2026

North Carolina Department of Transportation

High-Threat Invasive Plant Species and Removal Plan Report

April 21, 2026

This Report is prepared pursuant to Session Law 2025-47 (Senate Bill 391), Section 20(b)(ii);

The Department of Transportation and the Department of Natural and Cultural Resources, in consultation with North Carolina State University and North Carolina Agricultural and Technical State University, shall study and develop (ii) a list of high-threat invasive plant species and a plan for removing existing invasive plant species from State parks and highway rights-of-way.

Executive Summary

Pursuant to Session Law 2025-47, the North Carolina Department of Transportation (NCDOT), in consultation with North Carolina State University (NCSU) and other partners, conducted a comprehensive review of the existing invasive plant species sources and current roadside conditions to develop a list of high-threat invasive plants found within highway rights-of-way and targeted management strategies for the species.

The findings of the NCSU report, *Study and Evaluate the Impact of High-Threat Invasive Weed Species on NC Roadsides*, identified an initial fifteen invasive plant species posing a high-threat due to ecological degradation and reduced roadway safety. The report also identified appropriate management strategies for the removal of the plants for implementation by the NCDOT. The NCDOT removal strategy will incorporate a mix of herbicidal treatments, mechanical removal, and monitoring to effectively eliminate these invasive plants. The strategy will require cooperative removal of these invasive plants when populations extend beyond the rights-of-way to reduce the risk of reinfestation. A focus on working with other state and federal agencies, municipalities and private property owners will allow for cost-effective management and the best chance of successful removal. An aggressive target goal of eight years would be needed for the removal statewide, with an estimated expenditure of $94 million over that timeframe. These estimates are preliminary only and may vary widely based on numerous factors including the number of invasive plant locations, species, density, and needed management techniques.

High-threat Species of Concern to NC Roadside Environments

The North Carolina Department of Transportation (NCDOT), in coordination with North Carolina State University (NCSU) and other partners, conducted a comprehensive evaluation of invasive plant resource material to identify and produce a list of high-threat invasive species using State and Federal lists, the NC Invasive Plant Council, State Parks personnel and field observations from NCDOT staff. The table below, noted as Table 2 in the NCSU report, summarizes the findings with a list of the top fifteen high-threat invasive species for removal as well as a priority ranking due to prevalence, aggressiveness, and

ecological degradation. The table lists NCDOT internal priority rankings as (I) Extreme Threat; (II) Severe Threat; (III) Considerable Threat. This ranking system will allow the NCDOT to prioritize the addition of other invasive species as the need arises. The complete methodology for this compiled list may be found in Attachment 1.

High-Threat Invasive Species and Rankings

Common Name	Scientific Name	Rank
Kudzu	*Pueraria montana*	I
Cogongrass	*Imperata cylindrica*	III
Phragmites	*Phragmites australis*	I
Oriental bittersweet	*Celastrus orbiculatus*	III
Alligatorweed	*Alternanthera philoxeroides*	II
Tree of heaven	*Ailanthus altissima*	II
Privet spp.	*Ligustrum spp.*	II
Mimosa	*Albizia julibrissin*	III
Multiflora rose	*Rosa multiflora*	II
Miscanthus	*Miscanthus sinensis*	I
Wisteria spp.	*Wisteria spp.*	III
Autumn olive	*Elaeagnus umbellata*	III
Johnsongrass	*Sorghum halepense*	I
Japanese knotweed	*Reynoutria japonica*	I
Callery pear	*Pyrus calleryana*	II

Managing invasive and threatening plants is a core responsibility of the NCDOT roadside vegetation program. Currently, the NCDOT strives to implement an Integrated Roadside Vegetation Management (IRVM) approach that combines an array of management techniques with sound ecological principles to establish and maintain safe, healthy, and functional roadsides. The IRVM tool chest includes judicious use of herbicides, spot mowing, mechanical tree and brush removal, and the prevention and treatment of disturbances to existing vegetation. IRVM's long-term objective is to reduce roadside maintenance by creating stands of durable, long-lived, desired plants. Invasive weeds reduce biodiversity of native flora and fauna, create costly management needs and may pose a safety risk for highway users. NCDOT vegetation management prioritizes maintaining safe transportation corridors by ensuring hazard-free clear zones, low-growing roadside vegetation, and open sight distances for drivers. The NCDOT's current vegetation management approaches support roadway safety while also enhancing biodiversity, aesthetics, and the preservation of NC's biological, cultural, and landscape heritage. This is achieved by using a combination of routine mowing and other mechanical means to

suppress invasive weed growth and proliferation and chemical and biological treatments for the suppression and removal of invasive weed species from the rights-of-way.

The following section highlights each of the fifteen high-threat invasives identified in High-Threat Invasive Species Table describing the invasion threat, botanical description, and updated BMPs and control strategies based on the severity rankings. Ecoregional descriptions are also included to inform regional and locational priorities within the state. Most of the high-threat invasive species require a multi-year management approach using integrated herbicidal treatments and potential mechanical or manual removals for successful eradication of an infestation.

Rank I: Extreme Threat—invasive species which display the highest degree of environmental and management concern.

***1. Kudzu* (Fabaceae)**

Invasion Threat: Widespread invader of roadsides and natural areas from the Blue Ridge to the Middle Atlantic Coastal Plain ecoregions following widespread touting in the 1920-1930's for erosion control. Today, kudzu is a ubiquitous, perennial, semi-woody trailing or climbing vine than can reach up to 100 feet in length. The plant forms a dense, smothering canopy over trees, infrastructures (e.g., guardrails and signage), and safety zones, creating visibility hazards to drivers and increasing costs for the NCDOT. Open canopies and areas receiving direct sunlight allow for the most rapid growth potential, with kudzu growing up to one foot per day under favorable conditions.

Botanical Description: Stems are initially hairy, becoming woody with age. Leaves are compound with three broad leaflets, which may be entire or lobed. Flowers are purple and are produced in late summer, with hairy seedpods occurring in the fall (October to November). However, seeds have generally low viability, with primary spread and succession occurring via stolons. Kudzu has a highly persistent root system, enabling survival and regrowth even after repeated cutting and mowing operations, which complicates long-term control efforts along roadsides.

Best Management: Effective control requires a multi-year, integrated approach using systemic herbicides to kill the root system, with follow-up treatments to address re-sprouting. Foliar applications of glyphosate or triclopyr at 2-4% v/v with a non-ionic surfactant (NIS) at 0.5% v/v are generally effective; clopyralid applied at 1-3% v/v is also an effective option. Depending upon the foliar mixture used, non-target vegetation beneath the kudzu canopy is likely to be injured. Foliar applications of metsulfuron at 3-4 oz/A can be effective when safety to surrounding vegetation is needed (Miller 2006). Where non-target impacts are unacceptable, cut-stem applications of 50% v/v

glyphosate or triclopyr provide a more selective alternative. Targeted grazing with goats can help suppress aboveground biomass and gradually deplete root reserves in smaller infestation areas, but it is typically ineffective for established infestations and requires repeated treatments over multiple seasons.

***2. Japanese knotweed* (Polygonaceae)**

Invasion Threat: Well-established invader of roadsides, disturbed areas, and aquatic/riparian banks, from the Blue Ridge to the Middle Atlantic Coastal Plain ecoregions, Japanese knotweed was likely introduced in the 19th century for erosion control or ornamental value. Prolific seed producer, though aggressive rhizomes typically facilitate the plants rapid invasion along transportation corridors and floodplains. Ecologically, the weed displaces native vegetation by forming dense monocultures, which destabilize riparian systems, especially those open to light like the roadside and streambanks.

Botanical Description: Stems are smooth and hollow, with plants growing up to 10 feet in height. Leaves are oval or spade shaped. Flowers are white and plumy, produced in late summer/early fall (August to September). Triangular seeds may be produced, but do not serve as the primary means of spread. Japanese knotweed readily forms adventurous roots when cut or fragmented.

Best Management: Effective control requires a multi-year, integrated approach using systemic herbicides, as established populations are very difficult to eradicate. Late summer foliar applications of an aquatic approved glyphosate (when treating wetted areas) applied at 3-4 qt/A with a NIS at 0.5% v/v is effective. Imazapyr can also be an effective tank mix-partner to control rhizomes but can injury nearby vegetation due to a long soil residual. Routine monitoring should occur to inspect control efforts, with follow-up treatments occurring as needed to address re-growth. Mowing or mechanical removal is not advised since these activities can exacerbate plant spread and stimulate plant growth.

***3. Johnsongrass* (Poaceae)**

Invasion Threat: Well-established invader of roadsides, agricultural fields, pastures, and debris areas, from the Blue Ridge through the Middle Atlantic Coastal Plain ecoregions, Johnsongrass was introduced in the early 19th century as a forage species. Prolific seed production and aggressive rhizome spread facilitate rapid expansion along transportation corridors via water, wind, and equipment movement, quickly forming dense plant stands. Established infestations create recurring management challenges

along roadsides, where dense growth can obstruct sight lines and contribute to safety hazards.

Botanical Description: Stems are stout and pinkish near the plant base, with clumps of the perennial grass growing up to 8 feet tall. Leaves are long and smooth, with a prominent white colored mid-vein. Flowers are purplish and are arranged as large, pyramid-shaped panicles produced in late summer/early fall (August to September). Triangular seeds may be produced, but do not serve as the primary means of spread. Rhizomes readily regenerate from small fragments and can remain viable across a wide range of environmental conditions, further complicating long-term control along roadsides.

Best Management: Effective control is challenging and typically requires a multi-year, integrated approach using systemic herbicides, as established populations often persist due to an extensive rhizome network. Early summer foliar applications of glyphosate applied at 2% v/v with a NIS at 0.5% v/v is an effective control strategy and should occur prior to seed production. Imazapyr can also be an effective tank mix-partner to control rhizomes but can injury nearby vegetation due to a long soil residual. The most reliable chemical control of rhizomes can be achieved with a foliar application of sulfosulfuron at 1% v/v plus 0.5% NIS. Follow-up applications should occur as needed to address plant regrowth.

4. Miscanthus (Poaceae)

Invasion Threat: Common invader of roadsides, utility rights-of-way, disturbed areas, and a wide range of natural habitats, miscanthus occurs most commonly in the Blue Ridge and Piedmont, with lower prevalence in the Southeastern and Middle Atlantic Coastal Plain ecoregions. Introduced as an ornamental grass, miscanthus commonly escapes cultivation due to wind-dispersed seeds and rhizome movement in debris or on equipment. Dense clump forms displaces native species, and the persistent dry foliage poses a notable fire hazard along transportation corridors.

Botanical Description: Clumping, upright perennial grass growing 5 to 10 feet tall. Elongated leaves can reach 3 feet in length with finely serrated margins, and have a prominent mid-vein. Flowers appear feathery, are pink-to-red in color, and are produced in late summer/early fall (August to September). Rhizomes are the primary propagation source, which remain viable across a wide range of environmental conditions, further complicating long-term control along roadsides.

Best Management: Effective control is often difficult and typically requires multiple applications to exhaust the entire rhizome system. Mid- to late-summer foliar

applications of glyphosate applied at 2-3% v/v with a NIS at 0.5% v/v are effective and should occur prior to seed production. Repeated mowing can help deplete the rhizome storages if conducted for at least two consecutive growing seasons; however, equipment should be properly cleaned and sanitized following any cutting activities to reduce spread risk. Fire alone is not a recommended control strategy unless followed by herbicide application to target re-sprouting, as burning increases miscanthus vigor and seed set.

***5. Phragmites* (Poaceae)**

Invasion Threat: Commonly observed in brackish and freshwater marshes, wetted roadway corridors, drainage diches, and spoil deposit sites primarily within the Middle Atlantic Coastal Plains ecoregion. The non-native phragmites (*P. australis* ssp. *australis*) was first documented in NC in the 1950s and is believed to have been introduced accidentally from ship ballasts. Although prolific seed production occurs, aggressive rhizome spread is the primary means of rapid invasion along transportation corridors and marshy habitats. Ecologically, phragmites is detrimental, displacing native vegetation by forming impenetrable monocultures, degrades floodplain function, and reduces native marshland bird habitat. The weed is very common among roadside ditches and other managed drainage features, and dense growth can obstruct sight lines and contribute to safety hazards for drivers.

Botanical Description: Hollow stems are typically green in color, stout and cane-like, with the perennial grass growing 3 to 12 feet tall. Leaves are long and serrated, tapering to a point and are blueish-green. Flowers are purplish to silver in color and appear as feathery-shaped panicles produced in early to late summer (June to August). Rhizomes and stolons can grow upwards of 10 ft in a single season and readily regenerate from small fragments, which complicates long-term plant control.

Best Management: Effective control is very challenging and will require a multi-year, integrated approach using systemic herbicides, since established populations persist due to an extensive rhizome and stolon network. Late summer or early fall foliar applications of glyphosate applied at 2% v/v with a NIS at 0.5% v/v is an effective control option. When not in sensitive areas, the most effective chemical control can be achieved with a foliar application of imazapyr at 1-2% v/v plus a 0.5% v/v methylated seed oil (MSO). In sensitive areas, a wick-type application may be deployed to wipe the foliage with either glyphosate or imazapyr. Controlled burning following herbicide application can reduce standing biomass and allow for native plant regeneration. Mechanical removal or mowing can reduce standing biomass but is unlikely to provide

effective control and could exacerbate plant spread. Follow-up herbicide applications will be necessary to address plant regrowth.

Rank II: Severe Threat— invasive species which display a high degree of environmental and management concern, but are not perceived as threatening as Rank I.

***6. Tree of heaven* (Simaroubacea)**

Invasion Threat: Aggressive, fast-growing woody tree found along roadsides, forested areas, and disturbed sites following horticultural introduction to the US in the later 18th century. Tree of heaven is now common in the Blue Ridge and Piedmont, with lower prevalence observed in the Southeastern and Middle Atlantic Coastal Plains. Individual trees can produce several hundred thousand seeds annually, with the winged-shape seed facilitating rapid spread along transportation corridors via wind. Rapid establishment of seedling can occur within three months of seed germination, and the tree behaves as a pioneer species by releasing allopathic chemicals, which reduces native plant competitiveness. The plant establishes dense, clonal patches that displace native vegetation and can readily colonizes poor soil environments and natural areas. Roadways function as major dispersal corridors, accelerating statewide invasion.

Botanical Description: Deciduous tree, with generally smooth bark, growing up to 80 feet tall. Leaves are compound, with leaflets being lanceolate in shape and having small teeth near the leaflet base. The leaves are often mistaken for black walnut; however, Tree of heaven leaves have a distinct 'peanut butter' smell when crushed. Flowers are green to yellow and appear as panicles produced in mid to late summer (July to August). Seeds form in papery winged sheaths that allows for widespread wind dispersal along the roadside.

Management: Effective control of tree-of-heaven requires a multi-year, integrated approach, as established infestations persist through vigorous root suckering and seed spread. For dense thickets and saplings, foliar applications of glyphosate at 4% v/v plus a NIS at 0.5% v/v is effective. Metsulfuron (1.0 oz per 100 gal water plus 0.5% NIS) also provides effective control where permitted. For larger trees (>6-inch diameter), cut-stump applications of 50% v/v triclopyr plus appropriate carrier applied to freshly cut surfaces can be effective when conducted from mid-summer to early fall to maximize translocation to roots. Hack-and-squirt (50% v/v) and basal bark (25% v/v) applications of triclopyr are also effective for larger stems and sites where foliar applications are less practical, but treatments will likely require a follow-up in subsequent years to ensure control of root suckers and any resprouts. Mechanical removal alone is not recommended due to vigorous regrowth potential, though hand pulling of small seedlings in natural areas can be effective if all root material is removed.

7. Privet spp. (Oleaceae)

Invasion Threat: Widespread invader of roadsides, forests, bottomlands and natural areas from the Blue Ridge to the Middle Atlantic Coastal Plain ecoregions, Chinese privet (*L. sinense*) is most common in NC and is especially problematic in wetland sites. Introduction likely occurred in the 1950s as an ornamental hedge plant but quickly escaped cultivation. Prolific fruit production and bird dispersal drive rapid spread, with additional local expansion via suckering. Often Privet spp. form dense, impenetrable thickets, which shade out native vegetation along riparian and transportation corridors, while dense growth along roadsides obstruct sight lines and reduce safety for drivers.

Botanical Description: Large evergreen shrub growing upwards of 15 feet in height, with smooth grey bark. Leaves are generally small, with smooth leaf margins, and have hairy midribs. Flowering occurs early to mid-summer (June and July) towards the end of braches, with black colored fruits set by late summer to early fall (August to September). Both *L. sinense* and *L. japonicum* have similar phenology but differ slightly in leaf size and texture.

Best Management: Effective control of Privet spp. requires a multi-year approach, as eradication of established infestations is very difficult due to suckering and prolific seed production. Small seedlings (< 2-inch diameter) can be hand-pulled or mechanically removed in naturalized areas if all root material is extracted. Larger plants are effectively controlled with foliar applications of glyphosate or triclopyr at 2% v/v plus 0.5% NIS, ideally applied in late fall or early spring. Where foliar treatments are less practical due to site-dynamics or plant size, cut-stump (50% v/v) or basal bark (25% v/v) applications of triclopyr plus appropriate carrier can be effective. All treatments, mechanical or chemical, will require follow-up monitoring and retreatment to control basal sprouts and root suckers.

8. Callery pear (Rosaceae)

Invasion Threat: Most common along roadsides, fallow pastures, and disturbed areas from the Middle Atlantic Coastal Plain to Piedmont, with less prevalence in the Blue Ridge ecoregion; Callery pear was introduced in the 1900s for fire blight resistance. Later plantings occurred from the ornamental trade, with at least 20 cultivars known across the Southeast (‘Bradford pear’ most recognized) that readily hybridize, complicating management. Callery pear establishes dense woody stands, which displace native vegetation along road corridors, natural areas, and forest edges. In

addition to the ecological impacts, driver safety concerns occur along roadsides due to the tree's weak branch structure and brittle wood. Larger trees are especially subject to storm-related breakage, which creates debris hazards along roadways and reduces infrastructure wellbeing. Some wild type cultivars produce thorns that can puncture tires of roadway maintenance equipment. Active campaigns throughout the Southeast exist to either prohibit, or discourage, the planting of Callery pear as a landscape planting.

Botanical Description: Medium-sized deciduous tree with grey bark, growing upwards of 50 feet tall and 30 feet wide depending on the cultivar. Pyramidal canopy growth habit, with high angled branching. Flowering is prolific, with white blooms appearing prior to leafing in early spring. Callery pear is known for having a distinct, pungent odor that is generally considered unpleasant. Brown-colored fruits are produced from late spring to summer (May and June), but are not always visibly prominent. Some Callery pear cultivars produce thorns up to 4 inches long.

Best Management: Effective control of Callery pear requires an integrated approach, as dense growth, large thorns, and vigorous resprouting complicate removal. Small plants in naturalized areas can be hand-pulled or dug if roots are completely removed; however, this is generally not advisable due to the high likelihood of regrowth. Mature trees may be cut or mulched close to the ground, but this approach is labor-intensive, may require specialized equipment, and incomplete root removal will result in regrowth. For chemical control, foliar applications of glyphosate (5% v/v) or imazapyr (2% v/v) plus 1% v/v basal oil are effective on smaller stems where non-target impacts are less concerning (Vogt et al. 2020). Basal bark treatments with triclopyr at 20% v/v plus an appropriate carrier are effective for saplings and small trees where foliar applications are prohibitive (Vogt et al. 2020). For well-established plants, apply cut-stump treatments with glyphosate (50% v/v) or triclopyr (25% v/v) plus an appropriate carrier applied immediately after cutting. Hack-and-squirt techniques conducted in the fall using 0.5 to 1.0 mL per incision of imazapyr or aminocyclopyrachlor can also be effective for controlling larger trees; however, this method leaves standing biomass that may pose safety hazards along roadsides and require additional removal measures. Follow-up monitoring and retreatment are necessary to control resprouts.

9. Alligatorweed (Amaranthaceae)

Invasion Threat: Exhibits both aquatic and terrestrial growth forms and occurs most commonly in the Southeastern and Middle Atlantic Coastal Plain ecoregions, with additional invasions documented in the Piedmont, alligatorweed was first introduced to

the US in the early 20th century. The aquatic form is a serious weed in roadside ditches, ponds, and other wet or satuaated natural areas. Plant spread is almost exclusively through vegetative fragmentation, as the plant readily roots at the stem node, allowing broken pieces to establish new infestations. In aquatic systems, alligatorweed forms dense, interwoven mats along shorelines and across water surfaces, reducing water flow and displacing native flora. Infestations along roadside drainage corridors and wetlands can produce persistent management challenges and increase the potential of roadway flooding and erosion.

Botanical Description: Vine-like plant with mats capable of reaching 3-30 feet in length. In the aquatic form, stems are reddish-purple in color, and are hollow, providing buoyancy across large expanses of water, whereas in the terrestrial form, stems are minimally hollow and woody in structure. Leaves are opposite, elliptic in shape with smooth margins, and are typically 2 to 4 inches long. Flowering occurs from spring to fall, and appear as solitary, small, white, and clover-like flower heads.

Best Management: Control of alligatorweed requires a long-term, integrated approach, with early detection and prevention representing the most cost-effective strategies. Systemic herbicides are the most economical and effective control tools for eradication. Repeated foliar applications in spring and fall (when water temperatures >60 F) of glyphosate (2% v/v), triclopyr (1.5% v/v), or florpyrauxifen-benzyl (1 to 2 PDU/A) plus an appropriate aquatic adjuvant (0.5% v/v) provide effective control of initial infestations; annual treatments are typically sufficient once populations are reduced. Foliar applications of imazapyr at 0.5% v/v plus 1% methylated seed oil (MSO) can also achieve near-eradication over a 2-year period in sites where residual herbicide activity is acceptable. Biological control insects, such as the alligatorweed flee beetle (*Agasicles hygrophila*), have been released successfully in NC and may provide integrated plant suppression, but their use is not recommended as a primary management method for eradication. Physical and mechanical removal often fails due to plant fragmentation and subsequent spread potential and should generally be avoided.

10. Multiflora rose (Rosaceae)

Invasion Threat: Widespread, perennial invader of roadsides, natural areas, pastures, upland forests, and bogs from the Blue Ridge to the Middle Atlantic Coastal Plain ecoregions, multiflora rose was initially introduced to the US in the 1860s as an ornamental rootstock and later as a ‘living fence’. A single shrub can produce hundreds of thousands of seeds annually, which can remain viable for >10 years, and are widely

dispersed by birds. The woody species tolerates a broad range of environmental conditions, enabling rapid expansion across disturbed or fallowed landscapes. Multiflora rose forms dense, impenetrable thickets that suppress native understory vegetation, and disturbed roadway corridors provide ideal conditions for sustained spread.

Botanical Description: Medium-sized, deciduous, thorny shrub reaching up to 10 feet in height, with distinct arching stems. Leaves are compound, consisting of alternately arranged leaflets that are broadly oval with serrated margins. A distinctive feathery, stipule is present at the base of each leaf. Flowers form in clusters, which are white to pinkish-white in color, and bloom in late spring (May to June), with small red fruits (rose hips) developing during the summer months which, often persist through winter.

Best Management: Effective control of multiflora rose requires a multi-year, integrated approach, as mechanical methods alone suppress growth but rarely achieve complete control. Cutting or mowing at least once during the growing season can reduce plant vigor as part of an integrated approach where site conditions and safety allow. Foliar applications from late spring through mid-fall (June to September) of glyphosate or triclopyr at 2% v/v plus 0.5% v/v NIS when applied thoroughly to the foliage, are effective. Metsulfuron (1 oz per 100 gal water plus 0.5% v/v NIS) and fosamine (2% v/v plus 0.25% NIS) are also reliable foliar control options during this. Where foliar spraying is not permissible due to sensitive or natural areas, cut-stump treatments of glyphosate (undiluted) or triclopyr (25% v/v) plus an appropriate carrier are effective at any time when soils are not frozen. Follow-up monitoring and retreatment are necessary to control resprouting in subsequent seasons.

Rank III: Considerable Threat— invasive species which display varying degrees of environmental and management concern but are not perceived as threatening as Rank II.

11. Autumn olive **(Elaeagnaceae)**

Invasion Threat: Fast-growing, ornamental shrub commonly found in open forests, along field and pasture edges, and in naturalized areas of the Piedmont and Blue Ridge ecoregions, autumn olive was introduced to the US in the early 19th century. Mature plants produce tens of thousands of seeds readily dispersed by wildlife. The species resprouts vigorously following cutting or burning activities, challenging management along mowed roadsides and forested sites. Autumn olive tolerates drought and a wide range of soil conditions, and rapidly outcompetes native vegetation by forming dense, shading thickets that suppress natural plant succession. While less competitive in closed-canopy forests, the shrub quickly invades disturbed sites.

Botanical Description: Medium-sized, deciduous shrub reaching up to 20 feet in height, with slender branches that can form thorn-like shoots. Leaves are elliptic, 2 to 4 inches long, having as distinct silver-white underside surface. White, fragrant, flower clusters appear in spring, with small red to pink fruits produced in the fall.

Best Management: Effective control of autumn olive requires a multi-year approach. Small seedlings and sprouts in naturalized areas can be hand-pulled or dug when soils are moist to ensure complete root removal; partial root removal often results in regrowth. For this reason, mowing and controlled burning methods should be avoided. Foliar applications from spring through early fall (April to October) of triclopyr (2% v/v) or 2,4-D (1% v/v) plus 0.5% v/v NIS provides effective control, with metsulfuron (1 oz per 100 gal water plus 0.5% v/v NIS) offering another reliable option. For larger shrubs or where foliar applications are impractical, basal bark treatments with triclopyr (25% v/v) plus mineral oil or cut-stump treatments using triclopyr (50% v/v) applied immediately after cutting in late summer to fall (July–September) can be effective. Follow-up monitoring and retreatment are necessary to control resprouting.

12. Cogongrass (Poaceae)

Invasion Threat: Perennial grass, typically found in pinelands, grassy roadsides, and pastures in the Piedmont and ecoregions to the east, cogongrass is an extremely aggressive, federally listed noxious weed. Initially introduced to the US in the early 1900s, the species was widely planted for erosion control and forage, which accelerated spread throughout the Southeast. The plant rapidly invades pastures, fallow fields, forests, and highway and utility RoW, including ecologically and culturally sensitive longleaf and slash pine forests. Cogongrass spreads aggressively via scaly rhizomes and seed (>3,000 per plant, per season), and forms dense infestations that are difficult to manage. The plants biomass is highly flammable which, significantly increases wildfire risk around roadway infrastructure. Cogongrass readily regenerates after fire, allowing for rapid colonization in disturbed sites and RoW provide an ideal dispersal corridor for seed movement via wind, vehicles, equipment, and contaminated soil.

Botanical Description: Dense, colony-forming grass growing 2 to 4 feet tall, with erect leaf blades that are finely serrated, and yellow-green in color. A white, off-center midrib is a distinguishing characteristic. Sharply pointed rhizomes form dense, interwoven mats and can penetrate the soil 12 to 48 inches deep. Blooming occurs early to late spring (March to June), with showy white to silver, cylindrical flower spikes range 2 to 8 inches and contain fluffy dandelion-like seeds.

Best Management: Effective control of cogongrass requires a multi-year, integrated approach, as no single treatment provides eradication. Systemic herbicides are the most effective option for long-term control. Foliar applications of glyphosate at 1.5% v/v can suppress infestations, but repeated annual treatments are required. Imazapyr at 48 oz/ac can also provide excellent control; however, site conditions may restrict use where infestations occur near desirable vegetation due to residual soil activity. Mechanical control through frequent tillage can be an effective strategy, as cogongrass does not persist under intensive cultivation (Byrd and Maddox 2024). Physical methods such as mowing or burning only remove aboveground biomass and often stimulate regrowth from rhizomes and seedling establishment and should only be used as pretreatments to improve herbicide applications, not as stand-alone control methods. Follow-up monitoring and retreatment is required to prevent additional infestations.

13. Oriental bittersweet (Celastraceae)

Invasion Threat: Most commonly found in the Blue Ridge and Piedmont ecoregions, with less prevalence in the eastern regions of NC, Oriental bittersweet is a state-listed Class C noxious weed occurring along roadsides, forested sites, disturbed areas, and riparian zones. Introduced to the US in the mid-19th century for ornamental purposes due to its showy yellow and red-orange fruits, this perennial vine became popular for floral arrangements and fall wreaths, which continues to facilitate spread. Although cultivation is regulated in 18 counties in western NC, prolific seed production and bird-mediated dispersal enable continued range expansion, with seed germination rates reported as high as 95%. The species can tolerate low-light conditions, allowing persistence under closed forest canopies. Vegetative spread via rhizomes and root suckers further enhances invasion capacity, leading to dense infestations that outcompete native vegetation. Oriental bittersweet smothers other plants and can girdle trees, and the added canopy weight increases the likelihood of tree breakage or uprooting, creating possible safety concerns along transportation corridors.

Botanical Description: Woody, deciduous vine growing up to 60 feet in height when scaling trees and structures or may remain low-lying in dense patches. Leaves are round with finely serrated margins and alternately arranged. Plants are dioecious, with female plants forming small, whitish-green flowers at the leaf axils in late spring (May to June), and fruits forming early fall as green spherical capsules, which reveal red-orange colors during early winter.

Best Management: Effective control of Oriental bittersweet requires a persistent multi-year, integrated approach, as populations released in forested and roadside settings

rapidly and continually expand. Newly established patches can be hand-pulled or dug when soils are moist if complete root removal achievable to prevent resprouting; all plant material should be bagged and disposed of properly. Cutting vines at ground level can help release host vegetation, but cutting alone only suppresses growth. Pulling cut vines from the host trees is not advised due to safety risks and host tree injury. For low-lying, dense infestations, cut vines to the ground early in the growing season, allow regrowth, and apply a foliar treatment of triclopyr (2% v/v) approximately one month later. Where vines have climbed into a tree canopy, cut stems near the ground and apply triclopyr (50% v/v plus basal oil) or glyphosate (50% v/v solution) immediately to the cut surface. Follow-up monitoring and retreatment in subsequent seasons is necessary to control new seedlings and root suckers.

14. Wisteria spp. (Fabaceae)

Invasion Threat: Statewide invasions likely occur, but exotic wisteria spp. primarily invade disturbed woodlands and roadside corridors, within and east, of the Piedmont ecoregion. While *W. sinensis* remains more prevalent in NC than *W. floribunda*, both species pose similar risks to natural and managed habitats. Introduced to the US in the early 19th century as ornamental vines for arbors and garden structures, these species escaped cultivation and are now well distributed throughout much of the southeast. Wisteria spp. spread primarily through vegetative runners, with more limited succession from seed dispersal. Most infestations originate from old home sites and landscape plantings, which should be treated as source populations when located near roadways. Once established, these woody vines aggressively shade and girdle surrounding vegetation, suppressing native tree and understory growth. Although vine growth is most vigorous in full sun, plants can adapt and spread in partial shade, making forest edges and roadside corridors especially vulnerable to infestation.

Botanical Description: Woody, deciduous vine growing up to 70 feet long and 10 inches in stem diameter, with *W. sinensis* climbs counterclockwise and *W. floribunda* climbs clockwise around host plants. Leaves are alternate and compound, with leaflets tapering at the tip and having wavy margins. Fragrant, violet to blue-violet, showy flowers appear in spring (April to May). Both invasive wisteria spp. are distinguishable from the native wisteria (*W. frutescens*), which flowers only after fully leafing out. Resulting fruits are green to brown seedpods, which appear mid-summer and persist on the vine.

Best Management: Effective control of wisteria spp. requires a multi-year, integrated approach, as extensive runners and root systems make established infestations

difficult to eradicate. Established infestations typically require combined cut-stump and foliar herbicide treatments. Where vines climb into tree canopies, cut stems near ground level and perform a window cut, and immediately treat cut surfaces with clopyralid (50%), glyphosate (undiluted), or triclopyr (50% v/v) plus appropriate basal oil. Ground-cover infestations can be treated with foliar applications of clopyralid, glyphosate, or triclopyr (2% v/v) plus 0.5% v/v NIS to thoroughly wet the foliage. Treatments are most effective from spring through fall and follow-by retreatments will be necessary to control any resprouts.

15. Mimosa (Fabaceae)

Invasion Threat: Widespread and persistent woody invader of roadsides, woodlands, riparian corridors, and disturbed natural areas from the Blue Ridge to the Middle Atlantic Coastal Plain ecoregions, mimosa was introduced to the US in the mid-18th century as an ornamental. Well known for its showy pink flowers, this tree forms dense colonies through root suckering, with prolific seed production and long-term viability presenting the greatest risk of landscape-scale spread. The species prefers full sun and commonly invades roadside corridors, where water- and equipment-mediated dispersal accelerates invasion. Although tolerant of a wide range of soils and moisture regimes, mimosa is less common at higher elevations due to a more limited cold tolerance.

Botanical Description: Medium-sized, deciduous tree with an open, spreading canopy, that reaches 10 to 50 feet tall. Trunks are often multi-stemmed, with thin light-colored bark. Leaves appear delicate and fern-like (bi-pinnately compound). Flowering occurs in late spring to early summer (May to July), with fragrant, pink flower groups appearing at the ends of branches. Fruits are flat, long seedpods, which mature in late summer to fall (August to September) and often persist on trees into winter.

Best Management: Effective control of mimosa requires an integrated approach, and discouraging planting, or encouraging the removal of existing plants, by property owners adjacent to roadway corridors is strongly recommended to limit further spread. Small seedlings can be hand-pulled in naturalized areas, but vigorous regrowth often limits the effectiveness of physical removal techniques alone. Dense thickets can be treated with foliar applications of glyphosate or triclopyr at 2% v/v plus 0.5% v/v NIS during active growth. Cut-stump applications of glyphosate or triclopyr at 50% v/v can be effective against larger trees. Where cutting is impractical, hack-and-squirt or basal bark applications of triclopyr (25% v/v plus basal oil) can be effective. Follow-up

monitoring and retreatment are necessary to target resprouts and newly emerged seedlings.

High-threat Species Removal from Roadside Environments

The NCDOT currently partners with NCDA&CS in managing certain invasive/noxious weeds within highway rights-of-way. In addition, NCDOT partners with US Forest Service (USFS), USDA, and other state/federal agencies for the removal of invasive plants via agreements on various projects or mitigation sites. These efforts by the NCDOT will continue as the NCDOT expands to include targeted removal of the above noted high-threat invasive species.

The table below summarizes the invasive plant species management options available to the NCDOT. Safety considerations and logistics of prescribed burning and biological controls prevent usage of these techniques except under very limited circumstances and conditions. The NCDOT will utilize appropriate controls, including licensed applicators for herbicide applications, in compliance with all applicable state and federal regulations.

Control and Management Methods

Method Type	Description	Application Notes
Foliar Chemical Control	Systemic herbicides (ex: glyphosate, triclopyr, imazapyr)	Primary method; applied seasonally; requires repeat treatments
Mechanical Control	Mowing, cutting, removal	Limited effectiveness; may spread species if not managed properly
Cut-Stem Treatment	Direct herbicide application to cut stems	Used where non-target damage must be minimized
Biological Control	Targeted grazing (e.g., goats)	Supplemental; effective only for small infestations;
Prescribed Burning	Controlled burning	Requires supplemental herbicide treatment; not conducive to rights-of-way
Equipment Sanitation	Cleaning machinery between sites	Critical to prevent spread

Management decisions will account for budget constraints and the degree of invasive weed impact, which varies depending on roadway usage, location, and the species posing the greatest threat. Control efforts are further complicated by invasive weed source populations located on adjacent properties that NCDOT cannot directly manage without appropriate funding, legal authorization, or cooperative agreements. The NCDOT has,

historically, made attempts to remove invasive plant species with only minimal success. While effective management efforts were utilized and the targeted species removed from the right-of-way, reinfestation routinely occurred as adjacent existing populations beyond the right-of-way reestablished within the treated area, creating a perpetual cycle of invasive management and expense. While eradication of invasive plant species is beyond the ability of the NCDOT, with concurring management from adjacent property owners, localized removal of the high-threat invasives is an achievable targeted goal.

NCDOT Maintenance operations performed by the Roadside Environmental Units, Maintenance Units, and their contractors will provide the primary oversight and effort for these management activities. Various highway and structure construction projects also present an opportunity for removal of high-threat invasive plant species. Project special provisions may be included in construction plan packages where known infestations of these high-threat invasives occur, detailing management requirements consistent with the species as detailed earlier. The remainder of this report will focus on removal of these invasives by maintenance forces.

Invasive weed management requires diligence and long-term commitment to successfully control invasive plants along transportation corridors. NCDOT management priority will focus on four tiers for targeted management activities. These tiers are based on probable ability to obtain agreements with adjacent stakeholders who would perform invasive plant management activities prior to or concurrently with the NCDOT activities.

(i) State or Federal agency cooperation
(ii) Municipal cooperation
(iii) Utility/Rural association/private property owner cooperation
(iv) Unsupported

The NCDOT will obtain memorandums of agreement or other instruments with State, Federal, or Municipal partners. These instruments would provide mutually agreed management activities and financial responsibilities that each party will perform for the removal of the targeted high-threat invasive species within the delineated boundaries. Attachment 2 contains a sample agreement for private property owners or other non-government associations for the cooperative management of invasive plant species and the associated North Carolina Administrative Code supporting this mutual cooperation.

Initial efforts will be targeted with other Federal agencies, such as the USFS, and partnerships with other state agencies, such as the NCDA&CS, and NC Parks Service to cooperatively control the high-threat invasive plants in a cost-effective manner that minimizes the potential for reinfestation. The next stage will include the surveying of rights-

of-way within municipal boundaries for high-threat invasive plants and pursuing cooperation on removal of the infestations within NCDOT owned areas and the adjoining property. The NCDOT will then survey remaining roadsides for high-threat invasive plants. When populations are found, a determination will be made on the extent of the infestation within and outside of the right-of-way. Removal actions will occur for infestations that are contained within NCDOT property. For quantifiable infestations outside of the right-of-way, NCDOT will send out communications to the adjacent property owners requesting cooperation for the removal of the invasive species present. The NCDOT will pursue removal with the execution of an agreement with the private property owner, or other property manager. Where agreements cannot be reached, the NCDOT will evaluate the expense of removal and the benefit to the transportation facility versus the risk of constant reinfestation. The NCDOT may take some level of invasive control operations at these locations but will not pursue aggressive removal unless a quantifiable substantial benefit to the transportation facility is found. The NCDOT will utilize GPS based mapping and georeferencing of the invasive plant infestation locations to provide herbicide application history and monitoring and analysis of the management operations and their effectiveness. Routine monitoring will be performed to evaluate efforts and will be timed according to species phenology, as many invasive weeds are perennial or function perennially. Multi-year monitoring may be required so that management efforts succeed in removing these high-threat invasive species. The NCSU report *Study and Evaluate the Impact of High-Threat Invasive Weed Species on NC Roadsides* also provides emerging technologies for detection of invasive plant species. NCDOT Roadside Environmental staff will evaluate these technologies for a cost-benefit comparison to further enhance the NCDOT's ability to detect and monitor invasive plant species locations. These technologies may present an opportunity for early detection and prevent establishment of invasive plants. This prevention is critical for the long-term, cost-effective management of high threat invasive plants along transportation corridors. The NCDOT will continue its normal invasive/weed/pest management operations within the state's roadsides in concert with these high-threat invasive species management operations where applicable.

High-threat Invasive Plant Removal Expenditures

Program funding is key to the long-term successful removal of high-threat invasive plant species. The NCDOT manages approximately 330,000 acres of roadside along the over 80,000 miles of highway it operates. The current number of infestations of high-threat invasive plant species is unknown. Based on anecdotal evidence, up to one-third of the acreage may contain some form of invasive plant, including high-threat invasive plants species identified in this report. The table below provides a generalized cost estimate for

the various activities needed for the delineation and removal of high-threat invasive plant species.

High-threat Invasive Plant Removal Cost Estimates

Activity	Estimated Cost Range	Notes	Estimated Cost per Unit	Mileage	Acreage	Total Non-recurring Costs	Total Multiyear Costs
Initial Survey & Mapping	$50–$150 per mile	Includes labor and GIS integration	$90	80,000	-	$7,200,000	-
Herbicide Treatment	$100–$500 per acre annually	Varies by species, density, and terrain	$350	-	66,000	$23,100,000	-
Mechanical Removal	$200–$1,000 per acre	Higher for dense or woody infestations	$600	-	33,000	$19,800,000	-
Follow-up Treatments	$100–$350 per acre annually	As required by species for removal	$300	-	99,000	-	$29,700,000
Monitoring & Data Management	$25–$100 per mile annually	Ongoing monitoring and analysis	$60	60,000	-	-	$3,600,000
Vegetation Replanting	$3,000-$3800 per acre	Needed for stabilization of denuded areas	$3,200	-	3,300	$10,560,000	-
					Sum	$60,660,000	$33,300,000
					Total Cost of Control		**$93,960,000**

The NCDOT relies on its private contracting partners to perform much needed services across all programs and activities including vegetation management. NCDOT vegetation management contractors will be instrumental in the performance of all facets of the management efforts to remove high-threat invasive plant species. An initial survey of all highway milage will be needed to catalog these invasive species. For estimating purposes only, a nominal twenty percent of the current acreage may need invasive management activities, including herbicidal treatments with half that acreage requiring mechanical removal and disposal. Due to some herbicidal injury and damage during mechanical

removal to desired understory growth as well as severe invasive plant infestations disruption of other vegetation, an estimated five percent of the initial treated acreage will be severely denuded of vegetation and require establishment of other grasses and plant species to prevent erosion and slope failures. An estimated $60.6 million will be needed for these initial and non-reoccurring invasive management costs. Follow-up herbicidal treatments and potential supplemental mechanical removals will also be needed, with an expected fifty percent of the initial treatment acreage requiring some forms of multi-year management, estimated on a three-year cycle. Monitoring, treatment evaluation and data management will also be needed to confirm the removal and track progress across the state, with a similar twenty-five percent estimate of mileage reviewed annually over a three-year management cycle. These multiyear reoccurring costs are roughly estimated to be $33.3 million for these operations. The total estimated cost for control and removal of high-threat invasive plant species is anticipated to be approximately $94 million. Note this amount may vary widely and can only be refined once the initial survey and mapping is completed providing the number of infested acres and the infestation species.

The aggressive target goal for the removal of high-threat invasive species is completion of the initial herbicidal or mechanical treatments by the end of year five, with all follow-up treatments ending in year eight. The average annual cost over the eight years would be $11.7 million. The first year of the effort will focus on the initial survey and mapping as well as cooperative agreements with other agencies and some initial treatments. Years two through four will require the majority of effort as initial and follow-up treatments occur and overlap and the expansion to include municipalities and other private property owners. Year five will include wrapping up remaining initial treatment sites and an increase in monitoring and evaluation. Years six through eight should begin to wind down operations as follow-up treatments are completed and monitoring needs subside. It is anticipated that some level of continued monitoring and treatment will be needed to ensure that high-threat invasives do not reestablish from transport by some other vector long term. Achieving the stated goal of removing high-threat invasive species from the NCDOT rights-of-way is dependent on both cooperation from adjacent property owners and adequate funding to carry out the program.

Attachment 1

GENERAL ASSEMBLY OF NORTH CAROLINA

SESSION 2025: SESSION LAW 2025-47

SENATE BILL 391

USE AND STUDY OF NATIVE PLANTS

SECTION 20.(b) *The Department of Transportation and the Department of Natural and Cultural Resources, in consultation with North Carolina State University and North Carolina Agricultural and Technical State University, shall study and develop (i) a list of native grasses, plants, and seeds appropriate for use in place of nonnative turf grasses and nonnative grasses, plants, and seeds used for the purpose of soil and slope stabilization for erosion control and (ii) a list of high-threat invasive plant species and a plan for removing existing invasive plant species from State parks and highway rights-of-way. The Department of Transportation and the Department of Natural and Cultural Resources shall provide a report on the study and development of the lists and plan to the 2026 Regular Session of the 2025 General Assembly upon its convening.*

Title: Study and Evaluate the Impact of High-Threat Invasive Weed Species on NC Roadsides

Name: Drs. Rob Richardson/Andrew Howell

Background: Invasive plant species along transportation corridors can reduce roadway safety, degrade habitat quality, and increase maintenance costs. NCDOT seeks to better understand the distribution, ecological impact, and management implications of these species to inform vegetation management strategies and promote sustainable roadside practices.

Task 1 – Literature Review and Data Compilation – 35%

- Review existing research on invasive weed species affecting roadways in the Southeastern United States.
- Identify high-threat species of concern relevant to North Carolina roadside environments.
- Summarize best management practices (BMPs) and control strategies for individual species currently used by state DOTs for eradication

Task 2 – Impact Assessment – 35%

- Evaluate ecological and economic impacts of invasive weeds on roadside vegetation, infrastructure integrity, visibility, and safety.
- Quantify maintenance and control costs attributable to invasive species.
- Quantify long term maintenance relative to soil stabilization and competitive species to maintain eradication of invasives.

Task 3 – Management Recommendations – 30%

- Develop science-based recommendations for prevention, early detection, and control.
- Propose monitoring protocols and data management systems for continued assessment.

Task 1: Literature Review and Data Compilation

1.1 Overview

Invasive roadside weeds have the potential to reduce transportation safety, degrade ecological habitat, and increase maintenance frequency and ultimately, roadside management cost. Developing a better understanding and review of the current distribution, environmental impacts, and management operations performed by the North Carolina Department of Transportation (NCDOT) to control invasive vegetation promotes the most sustainable and effective roadside maintenance strategy. Prompted by *SENATE BILL 391: USE AND STUDY OF NATIVE PLANTS,* this literature review provides relevant understanding of the existing research and scientific resources available for invasive weeds affecting roadways in the Southeast, particularly North Carolina (NC), while also identifying high-threat species of concern and best management practices (BMPs) to control individual species by the NCDOT and the NC Department of Natural and Cultural Resources (NC State Parks) agencies.

1.2 Invasive Weeds

Invasive weeds affecting Southeastern roadsides are best identified by the respective proximity to a geographic region or physical landscape feature of incursion, like the coast or mountains (i.e., low to high elevation ecologies, respectively). These geographic regions of ecosystems, known as ecoregions, tend to behave similarly due to environmental similarities such as climate, geology, or soil type and thus provide a grouping framework for roadside managers (Harper-Lore et al. 2013). Ultimately, these environmental factors provide focus to which plants can grow where, and how specific weed species could affect the roadway. While the NCDOT divides responsibility into 14 unique Highway Divisions (https://www.ncdot.gov/divisions/highways/Pages/divisions.aspx), invasive weed species have the propensity to effect all of the divisions to varying degrees of likeness, especially when considering there are only four Level III ecoregions in the state (Fig 1). In simpler terms, even though two or more highway management divisions may be separated by 100 miles of roadway, if those divisions reside within the same or similar ecoregion(s), those highway divisions will likely have similar weed species compositions. It is important to note most of the ecoregions in NC continue into similar ecological areas of adjacent states, which requires further consideration when identifying/controlling new or existing invasive weeds near the state's boundaries. The effectiveness of reducing weed species introductions and subsequent control measures of introduced invasives within an ecoregion likely requires strong coordination with adjacent states.

While the geographic likelihood and locational proximity of a given invasive weed within a travel corridor remains critical in understanding where an individual weed species resides, the potential severity/weediness of the weed is an equally important concept. The United States Department of Agriculture defines an *invasive species* per Executive Order 13112 - Invasive Species (https://www.invasivespeciesinfo.gov/resource/8003) as one that is,

1) non-native (or alien) to the ecosystem under consideration and,

2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health.

Of critical importance is noting not all non-native species have invasive potential, but all invasive species by definition, are non-native and are known to cause harm. For example, kudzu (*Pueraria montana*) is a perennial vine native to southeast Asia, but has become a widely distributed invasive species throughout Southeastern roadsides, smothering native trees and covering signage. On the contrary, the native bush species Eastern baccharis (*Baccharis halimifolia*), while often *weedy* cannot by definition be considered invasive, but many Southeastern DOT agencies consider it a nuisance due to its prolific growth habits which choke out and outcompete native vegetation. Similarly to the *invasive* and *nuisance* weed paradigm is the term *noxious*, which is a legal term, used to describe a plant "…designated by federal, state or local government officials as injurious to public health, agriculture, recreation, wildlife or property…" (WSSA 2016). A comprehensive overview of weed terms, including legal frameworks and definitions can be found in Iannone et al.'s 2020 white-paper "Invasive Species Terminology: Standardizing for Stakeholder Education". Weeds designated by the *noxious* status have legal standing and legitimate penalties associated with transport, cultivation, and management (Harper-Lore et al. 2013). As highlighted, there is great importance in understanding the context of invasive weed terms when defining invasive weed species affecting roadways in the Southeastern US, including those that pose the highest threat to NC roadsides, and how to deploy BMP strategies.

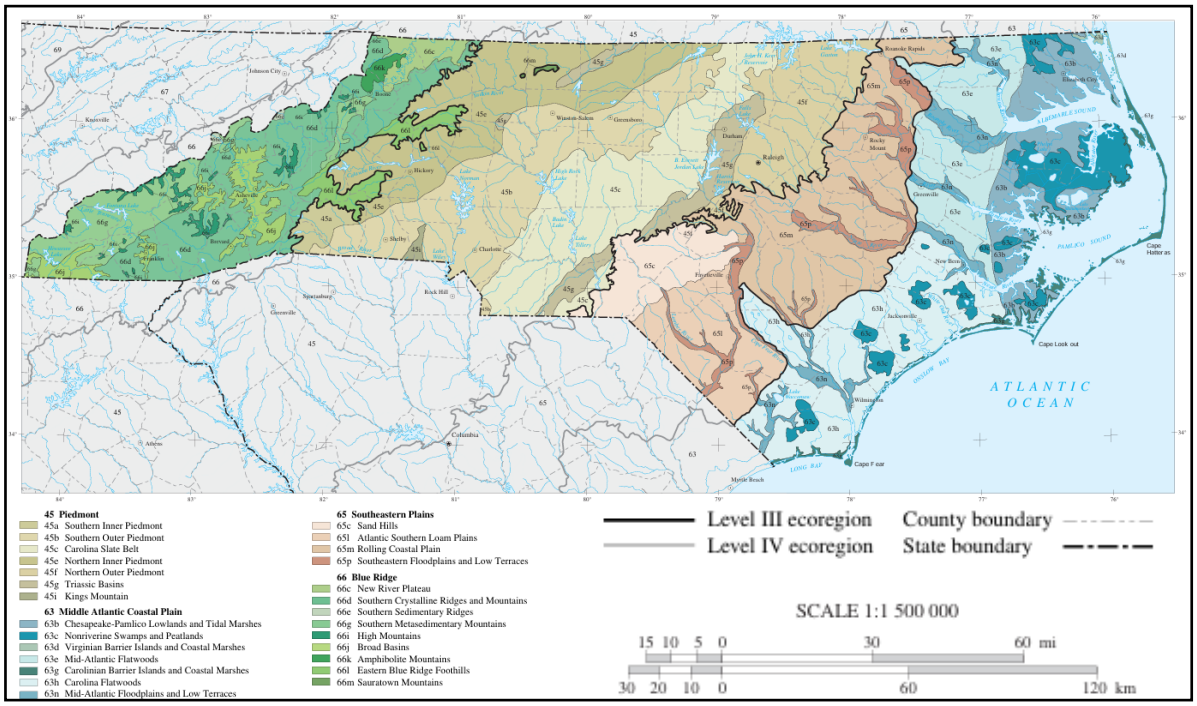

Figure 1. Ecoregions of North Carolina at the Level III and IV subdivisions. Map modified from Griffith et al. (2002).

Southeastern state DOT agencies generally designate an invasive species list using federal registries, reports from state-specific Invasive Species Councils/Working Groups (ISC/WG), or a relevant state agency with authority to distinguish such a list following state legislature directive (e.g., Department of Agriculture/Forest Service; Natural Resources/Game Commission). More often than not though, these various list sources contradict one another as it pertains to the severity of the invasive weed listed, the number of species of concern, 'localized' impacts, and the weeds' noxious status as outlined by federal and state/local regulations (Venner 2006). As previously eluded, a state's directive to indicate a weed as noxious is critical because there is legal action directed to the management of that weed species. For example, the Florida Department of Transportation (FDOT) lists the top 15 invasive species reported to the Florida (FL) ISWG; however, this list is not exhaustive to all of the weeds within the state recognized as noxious or prohibited. Those weeds designated in FL comprise a much larger list of species (>100 weeds) as defined by the FL Department of Agriculture and Consumer Services in the FAC *5B-57.007 Noxious Weed List* (FDACS 2020). While the FLDACS list is more comprehensive than the FDOT list, the broad gap in species listed between these state agencies does potentially limit management focus and direction, and could create confusion for site-specific management agencies such as a DOT. In an interview with noxious weed authorities in four states, the Weed Science Society of America (WSSA) reported that a narrowed focus, or a "less is more approach", provides the best management opportunity to tackle noxious weeds (WSSA 2018). Therefore, while less extensive, the smaller FDOT list ultimately provides greater utility since the list is site-specific to roadside corridors and provides managers with a list that directs species of 'higher' threat to the roadway. It should be noted, however, that three of weeds in the 'top 15 invasive species' reported by FDOT are not under the FL state noxious status but are nonetheless considered a high priority for management.

To indicate priority weeds, Department(s) of Agriculture in states such as Alabama, Virginia, and NC have deployed a tiered-based system to denote the severity of invasiveness and/or noxious status under regulatory authority (ADAI 2022; CV 2026; NCDA 2026). This approach provides a hierarchy of weeds using categories, typically arranged in three tiers (e.g., 'A', 'B', 'C' or '1', '2', '3'; highest to lesser priority, respectively), in terms of introduction or establishment potential and/or management containment and longevity of such management activities (e.g., 'A' tier weeds have no-to-limited distribution and are typically on a federal registry, 'B' tier weeds have limited distribution, whereas 'C' tier weeds are well-established). These categorizes do not necessarily indicate that a tier 'C' or '3' weed is less invasive than one in the 'A' or '1' tier, but again it does suggest management priority based on presence within the state. However, other Southeastern states such as South Carolina, Georgia, Florida, and Tennessee only provide invasive/noxious species lists in broader terms and do not utilize generally use this categorized approach. Ultimately, categorizing noxious/invasiveness in the tiered manor likely provides the best guidance for long-term DOT management programs to identify the most concerning plant threats, and supports weed eradications, control, and/or suppression since priority is directed

from small, incipient populations to those of more broad distribution within the state (Veneer 2006).

1.3 High-threat Species of Concern to NC Roadside Environments

To prioritize invasive plant species that pose the greatest risk to NC roadside environments, a tiered, severity-based framework is proposed. This approach mirrors the classification system used by the NCDA to identify the most threatening invasive weeds and adapts it specifically to roadside contexts. Using a ranking system similar to the *Invasive Species Assessment Protocol* outlined in the USDOT 'Roadside Weed Management' guidance, this framework focuses limited management resources on the most problematic invaders (Harper-Lore et al. 2007), those species with the greatest potential for ecologic and economic impact, spread, and persistence along transportation corridors within the state. Such a High-to-Low ranking system establishes clear priorities for identifying invasive weeds of concern, distribution assessment, and management response. In NC, the logical starting point for this evaluation is the noxious weed list already established by the NCDA Plant Industry Division (Table 1).

Table 1. Noxious weeds listed derived from the North Carolina Department of Agriculture Plant Industry Division.

Class A Noxious Weeds
Federally-listed species by USDA APHIS[1] (N=89 plants)
Other Class A Noxious Weeds (State-defined):
Crassula helmsii (Swamp Stonecrop)
Lagarosiphon spp. (African Elodea)
Nymphoides cristata (Crested Floating Heart)
Nymphoides indica (Water snowflake)
Nymphoides peltata (Yellow Floating Heart)
Salvinia spp. (all except S. minima; Water Fern)
Trapa spp. (Water-Chestnut)
Class B Noxious Weeds
Carduus acanthoides L. (Plumeless Thistle)
Carduus nutans L. (Musk Thistle)
Cayratia japonica (Thunb.) Gagnep. (Bushkiller)
Cirsium arvense (L.) Scop. (Canada Thistle)
Ludwigia hexapetala (Hook & Arn.) Zardini, Gu & Raven (Uruguay Waterprimrose)
Lythrum spp. (Any Lythrum spp. not native to North Carolina)
Myriophyllum spicatum L. (Eurasian Watermilfoil)
Persicaria perfoliata (Mile-a-Minute Weed)
Rorippa sylvestris (L.) Bess. (Yellow Fieldcress)
Tribulus terrestris L. (Puncturevine)
Vitex rotundifolia L.f. (Beach Vitex)
Class C Noxious Weeds
Celastrus orbiculatus Thunb. - (Oriental Bittersweet)

[1]United States Department of Agriculture, Animal and Plant Health Inspection Service: Federal Noxious Weed List (*https://www.aphis.usda.gov/media/document/46865/file*)

However, while the noxious weeds outlined by the NCDA provide an important starting point, not all listed species present direct implications for roadside management. For instance, many aquatic and wetland species included in Table 1 would be unlikely to occur along the majority of roadway environments across the state. Additionally, the submersed aquatic weed, *Lagarosiphon* spp., has not been documented within the US. Prioritizing such species based on regulatory status alone would therefore represent an inefficient use of NCDOT management resources. Nevertheless, other aquatic weed species on the NCDA list, such as *Nymphoides* spp. and *Salvinia* spp. may still warrant consideration in situations where roadways intersect or abut wetlands, drainage ditches, or adjacent properties under NCDOT jurisdiction. In this context, federally listed species designated as Class 'A' weeds can provide an additional, more targeted reference for further narrowing the subset of high-threat invasive species relevant to NC roadways.

Currently, the NCDOT Vegetation Management Section maintains a documented "noxious weeds" list consisting largely of species commonly encountered along NC roadways (NCDOT-VMS 2025). While the document provides practical examples of 'pestiferous' and aquatic weeds of management concern, it does not explicitly define "noxious" within the common regulatory framework, nor does it align consistently with state or federal noxious weed designations. In contrast, the 'official' NCDA and USDA noxious weed lists are regulatory in nature and identify species subject to legal control and/or exclusion. When cross-referenced, only Canada thistle (*Cirsium arvense*) from the NCDOT list appears on the regulated NCDA Noxious Weeds list [Class B species], and only dodder (*Cuscuta* spp.) overlaps with the federal noxious weed designation. The remaining species lack formal state or federal regulatory status and therefore fall more appropriately under general weed management or pestiferous species categories rather than legally defined noxious weeds as listed within the document. Note that this distinction does not diminish the potential invasiveness or ecological impact along roadsides of the NCDOT listed weeds; however, the document does potentially limit the regulatory authority and prioritization mechanisms available for management. Consequently, reliance on the existing NCDOT list alone lacks a defensible framework for identifying high-threat invasive species. A more effective approach integrates regulatory lists with additional science-based sources and ecoregional invasive species identified by relevant state land-management agencies, councils, and organizations, while also incorporating input from NCDOT staff who regularly visit and manage roadside vegetation. Because weed populations are dynamic and influenced by climate, disturbance events, and management actions, the weeds most frequently reported by NCDOT personnel warrant particular consideration, as these observations provide the most current, on-the-ground assessment of roadside invasive conditions. When coordinated within a hierarchical framework, this approach enables a more comprehensive and strong prioritization of roadside invasive weeds requiring management attention.

As noted previously, many other Southeastern state DOTs rely on invasive plant councils or interagency working groups to identify priority species for monitoring, management, or exclusion from roadside plantings. For example, South Carolina and Florida utilize general

noxious or invasive plant lists to identify species of concern for roadway environments, drawing from resources provided by the Southeast Exotic Pest Plant Council (SE-EPPC) and the Florida Invasive Species Working Group (ISWG), respectively. In South Carolina, while not used to directly guide weed management efforts, the SCDOT provides a comprehensive reference in its publication 'Roadside Plants to Avoid /Trees with Limitations on R/W' due to invasive potential or roadway concern (SCDOT 2014). Similarly, the Georgia DOT (GDOT) maintains a list of invasive plant species prohibited from planting on state rights-of-way (GDOT 2024); however, this list does not serve as a direct management directive. Instead, GDOT refers readers to the Georgia Exotic Pest Plant Council (GEPPC) for additional information on such weeds listed. Notably, GDOT identifies invasive species currently available in the nursery trade, which is a valuable consideration for roadside managers tracking potential pathways of introduction and spread.

Given this common reliance among Southeastern DOTs on advisory councils and expert-driven working groups, another potential source for identifying high-priority invasive weeds for NCDOT consideration is the North Carolina Invasive Plant Council (NCIPC). The NCIPC maintains a comprehensive, ranked-based invasive plant list developed with input from multiple federal, state, and non-governmental partners, including the NC Natural Heritage Program, USDA Forest Service, NC Botanical Garden, NC Department of Agriculture & Consumer Services, Piedmont Land Conservancy, NC Native Plant Society, and others. The NCIPC (2023) list categorizes invasive plants by threat level and includes a "watch list," with species ranked on a three-tier scale: Tier 1 (*severe threat*), Tier 2 (*significant threat*), and Tier 3 (*lesser threat*). While the NCIPC list is extensive (N = *145* ranked plants listed) and highlights species with federal or state regulatory status, its breadth demands further refinement to focus attention on those species most relevant to roadside environments and NCDOT management objectives.

Other valuable sources for developing a focused list of high-priority invasive species include management guides and species lists produced by Southeastern forest services and the North Carolina Wildlife Resources Commission (NCWRC). These agencies not only have extensive in-field experience with vegetation management in naturalized settings, but also regularly publish materials identifying species of concern for invasive plant managers. Such resources are directly relevant to NCDOT-managed areas, particularly in transition and natural environment zones, and align with invasive plant management priorities for NC State Parks under the Department of Natural and Cultural Resources. For example, the NC Forest Service (NCFS) maintains a list of 20 invasive plant species organized by growth form (tree, shrub, vine, or herbaceous/grass), which correspond to invasive weed species likely to invade NCDOT properties in similar forested or naturalized settings (NCFS 2026). The NCWRC's 2025 Statewide Action Plan provides a comprehensive inventory of non-native and invasive species (Appendix 3; Table 3-14), totaling 83 species, though it does not differentiate between flora and fauna (NCWRC 2025). For more targeted plant-specific guidance, Strope (2025) in a recent NC Wildlife Magazine article, highlights 33 common invasive plants from across the state, identifying species that are likely relevant for roadside and natural area management. Integrating these

sources can provide a more informed and context-specific foundation for prioritizing high-threat invasive species for NC roadways. Collectively, these sources provide a scientifically grounded, NC relevant basis for identifying invasive species most applicable to NCDOT's vegetation management program. Leveraging this information allows for a strategic prioritization of high-threat weeds and supports the creation of a list tailored to roadside management needs.

Table 2. Cross-reference list of the Top 15 high-threat invasive weeds of concern to North Carolina (NC) roadside environments, with additional severity rankings provided by NC Department of Transportation and NC State Parks representatives.

High-threat Invasive Species	Scientific Name	Cross-referenced List	NCDOT Ranked[§]	State Parks Ranked[§]
Kudzu	*Pueraria montana*	1 (Rank 1), 2, 5, 6, 7	*I*	*I*
Cogongrass	*Imperata cylindrica*	1 (Rank 2), 3, 4, 6	*III*	*I*
Phragmites	*Phragmites australis*	1 (Rank 1), 5, 6, 7	*I*	*II*
Oriental bittersweet	*Celastrus orbiculatus*	1 (Rank 1), 4 (Class C), 5, 7	*III*	*I*
Alligatorweed	*Alternanthera philoxeroides*	1 (Rank 1), 2, 6 ,7	*II*	*III*
Tree of heaven	*Ailanthus altissima*	1 (Rank 1),5, 7	*II*	*I*
Privet spp.	*Ligustrum sinense, L. japonicum*	1 (Rank 1), 5, 7	*II*	*II*
Mimosa	*Albizia julibrissin*	1 (Rank 1), 5, 7	*III*	*III*
Multiflora rose	*Rosa multiflora*	1 (Rank 1), 5, 7	*II*	*II*
Miscanthus	*Miscanthus sinensis*	1 (Rank 1), 5, 7	*I*	*I*
Wisteria spp.	*Wisteria sinensis, W. floribunda*	1 (Rank 1), 5, 7	*III*	*II*
Autumn olive	*Elaeagnus umbellata*	1 (Rank 1), 5, 7	*III*	*III*
Johnsongrass	*Sorghum halepense*	1 (Rank 2), 5, 7	*I*	*III*
Japanese knotweed	*Reynoutria japonica*	1 (Rank 1), 7	*I*	*II*
Callery pear	*Pyrus calleryana*	1 (Rank 1), 7	*II*	*III*

[1]North Carolina Invasive Plant Council. NC Invasive Plants List – Ranked Invasive Plant List 2023. (Rank 1: Severe Threat; Rank 2: Significant Threat; Watch List: Exotic and may become a problem).

[2]North Carolina Department of Transportation, Vegetation Management Section: Noxious and aquatic weeds.

[3]United States Department of Agriculture, Animal and Plant Health Inspection Service: Federal Noxious Weed List.

[4]North Carolina Department of Agriculture & Consumer Services: Plant Industry – Noxious weeds list.

[5]North Carolina Forest Service: Invasive Species Leaflets.

[6]North Carolina Wildlife Resources Commission: State Wildlife Action Plan 2025.

[7]Wildlife in North Carolina. September-October 2025: Quiet Invasions.

[§]Rank I invasive species display the highest degree of environmental and management concern, Rank II invasive species display a high degree of environmental and management concern, but are not perceived as threatening as Rank I, whereas Rank III invasive species display varying degrees of environmental and management concern, but are not perceived as threatening as Rank II.

Given the breadth and discrepancy of available resources, Table 2 presents a cross-reference of the top weeds of concern based on frequency of occurrence across relevant federal, state, and nongovernmental agency lists and publications. This table of species was further refined to a final set of the Top 15 High-Threat Species of Concern to NC Roadside Environments, identified in consultation with NCDOT (pers. comm., K. Clemmer) and NC State Parks (pers. comm., O. Denny and J. Short) personnel based on observed management severity, prevalence, and

distribution across the state. The table incorporates and builds upon the rankings from the NCIPC list to denote severity of concern within the state. While no single source fully captures roadside invasion risk throughout the state at present, this cross-referenced, multi-agency framework provides the most targeted approach to identify high-threat invasive plant species specific to NC transportation corridors.

In summary, this prioritized list integrates multiple authoritative sources recognizing species that are:

- Commonly invading NCDOT rights-of-way,
- Identified as noxious or invasive at state and regional scales, and/or
- Recognized across regulatory, conservation, and natural area management documentation as a severe threat to local ecologies.

By synthesizing state and federal regulatory lists (NCDA and USDA), operational priorities and science-based threat rankings from invasive plant professionals (NCDOT and State Parks personnel; NCIPC), and management/practitioner documents (NCFS, NC Wildlife Magazine, NCWRC SWAP), the resulting Table 2 list captures functionally impactful invasive plant species warranting both prioritized monitoring and management by the NCDOT. Ultimately, this approach provides a more narrowed focus across sources rather than subjective reliance on any single list, and aligns invasive plant threat levels with transportation corridor management realities. However, this developed "Top 15 high-threat invasive weeds of concern" list is adaptive and will require periodic updates as new species are introduced to roadside environments or existing invaders increase in landscape distribution or management difficulty.

For example, while severity rankings differed between the two agencies (Table 2; only six of the identified 15 species received the same severity ranking), these discrepancies are not surprising given inherent differences in site conditions, management objectives, and agency priority/responsibility. Additional species of concern identified by both agencies as identified through personal communication include Itchgrass (*Rottboellia cochinchinensis*), a NCIPC Watch list species and federal noxious weed; Princess tree (*Paulownia tomentosa*), a NCIPC Rank 2 species; and Chinese tallow (*Triadica sebifera*), a NCIPC Rank 2 species.

1.4 Best Management Practices (BMPs) and Control Strategies of High-threat Invasives

Managing invasive and threatening plants is a core responsibility of roadside vegetation programs. Invasive weeds threaten thousands of acres of NC's roadside each year, often forming dense infestations that reduce native flora and fauna biodiversity and increases safety risk of highway users. Vegetation managers prioritize maintaining safe transportation corridors by ensuring hazard-free clear zones, low-growing roadside vegetation, and open sight distances for drivers. Targeted vegetation management approaches supports roadway safety while also enhancing biodiversity, aesthetics, and the preservation of NC's biological, cultural, and landscape heritage. To date, the NCDOT strives to implement an Integrated Pest Management

(IPM) approach, based on core principles developed by the National Vegetation Management Association, to guide specific vegetation management and invasive species control practices.

The following section highlights each of the 15 high-threat invasives identified in Table 2. Each species profile reflects updated information building on content provided in *Invasive Exotic Plants of North Carolina* by Smith (2012) and describes invasion threat, botanical description, and updated BMPs and control strategies in order of NCDOT severity rankings. Ecoregional descriptions for each species are derived from Weakley and Southeastern Flora Team (2026) to inform regional and locational priorities within the state to guide NCDOT division relevance.

Rank I: Extreme Threat*—invasive species which display the highest degree of environmental and management concern.*

1. Kudzu (Fabaceae)

Invasion Threat: Widespread invader of roadsides and natural areas from the Blue Ridge to the Middle Atlantic Coastal Plain ecoregions following widespread touting in the 1920-30's for erosion control. Today, kudzu is a ubiquitous, perennial, semi-woody trailing or climbing vine than can reach up to 100 feet in length. The plant forms a dense, smothering canopy over trees, infrastructures (e.g., guardrails and signage), and safety zones, creating visibility hazards to drivers and increasing costs for the NCDOT. Open canopies and areas receiving direct sunlight allow for the most rapid growth potential, with kudzu growing up to one foot per day under favorable conditions.

Botanical Description: Stems are initially hairy, becoming woody with age. Leaves are compound with three broad leaflets, which may be entire or lobed. Flowers are purple and are produced in late summer, with hairy seedpods occurring in the fall (October to November). However, seeds have generally low viability, as primary spread and succession occurring via stolons. Kudzu has a highly persistent root system, enabling survival and regrowth even after repeated cutting and mowing operations, which complicates long-term control efforts along roadsides.

Best Management: Effective control requires a multi-year, integrated approach using systemic herbicides to kill the root system, with follow-up treatments to address re-sprouting. Foliar applications of glyphosate or triclopyr at 2-4% v/v with a non-ionic surfactant (NIS) at 0.5% v/v are generally effective; clopyralid applied at 1-3% v/v is also an effective option. Depending upon the foliar mixture used, non-target vegetation beneath the kudzu canopy is likely to be injured. Foliar applications of metsulfuron at 3-4 oz/A can be effective when safety to surrounding vegetation is needed (Miller 2006). Where non-target impacts are unacceptable, cut-stem applications of 50% v/v glyphosate or triclopyr provide a more selective alternative. Targeted grazing with goats can help suppress aboveground biomass and gradually deplete root reserves in smaller infestation areas, but

it is typically ineffective for established infestations and requires repeated treatments over multiple seasons.

2. Japanese knotweed **(Polygonaceae)**

Invasion Threat: Well-established invader of roadsides, disturbed areas, and aquatic/riparian banks, from the Blue Ridge to the Middle Atlantic Coastal Plain ecoregions, Japanese knotweed was likely introduced in the 19th century for erosion control or ornamental value. Prolific seed producer, though aggressive rhizomes typically facilitates the plants rapid invasion along transportation corridors and floodplains. Ecologically, the weed displaces native vegetation by forming dense, monocultures, which destabilizes riparian systems, especially those open to light like the roadside and streambanks.

Botanical Description: Stems are smooth and hollow, with plants growing up to 10 feet in height. Leaves are oval or spade shaped. Flowers are white and plumy, produced in late summer/early fall (August to September). Triangular seeds may be produced, but do not serve as the primary means of spread. Japanese knotweed readily forms adventurous roots when cut or fragmented.

Best Management: Effective control requires a multi-year, integrated approach using systemic herbicides, as established populations are very difficult to eradicate. Late summer foliar applications of an aquatic approved glyphosate (when treating wetted areas) applied at 3-4 qt/A with a NIS at 0.5% v/v is effective. Imazapyr can also be an effective tank mix-partner to control rhizomes, but can injury nearby vegetation due to a long soil residual. Routine monitoring should occur to inspect control efforts, with follow-up treatments occurring as needed to address re-growth. Mowing or mechanical removal is not advised since these activities can exacerbate plant spread and stimulate plant growth.

3. Johnsongrass **(Poaceae)**

Invasion Threat: Well-established invader of roadsides, agricultural fields, pastures, and debris areas, from the Blue Ridge through the Middle Atlantic Coastal Plain ecoregions, Johnsongrass was introduced in the early 19th century as a forage species. Prolific seed production and aggressive rhizome spread facilitate rapid expansion along transportation corridors via water, wind, and equipment movement, quickly forming dense plant stands. Established infestations create recurring management challenges along roadsides, where dense growth can obstruct sight lines and contribute to safety hazards.

Botanical Description: Stems are stout and pinkish near the plant base, with clumps of the perennial grass growing up to 8 feet tall. Leaves are long and smooth, with a prominent white colored mid-vein. Flowers are purplish and are arranged as large, pyramid-shaped panicles produced in late summer/early fall (August to September). Triangular seeds may be produced, but do not serve as the primary means of spread. Rhizomes readily regenerate

from small fragments and can remain viable across a wide range of environmental conditions, further complicating long-term control along roadsides.

Best Management: Effective control is challenging and typically requires a multi-year, integrated approach using systemic herbicides, as established populations often persist due to an extensive rhizome network. Early summer foliar applications of glyphosate applied at 2% v/v with a NIS at 0.5% v/v is an effective control strategy and should occur prior to seed production. Imazapyr can also be an effective tank mix-partner to control rhizomes, but can injury nearby vegetation due to a long soil residual. The most reliable chemical control of rhizomes can be achieved with a foliar application of sulfosulfuron at 1% v/v plus 0.5% NIS. Follow-up applications should occur as needed to address plant regrowth.

4. Miscanthus (Poaceae)

Invasion Threat: Common invader of roadsides, utility rights-of-way, disturbed areas, and a wide range of natural habitats, miscanthus occurs most commonly in the Blue Ridge and Piedmont, with lower prevalence in the Southeastern and Middle Atlantic Coastal Plain ecoregions. Introduced as an ornamental grass, miscanthus commonly escapes cultivation due to wind-dispersed seeds and rhizome movement in debris or on equipment. Dense clump forms displaces native species, and the persistent dry foliage poses a notable fire hazard along transportation corridors.

Botanical Description: Clumping, upright perennial grass growing 5 to 10 feet tall. Elongated leaves can reach 3 feet in length with finely serrated margins, and have a prominent mid-vein. Flowers appear feathery, are pink-to-red in color, and are produced in late summer/early fall (August to September). Rhizomes are the primary propagation source, which remain viable across a wide range of environmental conditions, further complicating long-term control along roadsides.

Best Management: Effective control is often difficult and typically requires multiple applications to exhaust the entire rhizome system. Mid- to late-summer foliar applications of glyphosate applied at 2-3% v/v with a NIS at 0.5% v/v are effective and should occur prior to seed production. Repeated mowing can help deplete the rhizome storages if conducted for at least two consecutive growing seasons; however, equipment should be properly cleaned and sanitized following any cutting activities to reduce spread risk. Fire alone is not a recommended control strategy unless followed by herbicide application to target re-sprouting, as burning increases miscanthus vigor and seed set.

5. Phragmites (Poaceae)

Invasion Threat: Commonly observed in brackish and freshwater marshes, wetted roadway corridors, drainage diches, and spoil deposit sites primarily within the Middle Atlantic Coastal Plains ecoregion. The non-native phragmites (*P. australis* ssp. *australis*) was first documented in NC in the 1950s, and is believed to have been introduce accidentally from

ship ballasts. Although prolific seed production occurs, aggressive rhizome spread is the primary means of rapid invasion along transportation corridors and marshy habitats. Ecologically, phragmites is detrimental, displacing native vegetation by forming impenetrable monocultures, degrades floodplain function, and reduces native marshland bird habitat. The weed is very common among roadside ditches and other managed drainage features, and dense growth can obstruct sight lines and contribute to safety hazards for drivers.

Botanical Description: Hollow stems are typically green in color, stout and cane-like, with the perennial grass growing 3 to 12 feet tall. Leaves are long and serrated, tapering to a point and are blueish-green. Flowers are purplish to silver in color, and appear as feathery-shaped panicles produced in early to late summer (June to August). Rhizomes and stolons can grow upwards of 10 ft in a single season and readily regenerate from small fragments, which complicates long-term plant control.

Best Management: Effective control is very challenging and will require a multi-year, integrated approach using systemic herbicides, since established populations persist due to an extensive rhizome and stolon network. Late summer or early fall foliar applications of glyphosate applied at 2% v/v with a NIS at 0.5% v/v is an effective control options. When not in sensitive areas, the most effective chemical control can be achieved with a foliar application of imazapyr at 1-2% v/v plus a 0.5% v/v methylated seed oil (MSO). In sensitive areas, a wick-type application may be deployed to wipe the foliage with either glyphosate or imazapyr. Controlled burning following herbicide application can reduce standing biomass and allow for native plant regeneration. Mechanical removal or mowing can reduce standing biomass, but is unlikely to provide effective control and could exacerbate plant spread. Follow-up herbicide applications will be necessary to address plant regrowth.

Rank II: Severe Threat—*invasive species which display a high degree of environmental and management concern, but are not perceived as threatening as Rank I.*

6. Tree of heaven **(Simaroubacea)**

Invasion Threat: Aggressive, fast-growing woody tree found along roadsides, forested areas, and disturbed sites following horticultural introduction to the US in the later 18th century. Tree of heaven is now common in the Blue Ridge and Piedmont, with lower prevalence observed in the Southeastern and Middle Atlantic Coastal Plains. Individual trees can produce several hundred thousand seeds annually, with the winged-shape seed facilitating rapid spread along transportation corridors via wind. Rapid establishment of seedling can occur within three months of seed germination, and the tree behaves as a pioneer species by releasing allopathic chemicals, which reduces native plant competiveness. The plant establishes dense, clonal patches that displace native vegetation and can readily colonizes poor soil environments and natural areas. Roadways function as major dispersal corridors, accelerating statewide invasion.

Botanical Description: Deciduous tree, with generally smooth bark, growing up to 80 feet tall. Leaves are compound, with leaflets being lanceolate in shape and having small teeth near the leaflet base. The leaves are often mistaken for black walnut; however, Tree of heaven leaves have a distinct 'peanut butter' smell when crushed. Flowers are green to yellow, and appear as panicles produced in mid to late summer (July to August). Seeds form in papery winged sheaths that allows for widespread wind dispersal along the roadside.

Management: Effective control of tree-of-heaven requires a multi-year, integrated approach, as established infestations persist through vigorous root suckering and seed spread. For dense thickets and saplings, foliar applications of glyphosate at 4% v/v plus a NIS at 0.5% v/v is effective. Metsulfuron (1.0 oz per 100 gal water plus 0.5% NIS) also provides effective control where permitted. For larger trees (>6 inch diameter), cut-stump applications of 50% v/v triclopyr plus appropriate carrier applied to freshly cut surfaces can be effective when conducted from mid-summer to early fall to maximize translocation to roots. Hack-and-squirt (50% v/v) and basal bark (25% v/v) applications of triclopyr are also effective for larger stems and sites where foliar applications are less practical, but treatments will likely require a follow-up in subsequent years to ensure control of root suckers and any resprouts. Mechanical removal alone is not recommended due to vigorous regrowth potential, though hand pulling of small seedlings in natural areas can be effective if all root material is removed.

7. Privet spp. (Oleaceae)

Invasion Threat: Widespread invader of roadsides, forests, bottomlands and natural areas from the Blue Ridge to the Middle Atlantic Coastal Plain ecoregions, Chinese privet (*L. sinense*) is most common in NC and is especially problematic in wetland sites. Introduction likely occurred in the 1950s as an ornamental hedge plant, but quickly escaped cultivation. Prolific fruit production and bird dispersal drive rapid spread, with additional local expansion via suckering. Often Privet spp. form dense, impenetrable thickets, which shade out native vegetation along riparian and transportation corridors, while dense growth along roadsides obstruct sight lines and reduce safety for drivers.

Botanical Description: Large evergreen shrub growing upwards of 15 feet in height, with smooth grey bark. Leaves are generally small, with smooth leaf margins, and have hairy midribs. Flowering occurs early to mid-summer (June and July) towards the end of braches, with black colored fruits set by late summer to early fall (August to September). Both *L. sinense* and *L. japonicum* have similar phenology, but differ slightly in leaf size and texture.

Best Management: Effective control of Privet spp. requires a multi-year approach, as eradication of established infestations is very difficult due to suckering and prolific seed production. Small seedlings (< 2 inch diameter) can be hand-pulled or mechanically removed in naturalized areas if all root material is extracted. Larger plants are effectively controlled with foliar applications of glyphosate or triclopyr at 2% v/v plus 0.5% NIS, ideally

applied in late fall or early spring. Where foliar treatments are less practical due to site-dynamics or plant size, cut-stump (50% v/v) or basal bark (25% v/v) applications of triclopyr plus appropriate carrier can be effective. All treatments, mechanical or chemical, will require follow-up monitoring and retreatment to control basal sprouts and root suckers.

8. Callery pear (Rosaceae)

Invasion Threat: Most common along roadsides, fallow pastures, and disturbed areas from the Middle Atlantic Coastal Plain to Piedmont, with less prevalence in the Blue Ridge ecoregion; Callery pear was introduced in the 1900s for fire blight resistance. Later plantings occurred from the ornamental trade, with at least 20 cultivars known across the Southeast ('Bradford pear' most recognized) that readily hybridize, complicating management. Callery pear establishes dense woody stands, which displaces native vegetation along road corridors, natural areas, and forest edges. In addition to the ecological impacts, driver safety concerns occur along roadsides due to the tree's weak branch structure and brittle wood. Larger trees are especially subject to storm-related breakage, which creates debris hazards along roadways and reduces infrastructure wellbeing. Some wild type cultivars produce thorns that can puncture tires of roadway maintenance equipment. Active campaigns throughout the Southeast exist to either prohibit, or discourage, the planting of Callery pear as a landscape planting.

Botanical Description: Medium-sized deciduous tree with grey bark, growing upwards of 50 feet tall and 30 feet wide depending on the cultivar. Pyramidal canopy growth habit, with high angled branching. Flowering is prolific, with white blooms appearing prior to leafing in early spring. Callery pear is known for having a distinct, pungent odor that is generally considered unpleasant. Brown-colored fruits are produced late spring to summer (May and June), but are not always visibly prominent. Some Callery pear cultivars produce thorns up to 4 inches long.

Best Management: Effective control of Callery pear requires an integrated approach, as dense growth, large thorns, and vigorous resprouting complicate removal. Small plants in naturalized areas can be hand-pulled or dug if roots are completely removed; however, this is generally not advisable due to the high likelihood of regrowth. Mature trees may be cut or mulched close to the ground, but this approach is labor-intensive, may require specialized equipment, and incomplete root removal will result in regrowth. For chemical control, foliar applications of glyphosate (5% v/v) or imazapyr (2% v/v) plus 1% v/v basal oil are effective on smaller stems where non-target impacts are less concerning (Vogt et al. 2020). Basal bark treatments with triclopyr at 20% v/v plus an appropriate carrier are effective for saplings and small trees where foliar applications are prohibitive (Vogt et al. 2020). For well-established plants, apply cut-stump treatments with glyphosate (50% v/v) or triclopyr (25% v/v) plus an appropriate carrier applied immediately after cutting. Hack-and-squirt techniques conducted in the fall using 0.5 to 1.0 mL per incision of imazapyr or

aminocyclopyrachlor can also be effective for controlling larger trees; however, this method leaves standing biomass that may pose safety hazards along roadsides and require additional removal measures. Follow-up monitoring and retreatment are necessary to control resprouts.

9. Alligatorweed (Amaranthaceae)

Invasion Threat: Exhibits both aquatic and terrestrial growth forms and occurs most commonly in the Southeastern and Middle Atlantic Coastal Plain ecoregions, with additional invasions documented in the Piedmont, alligatorweed was first introduced to the US in the early 20th century. The aquatic form is a serious weed in roadside ditches, ponds, and other wetted natural areas. Plant spread is almost exclusively through vegetative fragmentation, as the plant readily roots at the stem node, allowing broken pieces to establish new infestations. In aquatic systems, alligatorweed forms dense, interwoven mats along shorelines and across water surfaces, reducing water flow and displacing native flora. Infestations along roadside drainage corridors and wetland RoW can produce persistent management challenges, and increase the potential of roadway flooding and erosion.

Botanical Description: Vine-like plant with mats capable of reaching 3-30 feet in length. In the aquatic form, stems are reddish-purple in color, and are hollow, providing buoyancy across large expanses of water, whereas in the terrestrial form, stems are minimally hollow and woody in structure. Leaves are opposite, elliptic in shape with smooth margins, and are typically 2 to 4 inches long. Flowering occurs from spring to fall, and appear as solitary, small, white, and clover-like flower heads.

Best Management: Control of alligatorweed requires a long-term, integrated approach, with early detection and prevention representing the most cost-effective strategies. Systemic herbicides are the most economical and effective control tools for eradication. Repeated foliar applications in spring and fall (when water temperatures >60 F) of glyphosate (2% v/v), triclopyr (1.5% v/v), or florpyrauxifen-benzyl (1 to 2 PDU/A) plus an appropriate aquatic adjuvant (0.5% v/v) provide effective control of initial infestations; annual treatments are typically sufficient once populations are reduced. Foliar applications of imazapyr at 0.5% v/v plus 1% methylated seed oil (MSO) can also achieve near-eradication over a 2-year period in sites where residual herbicide activity is acceptable. Biological control insects, such as the alligatorweed flee beetle (*Agasicles hygrophila*), have been released successfully in NC and may provide integrated plant suppression, but their use is not recommended as a primary management method for eradication. Physical and mechanical removal often fails due to plant fragmentation and subsequent spread potential, and should generally be avoided.

10. Multiflora rose (Rosaceae)

Invasion Threat: Widespread, perennial invader of roadsides, natural areas, pastures, upland forests, and bogs from the Blue Ridge to the Middle Atlantic Coastal Plain ecoregions, multiflora rose was initially introduced to the US in the 1860s as an ornamental rootstock and later as a 'living fence'. A single shrub can produce hundreds of thousands of seeds annually, which can remain viable for >10 years, and are widely dispersed by birds. The woody species tolerates a broad range of environmental conditions, enabling rapid expansion across disturbed or fallowed landscapes. Multiflora rose forms dense, impenetrable thickets that suppress native understory vegetation, and disturbed roadway corridors provide ideal conditions for sustained spread.

Botanical Description: Medium-sized, deciduous, thorny shrub reaching up to 10 feet in height, with distinct arching stems. Leaves are compound, consisting of alternately arranged leaflets that are broadly oval with serrated margins. A distinctive feathery, stipule is present at the base of each leaf. Flowers form in clusters, which are white to pinkish-white in color, and bloom in late spring (May to June), with small red fruits (rose hips) developing during the summer months which, often persist through winter.

Best Management: Effective control of multiflora rose requires a multi-year, integrated approach, as mechanical methods alone suppress growth but rarely achieve complete control. Cutting or mowing at least once during the growing season can reduce plant vigor as part of an integrated approach where site conditions and safety allow. Foliar applications from late spring through mid-fall (June to September) of glyphosate or triclopyr at 2% v/v plus 0.5% v/v NIS when applied to thoroughly we the foliage, are effective. Metsulfuron (1 oz per 100 gal water plus 0.5% v/v NIS) and fosamine (2% v/v plus 0.25% NIS) are also reliable foliar control options during this. Where foliar spraying is not permissible due to sensitive or natural areas, cut-stump treatments of glyphosate (undiluted) or triclopyr (25% v/v) plus an appropriate carrier are effective at any time when soils are not frozen. Follow-up monitoring and retreatment are necessary to control resprouting in subsequent seasons.

Rank III: Considerable Threat—*invasive species which display varying degrees of environmental and management concern, but are not perceived as threatening as Rank II.*

11. Autumn olive **(Elaeagnaceae)**

Invasion Threat: Fast-growing, ornamental shrub commonly found in open forests, along field and pasture edges, and in naturalized areas of the Piedmont and Blue Ridge ecoregions, autumn olive was introduced to the US in the early 19th century. Mature plants produce tens of thousands of seeds readily dispersed by wildlife. The species resprouts vigorous following cutting or burning activities, challenging management along mowed roadsides and forested sites. Autumn olive tolerates drought and a wide range of soil conditions, and rapidly outcompetes native vegetation by forming dense, shading thickets that suppress natural plant succession. While less competitive in closed-canopy forests, the shrub quickly invades disturbed sites.

Botanical Description: Medium-sized, deciduous shrub reaching up to 20 feet in height, with slender branches that can form thorn-like shoots. Leaves are elliptic, 2 to 4 inches long, having as distinct silver-white underside surface. White, fragrant, flower clusters appear in spring, with small red to pink fruits produced in the fall.

Best Management: Effective control of autumn olive requires a multi-year approach. Small seedlings and sprouts in naturalized areas can be hand-pulled or dug when soils are moist to ensure complete root removal; partial root removal often results in regrowth. For this reason, mowing and controlled burning methods should be avoided. Foliar applications from spring through early fall (April to October) of triclopyr (2% v/v) or 2,4-D (1% v/v) plus 0.5% v/v NIS provides effective control, with metsulfuron (1 oz per 100 gal water plus 0.5% v/v NIS) offering another reliable option. For larger shrubs or where foliar applications are impractical, basal bark treatments with triclopyr (25% v/v) plus mineral oil or cut-stump treatments using triclopyr (50% v/v) applied immediately after cutting in late summer to fall (July–September) can be effective. Follow-up monitoring and retreatment are necessary to control resprouting.

12. Cogongrass (Poaceae)

Invasion Threat: Perennial grass, typically found in pinelands, grassy roadsides, and pastures in the Piedmont and ecoregions to the east, cogongrass is an extremely aggressive, federally listed noxious weed. Initially introduced to the US in the early 1900s, the species was widely planted for erosion control and forage, which accelerated spread throughout the Southeast. The plant rapidly invades pastures, fallow fields, forests, and highway and utility RoW, including ecologically and culturally sensitive longleaf and slash pine forests. Cogongrass spreads aggressively via scaly rhizomes and seed (>3,000 per plant, per season), and forms dense infestations that are difficult to manage. The plants biomass is highly flammable which, significantly increases wildfire risk around roadway infrastructure. Cogongrass readily regenerates after fire, allowing for rapid colonization in disturbed sites and RoW provide an ideal dispersal corridor for seed movement via wind, vehicles, equipment, and contaminated soil.

Botanical Description: Dense, colony-forming grass growing 2 to 4 feet tall, with erect leaf blades that are finely serrated, and yellow-green in color. A white, off-center midrib is a distinguishing characteristic. Sharply pointed rhizomes form dense, interwoven mats and can penetrate the soil 12 to 48 inches deep. Blooming occurs early to late spring (March to June), with showy white to silver, cylindrical flower spikes range 2 to 8 inches and contain fluffy dandelion-like seeds.

Best Management: Effective control of cogongrass requires a multi-year, integrated approach, as no single treatment provides eradication. Systemic herbicides are the most effective option for long-term control. Foliar applications of glyphosate at 1.5% v/v can suppress infestations, but repeated annual treatments are required. Imazapyr at 48 oz/ac

can also provide excellent control; however, site conditions may restrict use where infestations occur near desirable vegetation due to residual soil activity. Mechanical control through frequent tillage can be an effective strategy, as cogongrass does not persist under intensive cultivation (Byrd and Maddox 2024). Physical methods such as mowing or burning only remove aboveground biomass and often stimulate regrowth from rhizomes and seedling establishment, and should only be used as pretreatments to improve herbicide applications, not as stand-alone control methods. Follow-up monitoring and retreatment is required to prevent additional infestations.

13. Oriental bittersweet (Celastraceae)

Invasion Threat: Most commonly found in the Blue Ridge and Piedmont ecoregions, with less prevalence in the eastern regions of NC, Oriental bittersweet is a state-listed Class C noxious weed occurring along roadsides, forested sites, disturbed areas, and riparian zones. Introduced to the US in the mid-19th century for ornamental purposes due to its showy yellow and red-orange fruits, this perennial vine became popular for floral arrangements and fall wreaths, which continues to facilitate spread. Although cultivation is regulated in 18 counties in western NC, prolific seed production and bird-mediated dispersal enable continued range expansion, with seed germination rates reported as high as 95%. The species can tolerate low-light conditions, allowing persistence under closed forest canopies. Vegetative spread via rhizomes and root suckers further enhance invasion capacity, leading to dense infestations that outcompete native vegetation. Oriental bittersweet smothers other plants and can girdle trees, and the added canopy weight increases the likelihood of tree breakage or uprooting, creating possible safety concerns along transportation corridors.

Botanical Description: Woody, deciduous vine growing up to 60 feet in height when scaling trees and structures, or may remain low-lying in dense patches. Leaves are round with finely serrated margins and alternately arranged. Plants are dioecious, with female plants forming small, whitish-green flowers at the leaf axils in late spring (May to June), and fruits forming early fall as green spherical capsules, which reveal red-orange colors during early winter.

Best Management: Effective control of Oriental bittersweet requires a persistent multi-year, integrated approach, as populations released in forested and roadside settings rapidly and continually expand. Newly established patches can be hand-pulled or dug when soils are moist if complete root removal achievable to prevent resprouting; all plant material should be bagged and disposed of properly. Cutting vines at ground level can help release host vegetation, but cutting alone only suppresses growth. Pulling cut vines from the host trees is not advised due to safety risks and host tree injury. For low-lying, dense infestations, cut vines to the ground early in the growing season, allow regrowth, and apply a foliar treatment of triclopyr (2% v/v) approximately one month later. Where vines have climbed into a tree canopy, cut stems near the ground and apply triclopyr (50% v/v plus basal oil) or

glyphosate (50% v/v solution) immediately to the cut surface. Follow-up monitoring and retreatment in subsequent seasons is necessary to control new seedlings and root suckers.

14. Wisteria spp. (Fabaceae)

Invasion Threat: Statewide invasions likely occur, but exotic wisteria spp. primarily invade disturbed woodlands and roadside corridors, within and east, of the Piedmont ecoregion. While *W. sinensis* remains more prevalent in NC than *W. floribunda*, both species pose similar risks to natural and managed habitats. Introduced to the US in the early 19th century as ornamental vines for arbors and garden structures, these species escaped cultivation and are now well distributed throughout much of the southeast. Wisteria spp. spread primarily through vegetative runners, with more limited succession from seed dispersal. Most infestations originate from old home sites and landscape plantings, which should be treated as source populations when located near roadways. Once established, these woody vines aggressively shade and girdle surrounding vegetation, suppressing native tree and understory growth. Although vine growth is most vigorous in full sun, plants can adapt and spread in partial shade, making forest edges and roadside corridors especially vulnerable to infestation.

Botanical Description: Woody, deciduous vine growing up to 70 feet long and 10 inches in stem diameter, with *W. sinensis* climbs counter-clockwise and *W. floribunda* climbs clockwise around host plants. Leaves are alternate and compound, with leaflets tapering at the tip and having wavy margins. Fragrant, violet to blue-violet, showy flowers appear in spring (April to May). Both invasive wisteria spp. are distinguishable from the native wisteria (*W. frutescens*), which flowers only after fully leafing out. Resulting fruits are green to brown seedpods, which appear mid-summer and persist on the vine.

Best Management: Effective control of wisteria spp. requires a multi-year, integrated approach, as extensive runners and root systems make established infestations difficult to eradicate. Established infestations typically require combined cut-stump and foliar herbicide treatments. Where vines climb into tree canopies, cut stems near ground level and perform a window cut, and immediately treat cut surfaces with clopyralid (50%), glyphosate (undiluted), or triclopyr (50% v/v) plus appropriate basal oil. Ground-cover infestations can be treated with foliar applications of clopyralid, glyphosate, or triclopyr (2% v/v) plus 0.5% v/v NIS to thoroughly wet the foliage. Treatments are most effective from spring through fall, and follow-by retreatments will be necessary to control any resprouts.

15. Mimosa (Fabaceae)

Invasion Threat: Widespread and persistent woody invader of roadsides, woodlands, riparian corridors, and disturbed natural areas from the Blue Ridge to the Middle Atlantic Coastal Plain ecoregions, mimosa was introduced to the US in the mid-18th century as an ornamental. Well known for its showy pink flowers, this tree forms dense colonies through

root suckering, with prolific seed production and long-term viability presenting the greatest risk of landscape-scale spread. The species prefers full sun and commonly invades roadside corridors, where water- and equipment-mediated dispersal accelerates invasion. Although tolerant of a wide range of soils and moisture regimes, mimosa is less common at higher elevations due to a more limited cold tolerance.

Botanical Description: Medium-sized, deciduous tree with an open, spreading canopy, that reaches 10 to 50 feet tall. Trunks are often multi-stemmed, with thin light-colored bark. Leaves appear delicate and fern-like (bi-pinnately compound). Flowering occurs late spring to early summer (May to July), with fragrant, pink flower groups appearing at the ends of branches. Fruits are flat, long seedpods, which mature in late summer to fall (August to September) and often persist on trees into winter.

Best Management: Effective control of mimosa requires an integrated approach, and discouraging planting, or encouraging the removal of existing plants, by property owners adjacent to roadway corridors is strongly recommended to limit further spread. Small seedlings can be hand-pulled in naturalized areas, but vigorous regrowth often limits the effectiveness of physical removal techniques alone. Dense thickets can be treated with foliar applications of glyphosate or triclopyr at 2% v/v plus 0.5% v/v NIS during active growth. Cut-stump applications of glyphosate or triclopyr at 50% v/v can be effective against larger trees. Where cutting is impractical, hack-and-squirt or basal bark applications of triclopyr (25% v/v plus basal oil) can be effective. Follow-up monitoring and retreatment are necessary to target resprouts and newly emerged seedlings.

1.5 Additional Resources to Identify and Manage High-Threat Invasive Species

Recognizing that invasion risks and best management practices are typically site-specific for roadway corridors and likely evolve with time, the following resources provide vetted guidance to support identification of emerging infestations and inform adaptive management decisions. These resources, not directly referenced previously in this review, are relevant to NCDOT, NC State Parks, and public land managers across the Southeast, with newly identified invasive species threats highlighted in Rawlins et al. (2018).

- EDDMapS (https://www.eddmaps.org/)
- Invasive Plants Atlas of the United States (https://www.invasiveplantatlas.org/)
- North Carolina State University Extension Gardener: Toolbox (https://plants.ces.ncsu.edu/)
- North Carolina Wildlife Federation (https://ncwf.org/)
- North Carolina Agricultural Chemicals Manual (https://content.ces.ncsu.edu/north-carolina-agricultural-chemicals-manual)
- United States Department of the Interior: Invasive Species Strategic Plan (https://www.doi.gov/sites/doi.gov/files/doi-invasive-species-strategic-plan-2021-2025-508.pdf)

Task 2: Impact Assessment

2.1 Overview

Roadside vegetation management is complicated by the ecological and economic impacts that invasive weeds pose to transportation corridors. The NCDOT maintains the entirety of state-owned roadways, a responsibility that requires significant ecological understanding and fiscal investment. The NCDOT currently manages more than 80,000 miles of roadway, representing over 300,000 acres when compared spatially to other land management systems. In addition, the agency manages more than 11,000 acres of wetland habitat, over 13 miles of stream restoration, and approximately 3,500 acres within the roadside wildflower program (pers. comm., K. Clemmer).

Across these managed lands and waters, roadside managers regularly encounter invasive vegetation that degrades the safety, function, and ecological value of the transportation corridor. Management decisions must account for budget constraints and the degree of invasive weed impact, which varies depending on roadway usage, location, and the species posing the greatest threat. Control efforts are further complicated by invasive weed source populations located on adjacent properties that NCDOT cannot directly manage without appropriate funding, legal authorization, or cooperative agreements.

Considering these factors, invasive weed management requires diligence and long-term commitment to successfully control invasive plants along transportation corridors. This section provides insight into the impacts of invasive weeds on highway systems, summarizes the costs associated with invasive plant control, and outlines considerations for long-term maintenance strategies that promote soil stabilization and establish competitive vegetation to prevent reinvasion.

2.2 Associated impacts on roadway maintenance and infrastructure integrity.

Invasive weeds can substantially affect the type and frequency of maintenance required by state DOT(s) to sustain roadway infrastructure. By damaging pavement, contributing to embankment erosion, and reducing drainage capacity, invasive vegetation can directly compromise roadway integrity (Moore 2021). For example, Japanese knotweed can establish within cracked concrete or asphalt via its extensive rhizome system and further reduce structural stability. Similarly, Johnsongrass established along roadsides can degrade pavement margins over time, or accelerate existing deterioration, with its deep spreading root structures. Invasive plants, particularly aggressive vines like kudzu and wisteria, may also affect the integrity of adjacent infrastructure, including bridges, culverts, and retaining walls. As infestations expand, the frequency and cost of maintenance activities increases, both for controlling invasive vegetation and repairing damaged pavement or other infrastructure components necessary to maintain roadway safety and utility.

Secondary impacts include invasive species that increase wildfire risk by creating high fuel loads that burn hotter and longer than native vegetation species. For example, cogongrass can promote more frequent and intense roadside fires (Loewenstein and Miller 2007), which may damage nearby infrastructure such as guardrails, signage, drainage features, and associated utility structures within the RoW. Other invasive plants can impair stormwater management and increase water erosion potential. For example, dense stands of phragmites and alligatorweed can obstruct roadside ditches with thick rhizome mats and dense aboveground biomass, which restricts water flow, reduces drainage capacity, and can cause water to flood the roadway following a storm event. When critical water abatement systems are compromised due to invasive weeds, prolonged stormwater buildup can also wash out culverts and bridges (ISAC 2016).

2.3 Effects on highway visibility and safety.

Invasive weeds additionally create significant safety concerns along transportation corridors by obstructing driver visibility, weakening roadside trees, increasing roadside fire risk, and reducing the effectiveness of roadside safety zones. Maintaining clear sightlines and structurally stable conditions is critical to the mission of the NCDOT in ensuring safe travel corridors. When high-threat invasive plants, whether brush, vine, and/or tall grass species establish along the roadside, driver sightlines can be severely hindered. For example, dense infestations of kudzu can rapidly cover roadside vegetation and infrastructure, limiting a motorist's ability to detect hazards, oncoming traffic, or changes in roadway conditions. Similarly, excessively tall grass such as Johnsongrass, miscanthus, and phragmites, as well as large brush species like tree of heaven or multiflora rose, can obstruct visibility and conceal critical roadway signage, including speed limits, hazard warnings, and yield signs.

In additional to visibility concerns, invasive vines such as kudzu and wisteria can girdle mature roadside trees or add substantial canopy weight, increasing the likelihood of tree fall during storm events. These vines may also obscure dead or weakened vegetation, preventing early detection by maintenance crews, which increases the risk of trees striking vehicles. Invasive vegetation along road shoulders can further reduce roadway safety by limiting a driver's ability to safely pull off the roadway during emergencies and increase collision hazards where errant vehicles leave the roadway (Nemec et al. 2025). Encroachment of invasive weeds into roadside safety zones is particularly concerning along rural roads in the Mountain and Coastal Plain ecoregions, where available recovery space is already more limited. Furthermore, invasive vegetation can contribute to slope instability, increasing the likelihood of slope failure or landslides in susceptible areas (USGS 2026).

2.4 Interactions with, and Considerations of, other Invasive Species.

Other considerations for managing high-threat invasive plant species include their role as host plants for additional invasive species, particularly insects. Interactions between invasive plants and invasive insects can amplify ecological and economic impacts and further complicate

roadside management. For example, spotted lanternfly (*Lycorma delicatula*) closely associates with the roadside invasive, tree of heaven. Controlling tree of heaven along roadway corridors can therefore provide primary benefits to vegetation management while also reducing habitat that supports spotted lanternfly populations, which threaten high-value crops such as grapevines, hops, and various fruit trees.

Similarly, emerald ash borer (*Agrilus planipennis*) feeds on and completes its life cycle in native ash trees (*Fraxinus* spp.), which occur widely in NC and neighboring southeastern states. Once infested, ash trees typically die within two to five years. The emerald ash borer thus presents concern for NCDOT because ash trees are common in wetted roadside areas within the Piedmont and Mountain ecoregions. As tree health declines, standing dead timber can pose safety hazards to roadway users. In the context of roadside weed management, recent research has documented a positive association between emerald ash borer infestations and increased invasive plant establishment in forested areas (Gougherty et al. 2023). Where roadside areas are affected by emerald ash borer, NCDOT may consider removing infested ash trees in accordance with guidance from the NCFS to address safety risks and prepare for potential invasive plant establishment.

2.5 Maintenance and control costs attributable to invasive species.

Once invasive weeds reach a management threshold, control costs must be carefully considered. Thresholds may vary depending on species and regulatory status, ranging from a few plants per acre for regulated species to large, established infestations for others. In NC, invasive weed management along the roadsides represents a significant component of NCDOT vegetation management expenditures, with additional resources and partnerships required to address new and expanding infestations statewide. Overall costs are highly dependent on site complexity, terrain, accessibility, and the extent and density of the infestation.

For nearly all of the 15 high-threat invasive weeds identified in Table 2, mechanical methods alone are insufficient to achieve long-term control or eradication. Effective management typically requires an integrated approach with repeated treatments over time, particularly for persistent brush and vine species such as kudzu and tree of heaven. Mechanical methods are often deployed prior to herbicide application to improve site access and reduce herbicide demand, enabling more efficient and effective long-term control. However, herbicide applications remain the most cost-effective, selective, and reliable means of controlling invasive plant species in roadside environments. Additionally, herbicide treatments generally do not disturb the application site or target plants, reducing the risk of fragmentation and subsequent spread of invasive species.

Estimated costs associated with roadside invasive plant management are provided in Table 3. These values should be considered minimum estimates, as site-specific conditions may require substantially greater investment, including multiple contractors and repeated applications, depending on the target species, scale, and complexity of the infestation.

Table 3. NC Department of Transportation Engineer estimated cost of roadside invasive plant removal.

Invasive Plant Removal	Estimated Unit Cost (hr)	Equipment Quantity	Contractor Quantity	Minimum Estimated Cost[1]
Contractor	$ 60.00	-	-	$ 60.00
Transport				
Truck	$ 80.00	1	2	$ 200.00
Trailer	$ 30.00	1	-	$ 30.00
Mechanical Machine[2]				
Tractor w/brush cutter	$ 130.00	1	2	$ 250.00
Cut Mechanical	$ 60.00	1	2	$ 180.00
Tracked Skider	$ 250.00	1	2	$ 370.00
Slope Mower	$ 82.00	1	2	$ 202.00
Mechanical Contractor				
Pole Cut	$ 6.00	2	2	$ 132.00
String/Blade Trimmer	$ 6.00	2	2	$ 132.00
Wood Chipper	$ 200.00	1	2	$ 320.00
Herbicide[3]				
Backpack (4 gal)	$ 6.00	4	4	$ 264.00
UTV w/Skid Sprayer (75 gal)	$ 85.00	1	2	$ 205.00
Truck w/Skid Sprayer (200 gal)	$ 285.00	1	2	$ 405.00
Tractor w/Skid Sprayer (200 gal)	$ 150.00	1	2	$ 270.00

[1]Quantities and costs are based on minimum per hour requirements per site. Actual quantities could be higher based on additional site needs or vegetation control strategies.
[2]For brush species, mechanical methods typically occur prior to herbicide activities to allow for lower application volumes and site access.
[3]Herbicide applications for invasive plant control generally require successive treatments to achieve desired control. Additional cost considerations not estimated include site-specific quantities of herbicide and appropriate carrier.

2.6 Maintenance costs of soil stabilization, invasives suppression, and competitive species.

The establishment of desirable grasses and forbs is a critical component of limiting the spread and reinvasion of invasive weeds along roadside corridors. While invasive plant control is necessary for both safety and environmental considerations, treatment alone does not eliminate the need for continued management. Removal of invasive vegetation can create open niches that facilitate reinvasion or increase the risk of erosion if vegetation is not promptly reestablished.

Since NCDOT RoW's often border public, private, and commercial lands, maintaining stable and vegetated roadsides is also important for reducing potential liability and ensuring compliance with environmental regulations. Following mechanical or chemical treatment, soil stabilization measures are thus necessary to support invasive plant suppression and maintain compliance

with regulatory requirements (e.g., NPDES). Establishing competitive vegetation through seeding, sodding, or transplanting helps stabilize soils and limit reinvasion by occupying available niches. Depending on the roadside environment, ground cover establishment with warm and/or cool season grasses or wildflowers provides an attractive, safe, wildlife friendly, and soil stabilizing option. Additionally, stable vegetative cover can reduce the influence of hydrologic disturbances that often promote invasive plant reestablishment and spread. Specific vegetation establishment and seed recommendations are available in the '2017 NCDOT Vegetation Management Manual' (NCDOT 2017).

Estimated costs associated with roadside erosion mitigation and invasive plant suppression are provided in Table 4. These estimates should be considered minimum values, as site-specific conditions may require substantially greater resources, including multiple contractors and repeated mitigation activity, depending on the scale and complexity of the site. Investing in soil stabilization and invasive weed suppression through seeding and mulching strategies can reduce long-term expenditures associated with repeated invasive plant treatments, erosion control, and potential regulatory non-compliance.

Table 4. NC Department of Transportation Engineer estimated cost of roadside erosion mitigation and invasive plant suppression following control activities.

Erosion Mitigation and Invasive Plant Suppression	Estimated Unit Cost (hr)	Equipment Quantity	Contractor Quantity	Minimum Estimated Cost[1,2]
Contractor	$ 60.00	-	-	$ 60.00
Transport				
Truck	$ 80.00	1	2	$ 200.00
Trailer	$ 30.00	1	-	$ 30.00
Machinery				
Hydro-seeder (1,500 gal)	$ 360.00	1	2	$ 480.00
Truck w/spreader	$ 200.00	1	2	$ 320.00
Tractor w/spreader	$ 145.00	1	2	$ 265.00
Straw Blower	$ 215.00	1	2	$ 335.00

[1]Quantities and costs are based on minimum per hour requirements per site. Actual quantities could be higher based on additional site needs and mitigation strategies.
[2]Additional cost considerations not estimated include site-specific quantities of seed mix, lime, fertilizer, and mulch.

In summary, invasive plant control and soil stabilization represent interconnected components of roadside management costs. Effective, long-term management requires an integrated approach that will likely incorporate mechanical and chemical control with revegetation strategies to control existing infestations, suppress reinvasion potential, and maintain site stability with the goal of minimizing repeated management costs over time.

Task 3: Management Recommendations

3.1 Invasive weed prevention, early detection, and control.

The most effective strategy for managing invasive species is preventing their introduction and establishment. As with many threats to human, environmental, or fiscal condition, the phrase "*An ounce of prevention is worth a pound of cure*", fittingly summarizes the significance of preventing invasive species introductions. In practical terms, preventing invasive weeds is typically easier, more cost-effective, and more successful than attempting to contain or eradicate a species following introduction. Science-based guidance for preventing roadside infestations and applying eradication principles in transportation corridors are well described in "PREVENTION OF ROADSIDE INFESTATIONS" by Venner (2006).

When high-threat weed introductions do occur, however, deploying *Early Detection and Rapid Response* (EDRR) principles is critical. The EDRR framework minimizes impacts in newly invaded areas by enabling prompt identification and coordinated management before infestations expand. Successful response efforts often rely on collaboration and financial support from multiple property stakeholders and management agencies, which is why national initiatives like the 'National Early Detection and Rapid Response Framework' (https://geonarrative.usgs.gov/nationaledrrframework/) are an important resource for consideration. For example, giant hogweed (*Heracleum mantegazzianum*), a federally listed noxious weed capable of causing severe skin blistering upon contact, can also contribute to increased soil erosion along transportation corridors. Due to its large stature (up to 15 feet tall), the aggressive weed can quickly dominate slopped areas and stream banks, reducing suitable habitat for native flora and fauna. Following its initial detection in 2010, rapid response efforts successfully quarantined giant hogweed to Watauga County, NC where targeted herbicide treatments continue today (NCDA&CSa n.d.). This example highlights the importance of early detection and coordinated response efforts. Typically, early detection efforts are most effective when focused on areas most susceptible to invasion, particularly locations experiencing frequent disturbance (e.g., construction sites; debris piles following storm events). Ultimately, successful EDRR depends on rapid identification of high-threat introductions, accurate assessment of the invaded area, and a coordinated management response aimed at containment and eradication. Control methods used during EDRR should also minimize reinvasion risk, which is why mechanical techniques alone are often not well suited for rapid response management.

Once established, eradication of invasive weeds becomes rapidly more challenging and expensive. For this reason, early detection is critical for the NCDOT when managing high threat invasive weeds along transportation corridors. When considering classic invasion curve principles (Fig 2.), early detection at the time of species arrival largely determines the feasibility of successful eradication or containment measures. That is, as time since introduction increases, the effort and cost of management activities required exponentially increase, while

the likelihood of successful eradication and containment rapidly declines. The invasion curve again illustrates that prevention is the most efficient and effective approach to combat invasive species, minimizing the need for costly control measures and reducing financial strain on already limited management budgets.

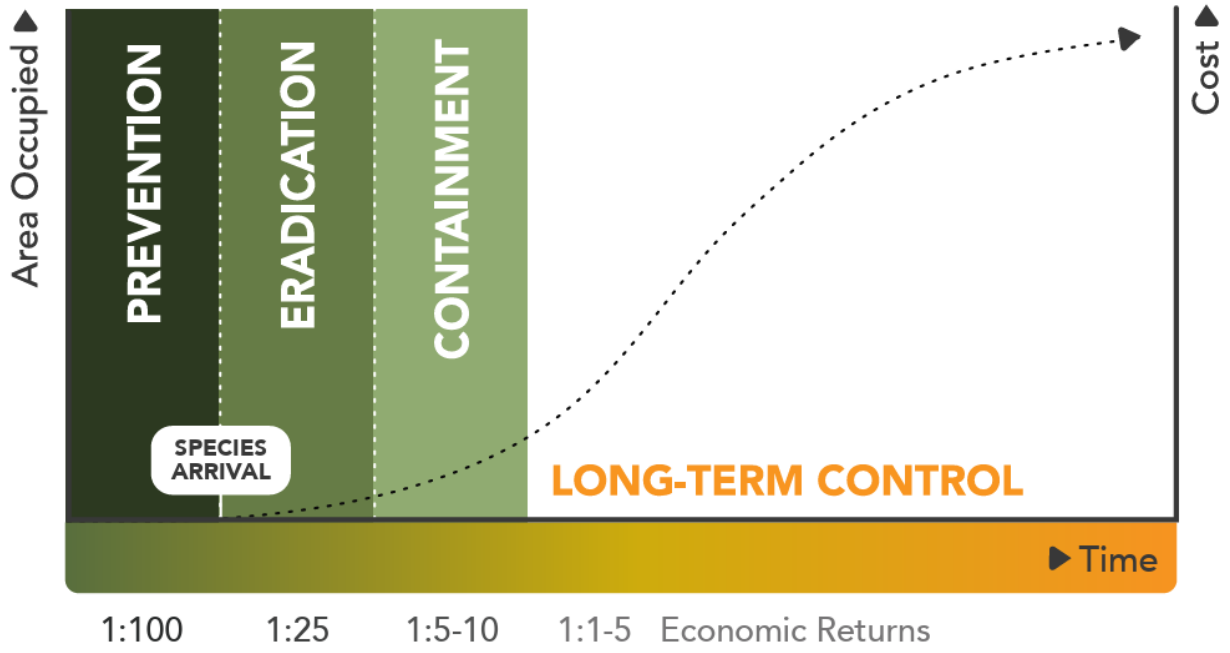

Figure 2. Invasion curve schematic showing the stages of management from prevention to long-term control efforts. Derived from: Invasive Species Centre. (2020). *Invasive species and stages of management: The invasion curve.* https://www.invasivespeciescentre.ca/wp-content/uploads/2020/04/Invasion-Curve-FINAL-WEB.pdf

When discussing invasive species management, it is also important to recognize that the term *eradication* carries significant expectations. Eradication implies the complete removal of an invasive species from a defined area, which can be beneficial for long-term management strategies but is often difficult to achieve. The feasibility of eradication is highly dependent on the size of the infestation and the extent of the weeds distribution. For example, kudzu is widespread throughout NC, making statewide eradication unrealistic. In contrast, Oriental bittersweet, which is primarily contained to a regulated 18-county region in western NC, may still present opportunities for eradication in neighboring counties where it has not yet become as well established. Similarly, itchgrass, a federally listed noxious weed present in one southeastern county of the state (NCDA&CSb n.d.), remains a candidate for eradication assuming sufficient resources and coordinated management efforts are directed toward removal. At present, itchgrass remains in the containment phase within NC.

For these reasons, the term ‘eradication’ should be used cautiously and should not be interchangeably used with ‘control’. Successful eradication requires eliminating all individuals of a species within a defined area, and as mentioned prior, the likelihood of achieving this goal declines rapidly as infestations expand across the landscape (e.g., <1 acre vs. 10 acres vs. 1,000

acres). Transportation managers should therefore establish realistic goals and pursue eradication when infestations are incipient and localized to prevent further spread using EDRR concepts. This is critical since as an invasive plant population expands, the opportunity for eradication eventually disappears and management efforts shift toward long-term maintenance control levels.

Following the containment phase, long-term weed control principles must be deployed. These concepts will be highly dependent upon the site, level of infestation, and the relative issues caused to NCDOT and/or adjacent property owners. Once a weed is beyond the containment phase and has become well established, managers must determine best control practices, site restoration techniques, or consider adapting to the weed invasion. Ultimately, the roadside environmental manager(s) determine what BMP actions might be appropriate or necessary during the control phase based upon experience, available documentation (e.g., Venner 2006; State Extension Publications), and invasion site characteristics relative to the ecoregion. It is possible that some weeds, though present, do not pose significant harm to the transportation corridor due to limited abundance or maturity, and simply waiting until an action threshold is met is the most appropriate strategy (NCDOT-VMM 2017). Action thresholds can be determined through roadside monitoring and evaluation of infestation levels, and determining what is an unacceptable weed presence on the landscape based upon plant- and site-specific dynamics.

Specific science-based recommendations for invasive weed prevention, early detection, and control include:

- Remaining informed and aware of emerging threats from neighboring states and regions through relevant literature, workshops, conferences, and collaborations with state, federal, academic, and nonprofit partners.
- Implement maintenance practices that promote complete groundcover to provide competition and reduce opportunities for invasive plant establishment.
- Conduct regular highway inventory surveys of known high-threat infestations and monitor highly disturbed sites with increased frequency.
- Coordinate with state agencies and local municipalities to limit the sale and roadway transport of species listed under NCDA Class C noxious weeds and support identification of additional species of concern.
- Encourage field crews to remain vigilant during maintenance activities and to report the presence of high-threat species promptly at each site observed.
- Properly clean and sanitize maintenance and control equipment when moving from invaded sites to uninvaded sites to prevent further plant spread.
- Consult subject-matter experts when novel infestations arise or when species show reduced response to previously effective control methods.
- When feasible, use selective management techniques to minimize impacts to desirable vegetation that supports soil stability and suppresses invasive weeds.

3.2 Monitoring protocols and data management systems for continued assessment.

3.2.1 Monitoring Protocols

Routine monitoring is essential to prevent high-threat invasive weed establishment and minimize the risk of spread along transportation corridors. Monitoring efforts should be timed according to species phenology, as many invasive weeds are perennial or function perennially, and will occur year-after-year in the absence of effective management efforts. As a result, consistent monitoring is necessary to detect new infestations early and evaluate the persistence of existing populations. Ultimately, monitoring data support an informed adaptive management strategy.

The NCDOT already maintains an established monitoring network that enables identification and reporting of problematic species at the regional level. This system allows observations to be communicated through the Roadside Environment Unit, which is then disseminated statewide via "alert" notices and/or electronic messaging that describe the emerging issue(s) and recommend management responses. Continued use of this EDRR framework is encouraged; however, advancements and integration of modern data collection, communication, and collaboration tools would further strengthen this current system.

A variety of standardized monitoring protocols and data management systems are available to support roadside vegetation management depending on specific program needs. One of the most comprehensive and relevant resources is *Roadside Revegetation: An Integrated Approach to Establishing Native Plants and Pollinator Habitat* (Armstrong et al. 2017), developed and recently updated by the USDOT. This guide provides a practical system for initiating, planning, implementing, and monitoring roadside vegetation programs, with strong alignment to the applications and current policies directed through the NC SENATE BILL 391: USE AND STUDY OF NATIVE PLANTS. Key takeaways for developing an effective monitoring plan include:

- Defining the scope and purpose of monitoring activities
- Determining appropriate monitoring intensity and frequency
- Identifying the level of expertise required to meet objectives
- Delineating site-specific characteristics and management priorities
- Accounting for logistical constraints and adapting monitoring approaches accordingly

Additional guidance on sampling design, soil and vegetation assessment, and data analysis can referenced within the document.

3.2.2 Emerging Techniques, Technologies, and Management Systems

As eluded to previously, recent advances in data collection, geospatial technology, and remote sensing provide new opportunities to enhance roadside monitoring programs. When

incorporated alongside existing monitoring efforts, these tools and management systems have the capacity to enhance detection accuracy, increase operational efficiency, and support more informed data-driven decision-making.

- Geographic information systems (GIS) inventory and prioritization tools have widely supported vegetation management decisions for decades. For instance, geospatial approaches have been shown to prioritize control efforts for species like cogongrass, improving treatment efficiency and outcomes (Yager and Smith 2009).
- Mobile-based GIS platforms (e.g., ArcGIS Field Maps, Survey123, QField) now enable real-time data collection, mapping, and sharing of invasive species occurrences while in-field. These tools are particularly valuable for EDRR programs, active- and long-term vegetation tracking by NCDOT managers and contractors.
- Regional and public reporting systems, such as EDDMapS (https://www.eddmaps.org/), allow managers to monitor invasive species spread beyond transportation corridors and anticipate encroachment from adjacent lands.
- Remote sensing technologies, like drone-based imagery and high-resolution satellite data, are increasingly effective for detecting and mapping invasive vegetation. For example, drone platforms provide rapid site assessments and enable managers to evaluate the extent and prioritize treatment areas on demand. Similarly, recent work on Callery pear demonstrates how satellite imagery and machine learning can identify invasive tree distributions across urban landscapes (Krohn et al. 2025). Similar approaches could be deployed to monitor other invasive woody and vine species common in RoW corridors like tree of heaven and wisteria.
- Vehicle-mounted sensor systems, such as CamAlien (https://theailab.dk/camalien), are emerging as automated tools for detecting and mapping invasive roadside vegetation during routine travel. Dyrmann et al. (2024) found these sensors provide real-time insight into invasive plant presence and spread while reducing dedicated survey efforts.
- Statewide or regional inventory efforts can further enhance understanding of invasive plant distribution and spread pathways. Similar inventory-based assessments in NC State Parks (e.g., Taggart et al. 2015) highlight the value of coordinated mapping efforts for informing potential management needs at broader scales.
- Treatment tracking systems designed to digitize spraying or mowing logs, can provide crucial feedback on management effectiveness and expenditures. These systems (e.g., SprayLogger™; OPTIX Technologies) document where and when treatments occur, establish baselines for comparison and supports adaptive management by identifying areas likely requiring future monitoring and management activity.

In summary, integrating current monitoring efforts with emerging technologies offers a powerful approach to invasive plant management along roadsides. Combining early detection practices, standardized monitoring protocols (e.g., Armstrong et al. 2017), and geospatial tools

and technologies, should enhance the efficiency, responsiveness, and long-term effectiveness of the current vegetation management assessment strategies deployed by NCDOT.

References

Alabama Department of Agriculture & Industries. 2022. Noxious Weed Rules: Chapter 80-10-14-.04 Noxious Weeds. Montgomery, AL: Alabama Dept. of Agriculture & Industries. Accessed [February 4, 2025]. https://agi.alabama.gov/plantprotection/wp-content/uploads/sites/12/2022/06/noxious-weeds.pdf

Armstrong, A et al. (2017). Roadside Revegetation: An Integrated Approach to Establishing Native Plants and Pollinator Habitat: Version 1.2. United States. Department of Transportation. Federal Highway Administration. https://rosap.ntl.bts.gov/view/dot/86675

Byrd JD and Maddox V. (2024) Cogongrass (*Imperata cylindrica*) in Mississippi (Publication P3190). Mississippi State University Extension Service. https://extension.msstate.edu/sites/default/files/publications/P3190_Final.pdf

Commonwealth of Virginia. (2026). 2VAC5-317-20. Tier 1, Tier 2, and Tier 3 noxious weeds. Virginia Administrative Code. Retrieved February 2, 2026, from https://law.lis.virginia.gov/admincode/title2/agency5/chapter317/section20/

Dyrmann M, Skovsen SK, Christiansen PH, Kragh MF, Mortensen AK. (2024) High-speed camera system for efficient monitoring of invasive plant species along roadways. F1000 Research. 13:360. 1-18. doi: 10.12688/f1000research.141992.2.

Gougherty, Andrew V., Jessica M. Elliott, Elizabeth A. LaRue, Joey Gallion, and Songlin Fei. 2023. Positive Association between Emerald Ash Borer Residence Time and Accumulation of Invasive Plants. Ecosphere 14(12): e4719. https://doi.org/10.1002/ecs2.4719

[GDOT] Georgia Department of Transportation. 2024. Policy for Landscaping and Enhancements on GDOT Right of Way. Policy No. 6755-9. Accessed [February 2026]. https://mydocs.dot.ga.gov/info/gdotpubs/PolicyandProcedures/552b7fdd-efdf-2bc9-c893-ddbb7383f627.pdf

Griffith, G.E., Omernik, J.M., Comstock, J.A., Schafale, M.P., McNab, W.H., Lenat, D.R., MacPherson, T.F., Glover, J.B., and Shelburne, V.B., 2002, Ecoregions of North Carolina and South Carolina, (color poster with map, descriptive text, summary tables, and photographs) Reston, Virginia, U.S. Geological Survey (map scale 1:1,500,000).

Harper-Lore, Bonnie, Maggie Johnson, and Mark W. Skinner, eds. 2007. Roadside weed management. US Department of Transportation, Federal Highway Administration.

Harper-Lore, Bonnie, Maggie Johnson, and William F. Ostrum, eds. 2013. Vegetation Management: An Ecoregional Approach. FHWA-HEP-13-043. Washington, DC: Federal

Highway Administration, U.S. Department of Transportation. https://www.environment.fhwa.dot.gov/env_topics/ecosystems/veg_mgmt_rpt/vegmgmt_ecoregional_approach.pdf

Iannone, B. V., Carnevale, S., Main, M. B., Hill, J. E., McConnell, J. B., Johnson, S. A., Enloe, S. F., Andreu, M., Bell, E. C., Cuda, J. P., & Baker, S. M. (2020). Invasive Species Terminology: Standardizing for Stakeholder Education. Journal of Extension, 58(3), Article 27. https://doi.org/10.34068/joe.58.03.27

[ISAC] Invasive Species Advisory Committee. (2016). Invasive species and infrastructure. U.S. Department of the Interior. https://www.doi.gov/sites/doi.gov/files/uploads/isac_infrastructure_white_paper.pdf

Krohn J, He H, Matisziw TC, Pile Knapp LS, Fraser JS, Sunde M. 2025. Detecting the Distribution of Callery Pear (*Pyrus calleryana*) in an Urban U.S. Landscape Using High Spatial Resolution Satellite Imagery and Machine Learning. Remote Sensing. 17(8):1453. https://doi.org/10.3390/rs17081453

Florida Department of Agriculture and Consumer Services. (2020). Noxious weed list (Fla. Admin. Code r. 5B-57.007). https://www.flrules.org

Loewenstein, N. J. and Miller, J. H. (Eds.). (2007). Proceedings of the Regional Cogongrass Conference: A cogongrass management guide. Alabama Cooperative Extension System, Auburn University. https://www.invasive.org/weedcd/pdfs/cogonmanagement.pdf

Miller JH (2006) Nonnative Invasive Plants of Southern Forests: A Field Guide for Identification and Control. USDA Forest Service Southern Research Station. General Technical Report SRS–62.

Moore, Voni. 2021. Invasive Species Impacts on Transportation Infrastructure. Washington, DC: Federal Highway Administration. https://www.environment.fhwa.dot.gov/env_topics/documents/Invasive_Species_Impacts_on_Transportation_Infrastructure_November_2021.pdf

[NCDA] North Carolina Department of Agriculture & Consumer Services. (2026). Plant Industry – Noxious weeds list. Retrieved February 2, 2026, from https://www.ncagr.gov/plant-industry-noxious-weeds-list

[NCDA&CSa] North Carolina Department of Agriculture and Consumer Services. (n.d.) *Giant hogweed (Heracleum mantegazzianum)*. https://www.ncagr.gov/plant-industry/giant-hogweed/download?attachment

[NCDA&CSb] North Carolina Department of Agriculture and Consumer Services. (n.d.) Itchgrass (*Rottboellia cochinchinensis*). https://www.ncagr.gov/plant-industry-itchgrass

[NCDOT] North Carolina Department of Transportation. (2017). Vegetation management section manual. Roadside Environmental Unit. https://www.ncdot.gov/initiatives-policies/environmental/vegetation/Documents/vegetation-management-section-manual.pdf

[NCDOT-VMS] North Carolina Department of Transportation, Vegetation Management Section. (2025). Noxious and aquatic weeds [PDF]. Retrieved February 6, 2026, from https://connect.ncdot.gov/resources/roadside/VegetationManagementDocuments/Noxious%20and%20Aquatic.pdf

[NCFS] North Carolina Forest Service. (2026) "Invasive Species Leaflets." In Publications, North Carolina Department of Agriculture & Consumer Services. Accessed February 5, 2026. https://www.ncagr.gov/divisions/nc-forest-service/publications#ForestHealth-8051

[NCIPC] North Carolina Invasive Plant Council. 2023. NC Invasive Plants List – Ranked Invasive Plant List. November 16, 2023. Accessed February X, 2026. https://nc-ipc.weebly.com/uploads/6/8/4/6/6846349/invasive_plant_list_-_ranked_-_2023-11-16.pdf

[NCWRC] North Carolina Wildlife Resources Commission. (2025). State Wildlife Action Plan 2025. Retrieved from https://www.ncwildlife.gov/state-wildlife-action-plan

Nemec, Kristine; Brandt, Josh; Henderson, Kirk; and Uthe, Jim, "Integrated Roadside Vegetation Management Technical Manual [2025]" (2025). Faculty Book Gallery. 772. https://scholarworks.uni.edu/facbook/772

Rawlins, K.A., R.L. Winston, C.T. Bargeron, D.J. Moorhead, and R. Carroll. 2018. New Invaders of the Southeast. USDA Forest Service, Forest Health Assessment and Applied Sciences Team, Morgantown, West Virginia. FHTET-2017-05.

Smith, C. (2012). Invasive Exotic Plants of North Carolina. N.C. Department of Transportation. https://connect.ncdot.gov/resources/Environmental/EPU/Policy/Documents/Invasive_Exotic_Plants_Manual_May_2012.pdf

South Carolina Department of Transportation. 2014. Roadside Plants to Avoid / Trees with Limitations on Rights-of-Way. October 31, 2014. Accessed [February 2026]. https://www.scdot.org/content/dam/scdot-legacy/business/pdf/plants_to_avoid.pdf

Stope, B. 2025. Quiet Invasions. Wildlife in North Carolina. September-October 2025: 12-19.

Taggart JB, Sasser JG, Dodson JW, Ellis JM. (2015). Distribution and management of invasive plant populations in state park properties of the North Carolina Coastal Plain. Natural Areas Journal, 35(3), 476–484.

[USGS] U.S. Geological Survey. 2026. Landslide Preparedness. U.S. Department of the Interior, https://www.usgs.gov/programs/landslide-hazards/landslide-preparedness-0. Accessed 9 Mar. 2026.

Venner, Marie. 2006. *Control of Invasive Species: A Synthesis of Highway Practice*. NCHRP Synthesis 363. Washington, DC: Transportation Research Board. https://www.trb.org/publications/nchrp/nchrp_syn_363.pdf

Vogt JT, Coyle DR, Jenkins D, Barnes C, Crowe C, Horn S, Bates C, and Roesch FA (2020) Efficacy of five herbicide treatments for control of *Pyrus calleryana*. Invasive Plant Sci. Manag 13: 252–257. doi: 10.1017/inp.2020.36

Weed Science Society of America. WSSA Weed Science Definitions. Weed Science Society of America, 2016. PDF file. https://wssa.net/wp-content/uploads/WSSA-Weed-Science-Definitions.pdf

Weed Science Society of America. (2018). Seven front-line best practices in the battle against noxious weeds (Fact sheet). https://wssa.net/wp-content/uploads/NOXIOUS-WEEDS-FACT-SHEET-FINAL-10july18.pdf

Weakley AS and Southeastern Flora Team. 2026. Flora of the southeastern United States Web App. University of North Carolina Herbarium, North Carolina Botanical Garden, Chapel Hill, USA. Accessed Feb 20, 2026.

Yager LY, Smith M. 2009. Use of GIS to Prioritize Cogongrass (*Imperata cylindrica*) Control on Camp Shelby Joint Forces Training Center, Mississippi. Invasive Plant Science and Management. 2(1):74-82. doi:10.1614/IPSM-08-074.1

Attachment 2

NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION

Cooperative Agreement For The Suppression Or Control of Invasive Species

This AGREEMENT is made and entered into on this the _____day of _____ 20___, between the NORTH CAROLINA DEPARTMENT OF TRANSPORTATION, an agency of the State of North Carolina, hereinafter referred to as the 'Department' and the 'property owner'. The purpose of this agreement is to cooperatively eradicate or successfully control high-threat invasive or other undesirable species within highway rights-of-way and on the property abutting highway rights-of-way under authority of NCGS 136 – 18(9) and 136-93. The provisions of this agreement are executed as follows:

1). The Division Engineer or his representative will meet with the property owner prior to beginning any eradication or control operations. They will jointly determine the specific location and type of undesirable vegetation to be treated, the kind and rate of pesticide to be used and any special precautions as stated in Section 5 of this agreement.

2) The property owner will perform only the work on their property and be responsible for all associated costs. The property owner shall perform the work on their property before the Department will perform the work along the rights-of-way. The Department will perform only the work on the highway rights-of-way and be responsible for all associated costs.

3) The property owner hereby releases (indemnifies) the Department from any and all damages to crops, grasses, trees, shrubs, etc. resulting from the application of pesticides by the Department. All reasonable and customary precautions shall be used during the eradication or control of the undesirable vegetation. All reasonable precautions shall be taken to prevent damage to desirable vegetation on highway rights-of-way during eradication or control operations on private property.

4) The property owner shall not treat any vegetation on the Department's rights-of-way; further, the property owner agrees to indemnify and save harmless the Department from any and all claims resulting from the application of pesticides used under the terms of this AGREEMENT.

5) Site / AGREEMENT specifics:

Species to be treated: _____

Location: _____

Treatment to be used by property owner: _____ and rate (if applicable) _____.

Treatment to be used by the Department: _____ and rate (if applicable) _____.

Scheduled date of treatment by property owner: _____

Special Precautions: _____
_____
_____

6) The property owner and the Department agree that the acceptable degree of eradication or control of the invasive specie(s) is to be _____ percent.

7) The Department shall terminate this agreement if in its discretion the property owner is determined to be in willful violation of the conditions specified in this agreement.

Signed:

Department of Transportation: _____
(Division Engineer)

Property Owner: _____ (NOTORIZED)

Address: _____

City and State: _____

Phone Number: _____

Cc: State Roadside Environmental Engineer
Division Roadside Environmental Engineer

CONTROL OF KUDZU AND UNDESIRABLE INVASIVE SPECIES

19A NCAC 02D .0201 COOPERATION WITH PROPERTY OWNERS

The Department of Transportation will cooperate with owners of property abutting highway rights-of-way in eradicating or satisfactorily controlling the growth of kudzu, and other invasive species, within limitations of available funds and personnel.
History Note: Authority G. S. 136-18(9); 136-93; 143B-350(f), (g).
Eff. July 1, 1978.
Amended September 6, 2007

19A NCAC 02D .0202 CONDITIONAL COOPERATION

(a) The extent of participation of the Department in eradication or control work shall be determined by the severity of damage to abutting property, the possibility of roadside erosion and drainage problems resulting from eradication, and the degree of responsibility for the plant infestation that is traceable to the Department.

(b) The property owner, or owners, and the Department shall agree in writing to the degree of eradication or control of such undesirable vegetation. The Department shall perform only the work on highway rights-of-way and the property owner shall perform the work on his property, according to the methods and additional conditions outlined in the written agreement.

(c) There shall be a stipulation in the written agreement indemnifying the Department from damage on private property to crops, grasses, trees, shrubs, etc. resulting from any pesticides which are applied on highway rights-of-way, with all reasonable and customary precautions for the eradication or control of the undesirable vegetation.

(d) All reasonable precautions shall be taken to prevent damage to desirable vegetation on highway rights-of-way during eradication or control operations on private property.

(e) It is the intent of the Department of Transportation to eradicate or control the growth of the undesirable vegetation on substantial sections of highway rights-of-way and abutting private property and not on one or a few isolated or scattered tracts of property. If this work is done on small sections, it would normally be expected that the undesirable vegetation would again spread from untreated properties to the controlled area and previous work would thus be ineffective.

History Note: Authority G. S. 136-18(9); 136-93; 143B-350(f); (g);
Eff. July 1, 1978;
Amended Eff. December 1, 1993.
Amended September 6, 2007