managed lands that are partially located in West Virginia. In 2010, an Implementation Plan for Managing Invasive Exotic Vegetation was completed for the New River Gorge National River and Bluestone Scenic River.

US Fish and Wildlife Service (USFWS) (www.fws.gov)
Canaan Valley and Ohio River Islands National Wildlife Refuges are run by USFWS. Canaan Valley has an active invasives management program which includes thrice-yearly volunteer patrols and mapping, neighboring landowner education, ongoing removal of targeted species (including yellow iris and Japanese stiltgrass), and removal/treatment of new infestations. The Ohio River Islands NWR is actively controlling for multiflora rose, various knotweeds, and Asiatic tearthumb (*Persicaria perfoliata*), among others.

USFWS Ecological Services Field Station Office (www.fws.gov/westvirginiafieldoffice)
The U.S. Fish and Wildlife Service West Virginia Field Office partners with state and federal organizations to conserve, protect, and enhance fish, wildlife and plants and their habitats. Staff work to recover threatened and endangered species; enforce federal fish, wildlife, and plant laws and regulations; partner with private landowners to restore natural habitats; and ensure that wildlife resources are considered by agencies during the planning and operating of wind, coal, hydropower, oil and gas, and road projects. The USFWS conducts invasive species removal, education, and is an active partner in many invasive species projects.

WEST VIRGINIA STATE GOVERNMENT

DEPARTMENT OF AGRICULTURE (www.wvagriculture.org)

The Plant Industries Division (PID)
The PID protects the State's agricultural interests and forest lands from destructive insects, plant diseases, noxious weeds, and other pest organisms through pest detection, survey, identification, and control efforts and by enforcing regulations that have been promulgated to protect our crops and forests (both urban and rural). Many of the programs within the Division operate under authority granted by the West Virginia Plant Pest Act (Chapter 19, Section12 of the Code of West Virginia) and the West Virginia Noxious Weed Act (Chapter19, Section 12D of the Code of West Virginia).

Agricultural Pest Survey Program Unit
The mission of this program is to carry out the provisions of certain agricultural laws and to enforce the rules, regulations and quarantines that have resulted from these laws. Includes the Black Fly Control Program, Cooperative Agricultural Pest Survey Program, Pest Identification Laboratory and Plant Pest Regulatory Program.

Forest Health Protection Programs Unit
The mission of this program is to provide for forest insect and disease surveillance and detection programs, and, when necessary, to plan and conduct forest pest suppression and/or abatement programs under the authority of the West Virginia Plant Pest Act. The unit participates in several formal agreements with USDA, Forest Service and cooperates with DOF and WVU Division of Plant and Soil Sciences, Entomology and Plant Pathology Departments in conducting surveys, identifying causal agents, delimiting infestations, planning control programs and assisting the citizens of WV in forest insect and disease related programs. Programs include Cooperative Forest Health Protection Program, Gypsy Moth Program and GIS Section.

Pesticide Regulatory Programs
"The WVDA Pesticide Regulatory Programs Unit regulates the production, use, sale and disposal of all pesticides in West Virginia under Article 16A West Virginia Pesticide Control Act of 1990; Title 61 Series 12A Certified Pesticide Applicator Rules; Title 61 Series 12B Licensing of Pesticide Businesses; and at least 5 other Legislative Rules ranging from Aerial Applications to Permanent Operational Areas. This program has the regulatory authority to control all pesticide applications on public and private land in the state as well as associated record keeping. All applicators of any pesticide who are operating under the employment of a government, business or even those volunteering for an agency or non-profit must either be a Certified Commercial Applicator, Certified Public Applicator or a Registered Technician operating under the supervision of a Certified Commercial Applicator or Certified Public Applicator. Even businesses or entities applying not-for-hire on their own lands using over the counter general use pesticides must be licensed and maintain records on all applications. Private landowners and their immediate

families do not need a license to apply general use pesticides on their own lands." (personal communication, Philip Smith, 9/23/14).

DEPARTMENT OF ENVIRONMENTAL PROTECTION (WVDEP) (www.wv.dep.gov)

The WVDEP deals with invasives in mine reclamation and restoration projects in its Division of Land Restoration. WVDEP also regulates minelands, oil, gas, and water resources. Currently its site restoration guidelines prohibit the use of federally-listed noxious weeds, but permit a variety of non-native plants.

DIVISION OF NATURAL RESOURCES (WVDNR) (www.wvdnr.gov)

The Division of Natural Resources owns or manages 1.4 million acres, on which it manages habitat and populations of fish and game wildlife. The division also manages habitat for non-game wildlife and rare, threatened, and endangered species. WVDNR staff informally monitor invasive species during the performance of other duties, provides taxonomic expertise, and coordinates with other agencies to identify infestations of and manage a variety of invasive species where possible.

The following items are available from the WVDNR, Wildlife Resources Section:

- List of Invasive Plant Species of West Virginia, ranked by threat level (1-4)
- Checklist and Atlas of the Vascular Flora of West Virginia
- Native Shrubs in Wildlife Landscaping (series of information sheets about the use of 50 native shrubs in wildlife planting, produced by the WV Native Plants Society and the WV Wildlife Diversity Program)
- List of companies within the mid-Atlantic region from which native nursery stock can be purchased
- Restoration Planting Tool, a free software tool running in Microsoft Access that provides customized recommended native plant lists based on site characteristics and location in West Virginia.

WVDNR is also leading state efforts to fight the spread of aquatic invasive species. Partnering with other Ohio River basin states, WVDNR is helping write an Asian Carp Action Plan. In 2013 the West Virginia legislature enacted Bill 467 to prohibit the possession, sale, and release of a variety of carp species (*Hypophthalmichthys* and *Mylopharyngodon spp*), diploid white amur (*Ctenopharyngodon idella*) and snakeheads (*Channa* spp). Fishermen are also encouraged to report aquatic invasive species to the WVDNR Wildlife Resources Section office in Parkersburg.

DIVISION OF FORESTRY (WVDOF) (www.wvforestry.com)

The West Virginia Division of Forestry (WVDOF) works statewide to manage invasive species that threaten the state's forests and wood products industries. In partnership with WVDA and other agencies, they monitor and treat for invasive forest pests such as gypsy moths, emerald ash borer, hemlock woolly adelgid, and others. Quarterly Forest Stewardship workshops are conducted on a variety of topics important to foresters and landowners including invasive species awareness and treatment options. The WVDOF partners with WVU extension to sponsor landowner workshops and a newsletter. Landowner assistance foresters work closely with landowners to develop forest stewardship programs and recommend land management practices to minimize and treat invasive species. The WVDOF also operates the Clements State Tree nursery, providing high quality native tree species for reforestation and mine reclamation.

WEST VIRGINIA CONSERVATION AGENCY (WVCA) (www.wvca.us)

The WVCA is a state agency that functions much the same as the NRCS. Its primary mission is to preserve West Virginia's soil and water resources. The State Conservation Committee oversees programs statewide in 14 Conservation Districts, and staff in each of the districts work with private landowners. Among other things, WVCA provides financial and technical assistance for implementing agricultural Best Management Practices, stream restoration, and pollution mitigation projects (ww.wvca.us).

The WVCA administers a Multiflora Rose Control Program. Farm owners or operators who are actively involved in grazing land agriculture may enroll in this program. As program participants, they must maintain the treated area as grassland for a minimum of five years. The program now allows participating landowners to apply their own herbicide if they hold a private pesticide applicators license. Previously, only spraying by a commercial herbicide applicator was allowed. The program is expanded to provide cost share for the treatment of autumn olive in specific counties.

WEST VIRGINIA UNIVERSITY EXTENSION SERVICE (WVUES) (www.ext.wvu.edu)

The WVUES develops and teaches best practices for sustainable agriculture, responsible use of renewable resources, and stewardship of natural resources in order to improve West Virginia's communities, workforce, and the economy. Extension teaches farmers integrated pest management, which saves them money and improves the local environment. WVUES researchers conduct invasive species research, and provide taxonomic expertise and technical assistance to WVDA, WVDNR, and other state and federal agencies.

INDUSTRY

NURSERIES

Many agencies and private landowners are exploring native alternatives for conservation purposes on public and private lands, and some West Virginia nurseries are beginning to sell varieties derived from West Virginia communities to be sold as alternatives to exotic species. A list of regional nurseries selling native plants is maintained at www.wvdnr.gov/Wildlife/NativeVegetation.shtm.

INVASIVE REMOVAL BUSINESSES

Controlling and eradicating invasive species is an expensive undertaking, and one that needs to be carried out by professionals to have large-scale impacts while not harming native ecological communities. This offers an economic opportunity for those with the appropriate knowledge, training, and equipment. Appalachian Invasive Management and Invasive Plant Control, Inc. are two companies working to eradicate invasives in West Virginia.

NON-PROFITS

THE NATURE CONSERVANCY (TNC) (nature.org)

The Nature Conservancy is the leading conservation organization working around the world to protect ecologically important lands and waters for nature and people. To date, the Conservancy has protected 119 million acres of land and 5,000 miles of river and operates more than 100 marine conservation projects globally. Established as a chapter in 1963, the Conservancy's West Virginia Program has for over 50 years set the standing for on-the-ground conservation, protecting over 120,000 acres of the state's finest forests, rivers, wetlands and grasslands. The Nature Conservancy's strategies to conserving West Virginia's biological resources are collaborative, science-based, and holistic. TNC works directly in the following: advancing land conservation, assessing cumulative impacts from energy development, working with industry to develop practices that can reduce impacts from energy development, supporting legislative efforts to expand conservation, and partnering with stakeholders to expand restoration of native systems, including control of invasive species on some of the most important landscapes in West Virginia. Current invasive species-related efforts include:

- Securing federal funding for invasive species management and for implementing regulatory changes that could slow their introductions to North America
- Increasing public awareness of forest health issues
- Assessing landscapes of the Central Appalachians to determine which may be the most resilient to large-scale changes such as climate change

- Identifying key habitat corridors important as potential pathways for species in a changing world
- Actively supporting efforts of the Ohio River Basin Fish Habitat Partnership to protect, restore and enhance priority habitat for fish and mussels in the Ohio River.
- "Don't Move Firewood" campaign
- Management and lead of PHCWPMA Field Crew
- Fiscal Agent for PHCWPMA
- Aquatic Invasive Species outreach

SELECTED PARTNERSHIP GROUPS

- WEST VIRGINIA INVASIVE SPECIES WORKING GROUP (WVISWG)
- POTOMAC HIGHLANDS COOPERATIVE WEED AND PEST MANAGEMENT AREA (PHCWPMA)
- HEMLOCK CONSERVATION WORKING GROUP (HCWG)
- CENTRAL APPALACHIAN SPRUCE RESTORATION INITIATIVE (CASRI)
- APPALACHIAN FOREST HERITAGE AREA (AFHA)
- APPALACHIAN FIRE LEARNING NETWORK (FLN)

All of these groups focus on different aspects of land and biodiversity conservation, and have an interest in minimizing invasive species in West Virginia. Most groups participate in and/or conduct education, habitat restoration projects, and planning. Several utilize volunteer efforts; others are primarily professionals who advance the group's goals from within their respective organizations. The West Virginia Invasive Species Working Group has been the primary driver of this strategic plan, and the Potomac Highlands CWPMA is the largest regional effort specifically focused on invasive species management and control. The Hemlock Working Group and AFHA are critical supporters of these organizations, providing outreach, materials, funding, volunteers, and other logistical support.

WEST VIRGINIA INVASIVE SPECIES WORKING GROUP (WVISWG) (sites.google.com/site/wviswg)

The West Virginia Invasive Species Working Group is a consortium open to state and federal agencies, land grant university research and extension, other colleges and universities, industry organizations, and private organizations and individuals with an interest in the invasive species problem. Its purpose is two-fold: (1) to address the threat of invasive species to the people of West Virginia and the state's resources and industries in a coordinated and unified manner and (2) to provide a forum for the statement and discussion of the objectives and interests of its members. The Working Group's authority rests only in the respective authority of its members.

The primary mission of the WVISWG is to maintain an inclusive statewide group to facilitate actions for the prevention or reduction of negative impacts of invasive species on managed and natural terrestrial and aquatic communities through coordinated planning and communication, assessment and research and education and control.

Recognizing that invasive species are a serious threat to the state, the Working Group endorses the continued development of a statewide program involving survey and detection, suppression, management, research, and education.

WVISWG Member Organizations as of 2013

- West Virginia Department of Agriculture
- West Virginia Division of Natural Resources
- West Virginia Nursery and Landscape Association
- West Virginia Garden Clubs
- West Virginia University Extension
- West Virginia Department of Environmental Protection

- West Virginia Conservation Agency
- West Virginia Division of Highways
- West Virginia Division of Forestry
- National Park Service - New River Gorge
- United States Department of Agriculture
    - USDA Forest Service—Monongahela National Forest
    - USDA Northern Research Station
    - USDA Northeastern State and Private Forestry
- United States Fish and Wildlife Service
- The Nature Conservancy
- AFHA AmeriCorps

POTOMAC HIGHLANDS COOPERATIVE WEED AND PEST MANAGEMENT AREA (PHCWPMA) (www.phcwpma.org)

The PHCPWMA is "a partnership between federal, state, and local agencies, community associations, non-profit organizations, and private land owners aimed at coordinating efforts and programs for addressing the threat of invasive species." The PHCWPMA works in three counties in eastern WV (Grant, Hardy, and Pendleton) and Highland County in Virginia.

PHCWPMA's goals include:

- Decrease the impacts of invasive species on native plant and animal communities, public and private forests, aquatic resources, agricultural lands and local economics using Integrated Pest Management.
- Develop and support partnerships among a diverse group of private land owners, concerned citizens, agencies, non-profit organizations, industries, educational facilities, and local governments.
- Increase public awareness of the invasive species problem through public workshops, field tours, community meetings, demonstration areas, and by sharing resources

PHCWPMA partners as of 2013:

- Appalachian Forest Heritage Area
- WV Division of Highways
- WV Department of Agriculture
- The Nature Conservancy
- WV Division of Forestry
- WV Division of Natural Resources
- WV Native Plant Society
- WV Rivers Coalition
- USFWS West Virginia Field Office
- USDA
    - NRCS
    - USFS
        - Monongahela, George Washington, and Jefferson National Forests
        - Northern Research Station
        - Northeastern Area State and Private Forestry

APPENDIX E: RESEARCH PRIORITIES

Research will provide current and future support when choosing among existing management options and defining new management strategies. Both basic and applied research studies are of value when it comes to understanding invasive species and the invasion process. Examples of basic research include studies that lead to a better understanding of the biology and ecology of key invasive species such that we can better predict their response to particular environmental conditions and associated native species. Basic research may also include developing a better understanding of ecosystems and their resiliency to invasion. Examples of applied research include the development of best management practices that include prevention of invasive species establishment and spread. Applied research may also focus on the rehabilitation or restoration of invaded sites.

This plan also supports both short-term and long-term research, and risk assessments and monitoring. Short-term research may address more immediate problems, such as testing the efficacy of an herbicide or biocontrol treatment. Long-term research will provide much needed data on the impacts invasive species are having on native species and ecosystem processes. Risk assessment attempts to combine what we have learned about invasive species and the systems they are invading with current distribution patterns of those species, within West Virginia and in their country of origin or other areas they have invaded. This enables us to predict both growth in current invasive species populations as well as future invasions, which may enable a more rapid and planned response to new outbreaks and new invasive species. Monitoring provides information over time on distribution and treatment efficacy at both coarse and fine scales within a given landscape, and is essential to managing and preventing spread at a landscape scale.

- Quantitative risk analyses to identify species that should not be propagated, imported, sold, or otherwise distributed in WV, and to prioritize research on individual species or species groups.
- Pathway analysis to identify key pathways for species' introductions and vectors of species spread, probable points of entry for surveillance for early detection, and eradication and control methods for species likely to enter WV.
- Better understand the life histories, shared characteristics, behaviors, and environmental thresholds of successful invaders.
- Better understand the effects of invasive plant species on native biodiversity and on ecosystem services, and the effects of multiple stressors such as disturbances, climate change, and invasive species on rare and endangered species. Develop protocols to mitigate these effects.
- Improve recognition of habitats most vulnerable to invasions and to potential loss of biodiversity and alteration of ecosystem services.
- Better understand the effectiveness of invasive management techniques for species established in WV, including biological, chemical, and physical controls, and their non-target effects.
- Better understand the impact of standard land management practices (such as grazing, fencing, herbicide application, timbering, etc.) on invasive species.
- Better understand the ecological and economic indicators of invasive species' impact, and assess ecological and economic impacts of invasive species in West Virginia.
- Determine effective and practical methods to reduce the risk of spreading invasive species during land disturbing activities and corridor maintenance.
- Determine the most effective and practical educational tools for K-12 students, how to implement them in West Virginia schools, and how to adjust them as needed
- Determine effectiveness of different types of outreach to different stakeholder groups, such as:
    - hunting, fishing, and outdoor recreation communities
    - natural resource managers
    - farming and aquaculture communities
    - land developers and community/homeowners' associations,
    - environmental restoration professionals including specialists in brownfields, mine reclamation, energy industries, etc.

APPENDIX F: OUTREACH AND EDUCATION AUDIENCES

Educational materials regarding invasive species biology, impacts, prevention, and control in a variety of formats including lesson plans, pamphlets, white papers, websites, social media, television, and radio should be targeted to particular groups, such as:

- Local governments and community organizations
- Motorized and non-motorized hunting, fishing, and outdoor recreation communities
- Farming, ranching, and aquaculture communities
- Producers and consumers of ornamental and exotic plants and animals
- Land developers and managers, including:
    - Community/homeowners' associations
    - Public utilities
    - Transportation/highways
    - Natural resource industry (gas, oil, wind, coal, lumber, hydroelectric, etc.) site developers and processing facilities
    - Government regulators
    - Municipalities
- Public and private providers of facilities, equipment and supplies to outdoor recreationists, agriculture, and the development community
- Natural resource managers
- Environmental restoration professionals specializing in:
    - Brownfields
    - Mine reclamation
    - Sensitive habitats & rare communities
    - Flagship species such as red spruce
- Students and formal and non-formal educators at all levels
- Conservation and Youth Groups
- Boy and Girl Scouts
- 4-H Groups
- Future Farmers of America

APPENDIX G: DEFINITIONS

Allelopathy: The direct or indirect inhibitory effect on growth in one plant species caused by chemicals or toxins produced by another. *Adj:* Allelopathic.

Biodiversity: The amount of diversity in a given area, not typically quantifiable as a number. Species richness, habitat variety and the number of natural communities are sometimes used as indicators of potential biodiversity.

Climate change: A change in global or regional climate patterns, in particular a change apparent from the mid to late 20th century onwards and attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels.

Disturbance: Any temporary or permanent change that alters local environmental conditions. Disturbance can be natural in the case of fire, flood, wind, and earthquakes; or anthropogenic in the form of pollution, land-clearing, or establishment of invasive species.

Ecosystem: a system involving the interactions between a community of living organisms in a particular area and its nonliving environment (www.dictionary.reference.com). Sometimes also referred to as Natural Community, or Ecological Community.

Endangered species: "any species which is in danger of extinction throughout all or a significant portion of its range other than species of the Class Insecta as determined by the Secretary to constitute a pest whose protection under the provisions of the Act would present an overwhelming and overriding risk to man." (www.fws.gov/endangered/laws-policies/index.html)

Invasive: "an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health." (EO 13112) In the Executive summary of the National Invasive Species Management Plan (NISMP) the term invasive species is more clearly defined as "a species that is non-native to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health." For a nonnative organism to be considered an invasive species in the policy context, the negative effects that the organism causes or is likely to cause must outweigh any benefits it may provide (ISAC 2006).

Native: For any given area, species living within the range of their natural dispersal potential that have been historically growing or living there, without direct or indirect human intervention.

Naturalized: When a non-native species is reproducing outside of cultivation, but not out-competing native species or causing ecological or economic harm. Naturalized species can become invasive, and invasive species can become naturalized, depending on natural selection, the impact of climate change, evolving predator-prey relationships and interspecific competitive dynamics, etc.

Non-native: A species living outside its historic range. Also referred to as Alien, Exotic, Foreign, Introduced, or Non-Indigenous. Often introduced through human activity, either by accident or by design.

Rare species: A group of organisms that is very uncommon or scarce, locally or globally. Threatened and Endangered Species (capitalized) are protected by the Endangered Species Act. Species can also be threatened, endangered, and rare (uncapitalized) but not protected by any law. There are also many species that are rarer, more threatened, and more endangered than T&E species, but are not protected by law.

RTE species: Rare, Threatened, and Endangered species.

Threatened species: "any species which is likely to become an endangered species in the foreseeable future throughout all or a significant portion of it range." (www.fws.gov/endangered/laws-policies/index.html)

APPENDIX H: LIST OF ACRONYMS

Acronym	Agency or Organization
AFHA	Appalachian Forest Heritage Area
APHIS-PPQ	Animal and Plant Health Inspection Service-Plant Protection and Quarantine
FLN	Fire Learning Network
MRP	Marketing and Regulatory Programs
NAAHTF	National Aquatic Animal Health Task Force
NPS	National Park Service
NRCS	Natural Resource Conservation Service
NRS	Northern Research Station
PHCWPMA	Potomac Highlands Cooperative Weed and Pest Management Area
STOMP	Slowing the Onward Movement of Pests
TNC	The Nature Conservancy
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USDOI	U.S. Department of the Interior
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
WVCA	West Virginia Conservation Association
WVDA	West Virginia Department of Agriculture
WVDEP	West Virginia Department of Environmental Protection
WVDHHR	West Virginia Department of Health and Human Resources
WVDNR	West Virginia Division of Natural Resources
WVDOF	West Virginia Division of Forestry
WVDOH	West Virginia Division of Highways
WVISWG	West Virginia Invasive Species Working Group
WVU	West Virginia University

APPENDIX I: PERSONAL COMMUNICATIONS

Name	Title	Affiliation
Rich Bailey	State Ornithologist	WVDNR
Mark C. Collins	Environmental Resources Analyst	WVDEP
Eric Ewing	Director, Plant Industries Division	WVDA
Jim Fregonara	Wildlife Biologist	WVDNR
Jeff Hajenga	District Biologist	WVDNR
P.J. Harmon	Endangered Species and Natural Heritage Botanist	WVDNR
Amy Hill	Entomologist	USDA FS
Sherrie Hutchinson	Director, Plant Industries Division	WVDA
Frank Jernejcic	District Fishery Biologist	WVDNR
Walt Kordek	Assistant Chief of Wildlife Resources	WVDNR
Keith Krantz	Upland Game Biologist	WVDNR
Susan Kuhn	Certified Grants Management Specialist	WVDA
Patricia Morrison	Refuge Biologist, Ohio River Islands NWR	USFWS
Donna Murphy	Landscape Architect	USFS NRS
Chris O'Bara	Fish Biologist	WVDNR
John Perez	Biologist	NPS
Paul Poling	State Apiarist	WVDA
Quentin Sayers	Assistant Director, Plant Industries Division	WVDA
Cindy Sandeno	Ecologist	USFS
Philip Smith	Compliance Assistance Spec., Pesticide Regulatory Programs	WVDA
Tim Tomon	Entomologist	WVDA
Jim Vanderhorst	Vegetation Ecologist	WVDNR
Mike Welch	Zoologist	WVDNR

Note: Affiliations and job titles are listed as they were at the time of communication; some may have changed.

APPENDIX J: SUMMARY OF PUBLIC COMMENTS

In addition to the multiple rounds of professional review and dozens of comments received therein, this document was posted on the WVDNR website for public comment for 30 days. It was advertised with a press release, radio interview, and online news article. Public comment was received from seven individuals and one organization:

Mark Collins
Jeff Hajenga
Charles Nichols
Dr. Ryan Sharp
Philip Smith
Dan Stiles
David Warner
The Nature Conservancy, West Virginia Chapter

General comments and recommendations for improvement of the current text were incorporated or addressed below. Recommendations for additional content, analysis, or revisions to management and administrative goals may be addressed in the next revision. A few comments, though valid, addressed issues or debates outside the scope of this document, and are not included here.

General comments:

Thank you for finally publishing the draft report; it should be quickly adopted.

The plan is a "marvelous, much needed, much appreciated effort. Lots of people will find a great deal of practical and useful information in it."

"Great job; good work."

"This is fantastic, and a successful attempt at controlling invasive species cannot be done without public input and engagement."

"I support the idea of a greater effort to work collectively to control/prevent the spread of invasive species and I really like the proposed strategic plan."

"The Nature Conservancy applauds the West Virginia Division of Natural Resources in developing and releasing for public comment this important Strategic Plan. … The West Virginia Invasive Species Strategic Plan goes a long way in raising awareness of the threats of invasive species and provides a framework for collaboratively addressing the problem at the scale at which it occurs. In this, The Nature Conservancy wishes to express its strong support in the West Virginia Invasive Species Strategic Plan."

Summary of recommendations for improvement (C=Comment; A=Answer):

C: The harm Kentucky 31 fescue has caused should be discussed.
A: Limited space precludes describing all harm all invasive species cause to native ecosystems. However, tall fescue (*Schedonorus phoenix)* is listed on page 43 in the highest threat category of invasive plants in West Virginia.

C: Climate change should be defined.
A: A definition was added in Appendix G. References for more definitions and additional information were added in the body of the document.

C: Prescribed fire as a management tool should be used more and discussed in this plan.

A: Prescribed fire is an essential tool for some forms of invasive species management, and is used in West Virginia by the U.S. Forest Service to control invasive species. As this is not an operational plan, however, specific management techniques are not discussed.

C: Management strategies should be made more specific.
A: This is a strategic document, not operational. Specific management prescriptions will be described in operational documents that reference this plan.

C: Caliciopsis canker should be mentioned.
A: It was mentioned in a previous draft, but removed for space issues. It has been re-included in this final version. It is not included in the Pathogens list on page 47 because the list (developed with the assistance of forest health experts at WVDA, among others) is meant to be representative rather than comprehensive.

C: Do you have any plans for assessment of the effectiveness of these education and outreach efforts?
A: No concrete plans at this time, but more detailed educational and outreach efforts will be developed, which will include an effectiveness assessment component.

C: Feral hogs should be addressed in more detail. Will there be discussion of other invasive animals, such as black and Norway rats, house mice, feral dogs, common carp, house finches, and pigeons? Also, grass carp are supposed to be triploid and sterile, and are regulated, so this should be taken into account in future ranking efforts.
A: Space constraints limit what can be added at this point, but more detail was added about feral hogs, and rodents were mentioned. Fish biologists did not include common carp, so the author deferred to their expertise; the list on pages 45 and 46 is meant to be representative, rather than exhaustive. Grass carp sterility will be taken into account if and when invasive animals are ranked.

C: Any promotion of control tactics must involve explanations of licensing and record keeping regulations.
A: This is an excellent point and additional text from this commenter has been added to the document.

Summary of recommendations for additional content or analysis, which will be considered in the next revision:

Page 22 Administrative goals: Specify a lead organization to oversee and coordinate implementation of the Strategic Plan. Those responsibilities would best be accomplished by a full-time dedicated NNIS Coordinator that would work to implement the administrative and management goals of the plan, and coordinate between the various organizations and agencies.

Develop and secure funding to implement the administrative and management goals of the Invasive Species Strategic Plan.

Page 23 Management Goal 1: Coordination: Develop an NNIS council or further empower WVISWG to act as a technical advisory committee on state level NNIS issues, help coordinate actions among various organizations, and serve as a venue for education and outreach to partners and the public.

Page 25 Management Goal 3: Early Detection: Establish a lead agency and a standardized process for collecting Early Detection data and disseminating that information through spatial products for use by collaborators.

Page 27 Management Goal 5: Control and Management: Include a provision that requires state agencies managing public land to develop and implement policies and procedures, consistent with this Strategic Plan, that control and manage NNIS on public land.

Pages 43 through 47: Invasive Species in West Virginia: Develop and assign a threat ranking for invasive animals and microbes and pathogens, similar to that specified for invasive plants.

APPENDIX K: WORKS CITED

Note: Personal Communications are listed in Appendix I.

1. Allendorf, F.W., L.L. Lundquist. 2003. Introduction: Population Biology, Evolution, and Control of Invasive Species. Conservation Biology, 17: 24–30.

2. Anderson, M.G., M. Clark, and A. Olivero Sheldon. 2012. Resilient Sites for Terrestrial Conservation in the Northeast and Mid-Atlantic Region. The Nature Conservancy, Eastern Conservation Science. 168 pp.

3. Aukema J.E., et al., 2011. Economic Impacts of Non-Native Forest Insects in the Continental United States. PLoS ONE 6(9): e24587. Available: www.emeraldashborer.info/documents/research/Aukema_etal_2011.pdf [2013, May 23]

4. Bayliss HR, Stewart GB, Wilcox A, Randall NP (2013) A perceived gap between invasive species research and stakeholder priorities. NeoBiota 19: 67–82 Available: http://www.pensoft.net/journals/neobiota/article/4897/ [2013, December 1]

5. Bennett, Warren O., J.T. Paget, D. Mackenzie. 2013. Surgery for a Tree Surgeon? Acute presentation of contact dermatitis due to Ailanthus altissima. Journal of Plastic, Reconstructive, and Aesthetic Surgery. 66:3 e79-e80. Available: www.sciencedirect.com/science/article/pii/S1748681512007188. [2014, January 24]

6. Bergmann, C., J. Swearingen (a). Plant Conservation Alliance's Alien Plant Working Group's Multiflora Rose web page. Available: www.nps.gov/plants/alien/fact/romu1.htm [2013, May 21]

7. Bergmann, C., J. Swearingen (b). Plant Conservation Alliance's Alien Plant Working Group's Kudzu web page. Available: www.nps.gov/plants/alien/fact/pumo1.htm [2013, September 8]

8. Bergmann, C., J. Swearingen (c). Plant Conservation Alliance's Alien Plant Working Group's Japanese knotweed web page. Available: www.nps.gov/plants/alien/fact/faja1.htm [2013, September 10]

9. Blossey, B., R. Notzold. 1995. Evolution of increased competitive ability in invasive nonindigenous plants: a hypothesis. Journal of Ecology 83: 887-889.

10. Borgmann, K.L., A.D. Rodewald. 2004. Nest predation in an urbanizing landscape: the role of exotic shrubs. Ecological Applications 14:1757–1765.

11. Boyles, J.G., P. M. Cryan, G. F. McCracken, T. H. Kunz. 2011. Economic Importance of Bats in Agriculture. Science: 332(6025): 41-42.

12. Bross-Fregonara, N. 2004. What's Eating our Trees? In: West Virginia Wildlife Magazine, Spring 2004. Available: www.wvdnr.gov/wildlife/magazine/Archive/04Spring/WhatsEatingOurTrees.shtm. [2013, September 12]

13. Buck, J. 2008. Responsibilities, regulations & risks. APHIS Cooperative EAB Project. Presented at the Northeastern Area, State & Private Forestry, Proceedings of Firewood Forum 2008, Frelinghuysen Arboretum, New Jersey, April 15, 2008. Available: na.fs.fed.us/firewood/proceedings/08/proceedings08.shtm.

14. Burgiel, S. W. & Muir, A. A. 2010. Invasive species, climate change and ecosystem-based adaptation: Addressing multiple drivers of global change. Washington, DC: Global Invasive Species Programme. Available: www.cakex.org/virtual-library/invasive-species-climate-change-and-ecosystem-based-adaptation-addressing-multiple-d [2014, January 24]

15. Byers, E. A., J. P. Vanderhorst, and B. P. Streets. 2007. Classification and Conservation Assessment of High Elevation Wetland Communities in the Allegheny Mountains of West Virginia. West Virginia Natural Heritage Program, WVDNR. Elkins, WV. 546 pp.

16. Cadotte, Marc W. 2013. Experimental evidence that evolutionarily diverse assemblages result in higher productivity. PNAS vol. 110, no. 20. Available: www.pnas.org/content/early/2013/05/14/1301685110. [2013, May 21]

17. Cal-IPC. 2012. Preventing the Spread of Invasive Plants: Best Management Practices For Transportation and Utility Corridors. Cal-IPC Publication 2012-1. California Invasive Plant Council, Berkeley, CA. Available: cal-ipcwww.cal-ipc.org/ip/prevention/tuc.php. [2013, December 16]

18. Charles, H., J. Dukes. 2007. Impacts of Invasive Species on Ecosystem Services. In: Nentwig, W. (Ed.) Biological Invasions. © Springer-Verlag Berlin Heidelberg. Available: link.springer.com/chapter/10.1007/978-3-540-36920-2_13#page-2. [2013, May 21]

19. Colautti, R.I., S.C.H. Barrett. 2013. Rapid Adaptation to Climate Facilitates Range Expansion of an Invasive Plant Science 342(6156): 364-366

20. Corn, M.L., Johnson, R. 2013. Invasive Species: Major Laws and the Role of Selected Federal Agencies. U.S. Congressional Research Service. R43258. Available: http://www.aquaticnuisance.org/wordpress/wp-content/uploads/2009/01/Invasive-Species-Major-Laws-and-the-Role-of-Selected-Federal-Agencies-Oct-2013.pdf [2013, November 15]

21. Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. O'Neill, J. Paruelo, R. G. Raskin, P. Sutton, M. van den Belt. 1997. The Value of the World's Ecosystem Services and Natural Capital. Nature, Vol. 387.

22. D'Antonio, C.M., and J.C. Chambers. 2006. Using Ecological Theory to Manage or Restore Ecosystems Affected by Invasive Plant Species. In: Foundations of Restoration Ecology. Eds: Falk, D.A., M. Palmer, J. Zedler. Island Press, 378 pages.

23. Dukes, J.S., and H.A. Mooney. 1999. Does global change increase the success of biological invaders? Trends in Ecology and Evolution. 14 (4): 135-139. Available: www.sciencedirect.com/science/article/pii/S0169534798015547 [2013, December 16]

24. Ehrenfeld J.G., N.S. Scott. 2001. Invasive species and the soil: effects on organisms and ecosystem processes. Ecological Applications 11(5):1259–1260.

25. Eisworth, M.E., W.S. Johnson, J. Agapoff, T. D. Darden, T. R. Harris. 2006. Economic Impacts from the Effects of Invasive Weeds on Outdoor Recreation: An Input-Output Model. University of Nevada Cooperative Extension, Special Publication SP-05-06. Available: www.unce.unr.edu/publications/files/nr/2005/SP0506.pdf. [2013, May 24]

26. Elton, C.S. 1958. The ecology of invasions by animals and plants. Chicago: University of Chicago Press.

27. Exec. Order No. 13,112, 64 Fed. Reg. 2419 (Jan. 14, 1999).

28. Fridley, J.D. 2008. Of Asian Forests and European Fields: Eastern U.S. Plant Invasions in a Global Floristic Context. PLoS ONE 3(11): e3630 Available: http://www.plosone.org/article/info:doi/10.1371/journal.pone.0003630 [2013, December 1]

29. Fryer, J.L. 2010. Ailanthus altissima. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: www.fs.fed.us/database/feis/ [2013, May 21].

30. Fuller, P.F., A.J. Benson, and M.E. Neilson. 2013. Channa argus. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. Available: nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=2265 [2013, December 16]

31. Green, D.E. 2012. Ranavirus: USGS scientists have isolated ranaviruses associated with die-offs involving more than 20 species of amphibians and turtles. Available: www.nwhc.usgs.gov/disease_information/other_diseases/ranavirus.jsp [2013, May 22]

32. Gucker, C.L. 2009. Heracleum mantegazzianum. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: www.fs.fed.us/database/feis/ [2013, November 6]

33. Harmon, P.J. 1995. Invasive Plant Species: a Growing Threat to Natural Areas of West Virginia. Technical document 95-8. West Virginia Division of Natural Resources, Wildlife Resources Section, Nongame and Natural Heritage Programs.

34. Haynes, S.C., Q. Sayers, S. McCauley, J. Judy, L. Carnell, J. Hays, A. Onken, J. Brooks. 2005. West Virginia Gypsy Moth Damage Assessment Report. West Virginia Department of Agriculture. Available: www.wvagriculture.org/images/Plant_Industries/WV_GM_Damage_Assessment_Report_05.pdf [2013, May 22]

35. Hegar, T., Saul, W.C., and Trepl, L. 2013. What biological invasions “are” is a matter of perspective. Journal for Nature Conservation 21: 93-96.

36. Hooper, D.U., F. S. Chapin III, J. J. Ewel, A. Hector, P. Inchausti, S. Lavorel, J. H. Lawton, D. M. Lodge, M. Loreau, S. Naeem, B. Schmid, H. Setälä, A. J. Symstad, J. Vandermeer, and D. A. Wardle. 2005. Effects of Biodiversity on Ecosystem Functioning: a Consensus of Current Knowledge. Ecological Monographs 75:3–35. Available: dx.doi.org/10.1890/04-0922 [2013, May 24]

37. Invasive Species Advisory Committee (ISAC). 2006. Invasive Species Definition Clarification and Guidance White Paper. National Invasive Species Council. www.invasivespeciesinfo.gov/docs/council/isacdef.pdf

38. Jernecjec, F. Attack of the Alien Invaders. In: West Virginia Wildlife Magazine, Summer 2004. Available: www.wvdnr.gov/wildlife/magazine/Archive/04Summer/Attack_of_the_Alien_Invaders.shtm. [2013, September 20]

39. Johnnson, L. E., A. Ricciardi, and J.T. Carlton. 2001. Overland Dispersal of Aquatic Invasive Species: A Risk Asessment of Transient Recreational Boating. Ecological Applications 11:1789–1799.

40. Keane, R. M. and Crawley, M. J. 2002. Exotic plant invasions and the enemy release hypothesis. TRENDS in Ecology & Evolution, 17 (4): 164-170.

41. Krull, I.S., B.K. Nunnally. 2004. *Prions and mad cow disease*. New York, N.Y: Marcel Dekker. p. 6. Available: books.google.com/books?id=WjeuaHopV5UC&pg=PA6&hl=en#v=onepage&q&f=false [2013, November 17]

42. Heleno, R.H., Ceia, R. S., Ramos, J. A. and Memmott, J. 2009. Effects of Alien Plants on Insect Abundance and Biomass: a Food-Web Approach. Conservation Biology, 23: 410–419.

43. Hellmann, J. J., J.E. Byers, B.G. Bierwagen, and J.S. Dukes. 2008. Five Potential Consequences of Climate Change for Invasive Species. Conservation Biology, 22: 534–543.

44. Hobbs, R.J., L.F. Huenneke. 2002. Disturbance, Diversity, and Invasion: Implications for Conservation. Conservation Biology, 6: 324–337.

45. Holzman, D. 2012. Accounting for Nature's Benefits: the Dollar Value of Ecosystems. Environmental Health Perspectives. 120(4): a152–a157. Available: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3339477/ [2013, December 12].

46. International Union for the Conservation of Nature (IUCN). 2008. Forest Environmental Services. Available: http://www.eoearth.org/view/article/152818/ [2013, December 12]

47. Invasive species specialist group. 2000. IUCN Guidelines for the Prevention of Biodiversity Loss caused by Alien Invasive Species. Available: intranet.iucn.org/webfiles/doc/SSC/SSCwebsite/Policy_statements/IUCN_Guidelines_for_the_Prevention_of_Biodiversity_Loss_caused_by_Alien_Invasive_Species.pdf [2013, September 19]

48. Johnson, L. E., A. Ricciardi, J. T. Carlton. 2001. Overland dispersal of aquatic invasive species: a risk assessment of transient recreational boating. Ecological Applications 11:1789–1799.

49. Jones, C. and M. Dale. 2010. Battle for Bats: The WNS Tragedy. (Brochure) U.S. Forest Service. Available: www.fs.fed.us/biology/resources/pubs/tes/wns-brochure8310.pdf [2013, December 5]

50. Keller, R.P., D. M. Lodge, D. C. Finnoff. 2006. Risk assessment for invasive species produces net bioeconomic benefits. Proceedings of the National Academy of Sciences of the United States of America. 104 (1): 203-207.

51. Kilian, J. V., R. J. Klauda, S. Wildman, M. Kashiwagi, R. Bourquin, S. Weglein, J. Schuster. 2012. An assessment of a bait industry and angler behavior as a vector of invasive species. Biol. Invasions. 14:1469-1481.

52. Kremen, C. 2005. Managing ecosystem services: what do we need to know about their ecology? Ecology Letters 8: 468-479.

53. Lake, J.C., M.R. Leishman. 2004. Invasion success of exotic plants in natural ecosystems: the role of disturbance, plant attributes and freedom from herbivores. Biological Conservation 117 (2): 215-226. Available: www.sciencedirect.com/science/article/pii/S0006320703002945 [2013, December 16]

54. Leskey, T., 2010. Brown Marmorated Stink Bug: Damage Survey and Monitoring Efforts. Appalachian Fruit Research Station, USDA-ARS, Kearneysville, WV. Available: http://anr.ext.wvu.edu/r/download/74527 [2013, November 20].

55. Lodge, D.M., C.A. Taylor, D.M. Holdich, J. Skurdal. 2000. Nonindigenous Crayfishes Threaten North American Freshwater Biodiversity: Lessons from Europe. Fisheries 25:8 7-20.

56. Lowe, S., M. Browne, S. Boudjelas, and M. DePoorter. 2000. 100 of the world's worst invasive alien species: A selection from the global invasive species database. IUCN/SSC Invasive Species Specialist Group (ISSG), Auckland, New Zealand.

57. McCollough, D., R. Usborne. 2013. Emerald Ash Borer Frequently Asked Questions. Available: www.emeraldashborer.info/faq. [2013, April 30]

58. McShea, W.J., N.A. Bourg, C.M. Stewart. Potential Synergy of White-tailed Deer and Invasive Plants for Impacting Forest Plant Diversity. Presentation for the National Park Service 2008 Conference, "Spotlight on National Park Resources." Available: www.nps.gov/cue/events/spotlight08/Talks_PDFs/mcshea.pdf. [2013, September 9]

59. MDDEP-MRNF. 2007. What Is Didymo and How Can We Prevent It From Spreading In Our Rivers? Scientific Advisory Committee on Didymosphenia geminate. Available: http://www.mddep.gouv.qc.ca/eau/eco_aqua/didymo/didymo-en.pdf [2013, November 6]

60. Midwest Invasive Plant Network (MIPN.org). 2011. CWMA Cookbok: A Recipe for Success.

61. Mohan, J.E., L. H. Ziska, W. H. Schlesinger, R. B. Thomas, R. C. Sicher, K. George, J. S. Clark. 2006. Biomass and toxicity responses of poison ivy (*Toxicodendron radicans*) to elevated atmospheric CO_2. Proceedings of the National Academy of Sciences of the United States. 103 (24): 9086-9089

62. Moser, W. K., E. L. Barnard, R. F. Billings, S. J. Crocker, M. E. Dix, A. N. Gray, G. G. Ice, M. Kim, R. Reid, S. U. Rodman, W. H. McWilliams. 2009. Impacts of nonnative invasive species on US forests and recommendations for policy and management. Journal of Forestry, 107(6): 320-327.

63. Mooney, H.A., R.J. Hobbs. 2000. Invasive species in a changing world. Washington, D.C., Island Press.

64. Munger, G.T. 2003. Elaeagnus umbellata. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: www.fs.fed.us/database/feis/ [2013, May 21].

65. National Aquatic Animal Health Task Force (NAAHTF). 2008. National Aquatic Animal Health Plan for the United States. Available: www.aphis.usda.gov/animal_health/animal_dis_spec/aquaculture/downloads/naahp.pdf [2013, December 16]

66. National Invasive Species Council (NISC). 2008. 2008-2012 National Invasive Species Management Plan. Available: www.oar.noaa.gov/oceans/2008-2012NationalInvasiveSpeciesManagementPlan.pdf [2013, May 21]

67. National Wildlife Federation. 2012. Extreme Allergies and Global Warming. Available: www.nwf.org/~/media/PDFs/Global-Warming/Reports/NWF_AllergiesFinal.ashx. [2013, May 24]

68. Niemiera, A. X., and B. Von Halle. 2011. Invasive Plants and the Nursery Industry. In: American Nursery Magazine, September 2011. Available: www.amerinursery.com/article-7318.aspx. [2013, December 16]

69. Oregon Department of Agriculture (ODA). 2000. Economic analysis of containment programs, damages, and production losses from noxious weeds in Oregon. Available: www.oregon.gov/ODA/PLANT/docs/pdf/weed_body_a.pdf. [2013, June 10]

70. Paradis, A., J. Elkinton, K. Hayhoe, J. Buonaccorsi. 2007. Role of winter temperature and climate change on the survival and future range expansion of the hemlock woolly adelgid (*Adelges tsugae*) in eastern North America. Mitig Adapt Strat Glob Change. 13.5-6: 541-554

71. Paynter, Ben. February 15th, 2012. Jaw-Breaking Midwest Carp Flying Home to China's Dinner Plates. Bloomberg News. Available: www.bloomberg.com/news/2012-02-16/jaw-breaking-midwest-carp-flying-home-to-china-s-dinner-plates.html [2013, November 15]

72. Pejchar, L., H.A. Mooney. 2009. Invasive species, ecosystem services and human well-being. Trends in Ecology and Evolution, Vol. 24, No. 9. Available: www.environment.ucla.edu/media_IOE/files/Pejchar-and-Mooney-2009---invasives-and-ecosystem-services-ls-y5k.pdf. [2013, May 24]

73. Perrot-Maître, D., P. Davis, Esq. 2001. Case Studies of Markets and Innovative. Financial Mechanisms for Water Services from Forests. Available: http://www.forest-trends.org/documents/files/doc_134.pdf [2013, September 20].

74. Pickering, C., A. Mount. 2010. Do tourists disperse weed seed? A global review of unintentional human-mediated terrestrial seed dispersal on clothing, vehicles and horses. Journal of Sustainable Tourism 18 (2):239-256. Available: www.tandfonline.com/doi/abs/10.1080/09669580903406613#.UrCVfSe7_ZG [2013, December 16]

75. Pimentel, D. 2011. "Environmental and Economic Costs Associated with Alien Invasive Species in the United States" in Biological Invasions: Economic and Environmental Costs of Alien Plant, Animal, and Microbe Species. CRC Press.

76. Pimentel, D., R. Zuniga, and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 52 (2005) 273– 288. Available: www.sciencedirect.com/science/article/pii/S0921800904003027. [2013, September 12]

77. Potomac Highlands Cooperative Weed and Pest Management Area (PHCWPMA). 2013. Fighting Invasive Pests and Pathogens in West Virginia. Available: www.phcwpma.org/ForestPestsPathogensBrochure_Feb2013.pdf [2013, November 20]

78. Powell, K. I., J. M. Chase, T. M. Knight. 2011. A synthesis of plant invasion effects on biodiversity across spatial scales**.** *American Journal of Botany.* 98 (3): 539

79. Pyšek, P., V. Jarošík, P. E. Hulme, J. Pergl, M. Hejda, U. Schaffner, M. Vilà. 2012. A global assessment of invasive plant impacts on resident species, communities and ecosystems: the interaction of impact measures, invading species' traits and environment. Global Change Biology, 18: 1725–1737.

80. Pyšek, P., Chytrý, M. 2013. Habitat invasion research: where vegetation science and invasion ecology meet. Journal of Vegetation Science doi: 10.1111/jvs.12146.

81. Rejmanek, M., D.M. Richardson. 1996. What Attributes Make Some Plant Species More Invasive? Ecology 77:1655–1661

82. Rentch, James S., R. Fortney, W. N. Grafton, S. L. Stephenson, R. Coxe. 2013. Vascular Flora of Roadside Habitats in West Virginia, USA. Castanea. 78 (1): 56-78.

83. Robinson, S. K., et al., 1993. Management implications of cowbird parasitism on neotropical migrant songbirds. In: Finch, Deborah M., Stangel, Peter W. (eds.). Status and management of neotropical migratory birds: September 21-25, 1992, Estes Park, Colorado. Gen. Tech. Rep. RM-229. Fort Collins,

Colo.: Rocky Mountain Forest and Range Experiment Station, U.S. Dept. of Agriculture, Forest Service: 93-102. Available: http://www.treesearch.fs.fed.us/pubs/22891. [2013, September 16]

84. Rogerson C.T., G.J. Samuels. 1996. Mycology at the New York Botanical Garden, 1985-1995. *Brittonia* 48(3):389-98.

85. Rooney, T.P. 2005. Distribution of Ecologically-Invasive Plants Along Off-Road Vehicle Trails in the Chequamegon National Forest, Wisconsin. The Michigan Botantist 44 (4). Available: http://quod.lib.umich.edu/m/mbot/0497763.0044.402?rgn=main,view=fulltext [2013, June 10]

86. Ruiz, G.M., J.T. Carlton. 2003. Invasive species: vectors and management strategies. Island Press, Washington, DC.

87. Sarver, M., A. Treher, L. Wilson, R. Naczi, and F.B. Kuehn. 2008. Mistaken Identity? Invasive Plants and their Native Look-Alikes: an Identification Guide for the Mid-Atlantic, Delaware Department Agriculture.

88. Schmidt, K.A. C.L. Whelan. 1999. Effects of exotic lonicera and rhamnus on songbird nest predation. Conservation Biology 13(6): 1502-1506.

89. Spaulding, S., L. Elwell. 2007. Increase in nuisance blooms and geographic expansion of the freshwater diatom Didymosphenia geminate: Recommendations for response. U. S. EPA and Federation of FlyFishers White Paper. Available: www.epa.gov/region8/water/didymosphenia/White%20Paper%20Jan%202007.pdf.

90. Stein, B.A., S. R. Flack, eds. 1996. America's Least Wanted: Alien Species Invasions of U.S. Ecosystems. The Nature Conservancy, Arlington, Virginia

91. Swearingen, Jill. 2005. Fact Sheet: Purple Loosestrife. Plant Conservation Alliance's Alien Plant Working Group. Available: http://www.nps.gov/plants/alien/fact/lysa1.htm. [2014, January 23]

92. The Nature Conservancy (TNC) and Association for Biodiversity Information. 2000. Precious Heritage: The Status of Biodiversity in the United States. Oxford University Press, New York. 399 pages.

93. The Wildlife Society. 2009. Ecological Impacts of Feral Cats. Available: joomla.wildlife.org/documents/cats_ecological_impacts.pdf [2013, October 16]

94. Transportation Research Board. 2006. Control of Invasive Species: A Synthesis of Highway Practice. National Cooperative Highway Research Program Project 20-5 (Topic 26-05). Washington, D.C. Available: books.google.com/books?isbn=0309097746. [2013, December 16]

95. Uesugi A., A. Kessler. 2013. Herbivore-exlusion drives the evolution of plant competitiveness via increased allelopathy. New Phytologist 198: 916-924.

96. U.S. Department of Agriculture (USDA) Forest Service. 2012. Gypsy Moth Management the U.S.: A Cooperative Approach. Final Supplemental Environmental Impact Statement. Available: na.fs.fed.us/pubs/fhp/gm-management/record-of-decision-121211.pdf [2014, January 23]

97. U.S. Department of Agriculture (USDA) Marketing and Regulatory Programs (MRP) Animal and Plant Health Inspection Service (APHIS). 2003. Importation of Solid Wood Packing Material: Final Environmental Impact Statement—August 2003. Available: www.aphis.usda.gov/plant_health/ea/downloads/swpmfeis.pdf [2013, December 16]

98. U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS). 2010. Risk Assessment of the Movement of Firewood within the United States. Plant Epidemiology and Risk Analysis Laboratory, Center for Plant Health Science and Technology, Raleigh, NC. Available: www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5331675.pdf. [2013, December 13]

99. U.S. Forest Service (USFS). 2006. Monongahlea National Forest Land and Resource Management Plan. Available: www.fs.usda.gov/detailfull/mnf/landmanagement/planning/?cid=FSM9_011361. [2014, January 14]

100. U.S. Department of the Interior (USDOI), U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. 2013. 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.

101. Vanderhorst, J. 2010. "Wetlands." e-WV: The West Virginia Encyclopedia. Available: www.wvencyclopedia.org/articles/1154. [2013, November 22].

102. Vanderhorst, J. P., J. Jeuck, and S. C. Gawler. 2007. Vegetation classification and mapping of New River Gorge National River, West Virginia. Technical Report NPS/NER/NRTR-2007/092. USDI National Park Service. Philadelphia, PA.

103. Van Kleunen, M., Weber, E. and Fischer, M. 2010. A meta-analysis of trait differences between invasive and non-invasive plant species. Ecology Letters, 13: 235–245.

104. Vilà, M., J. L. Espinar, M. Hejda, P. E. Hulme, V. Jarošík, J. L. Maron, J. Pergl, U. Schaffner, Y. Sun, P. Pyšek. 2011. Ecological impacts of invasive alien plants: a meta-analysis of their effects on species, communities and ecosystems. Ecology Letters, 14: 702–708.

105. Weidenhamer, J.D., R.M. Callaway. 2010. Direct and Indirect Effects of Invasive Plants on Soil Chemistry and Ecosystem Function. Journal of Chemical Ecology 36:1, 59-69

106. West Virginia Department of Environmental Protection (WV DEP). 2011. West Virginia Surface Mining Rules, West Virginia Surface Coal Mining and Reclamation Act, §38-2-9.

107. West Virginia Division of Forestry. 2005. West Virginia's Forests: A Growing Resource For our Future. Available: www.wvforestry.com/A%20Growing%20Resource%20for%20our%20Future.pdf. [2013, December 19]

108. West Virginia Division of Natural Resources. 2009. Invasive Plant Species of West Virginia. Wildlife Diversity Unit, Division of Natural Resources. Available: www.wvdnr.gov/Wildlife/Handout%20 Invasive%20Plants%20of%20WV%202009.pdf. [2013, February 28]

109. West Virginia Division of Natural Resources and West Virginia Department of Environmental Protection (WVDEP). 2011. West Virginia Wetland Program Plan. Elkins, West Virginia.

110. Whittaker, K., V. Vredenburg. 2011. An Overview of Chytridiomycosis. Available: www.amphibiaweb.org/chytrid/chytridiomycosis.html [2013, May 22]

111. Wixted, K., J. McGraw. 2010. Competitive and allelopathic effects of garlic mustard (*Alliaria petiolata*) on American ginseng (*Panax quinquefolius*). Plant Ecology. 208 (2): 347-357

112. Wixted, K., J. McGraw. 2008. A Panax-centric view of invasive species. Biological Invasions. DOI 10.1007/s10530-008-9301-7

113. Zedler, J.B., S. Kercher. 2004. Causes and Consequences of Invasive Plants in Wetlands: Opportunities, Opportunists, and Outcomes. Critical Reviews in Plant Science. 23 (5): 431-452. Available: www.tandfonline.com/doi/abs/10.1080/07352680490514673#.Uo_FeCfODZF [2013, November 22]

114. Ziska, L.H., K. George. 2004. Rising carbon dioxide and invasive, noxious plants: potential threats and consequences. World Resource Review 16:427-447.