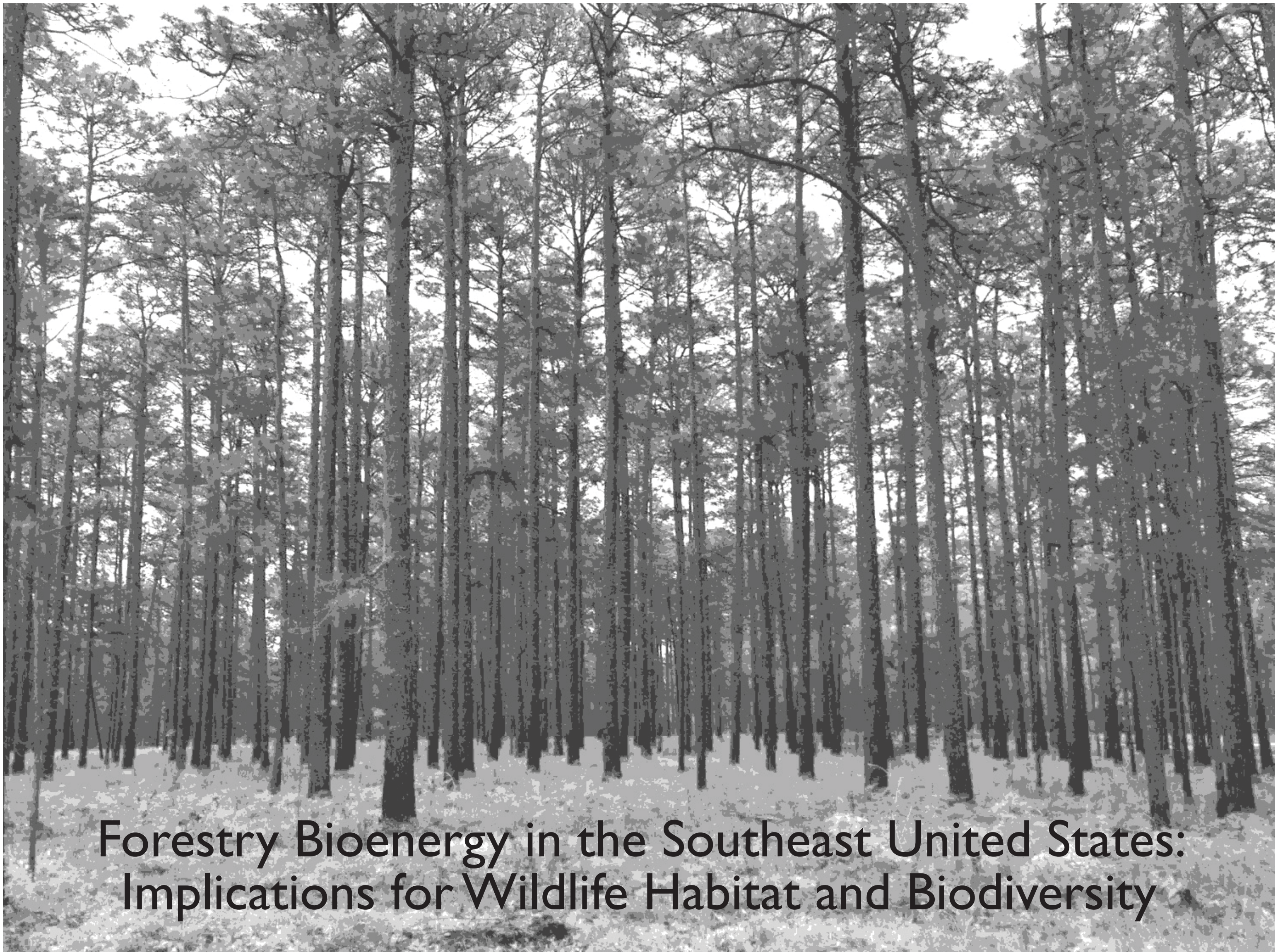

Forestry Bioenergy in the Southeast United States: Implications for Wildlife Habitat and Biodiversity

Executive Summary
November 2013

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Research for this project was conducted through a collaborative effort between faculty and graduate student researchers at the University of Georgia, University of Florida, and Virginia Polytechnic Institute and State University (a.k.a., Virginia Tech University). Chapter 2, authored by Daniel Geller (University of Georgia, College of Engineering) and Jason M. Evans (University of Georgia, Carl Vinson Institute of Government), provides an overview of facilities chosen for the study's focus. Chapter 3, authored by Divya Vasudev, Miguel Acevedo, and Robert J. Fletcher, Jr. (all from University of Florida, Department of Wildlife Ecology and Conservation), provides a presentation of conservation analysis methods and identification of indicator species. Chapter 4, authored by Jason M. Evans, provides a technical explanation of spatial modeling methods employed for the facility case studies. Chapters 5-10, authored by Jason M. Evans, Alison L. Smith (University of Georgia, College of Environment and Design), Daniel Geller, Jon Calabria (University of Georgia, College of Environment and Design), Robert J. Fletcher, Jr., and Janaki Alavalapati (Virginia Tech University, Department of Forest Resources and Environmental Conservation) provide the results and discussion of facility case study analyses. Chapter 11, authored by Pankaj Lal (Montclair State University, Department of Earth and Environmental Studies), Thakur Upadhyay (Virginia Tech University, Department of Forest Resources and Environmental Conservation) and Janaki Alavalapati, provides an overview of forestry biomass energy policies within state, federal, and international contexts, as well as the increasing policy attention to biodiversity concerns. Chapter 12, co-authored by all investigators, synthesizes the results of the report into a series of suggestions for policy consideration and future research studies. Executive Summary and Final Report layout completed by Alison L. Smith.

Christopher Stebbins, a graduate student at the University of Georgia's College of Environment and Design, provided key technical support for developing a number of GIS analyses and map designs. Robinson Schelhas, an undergraduate intern at the University of Georgia, provided tireless assistance with developing maps, assembling literature databases, formatting tables, and taking numerous photographs. Sumner Gann, a graduate student at the University of Georgia's College of Environment and Design, provided document layout and formatting assistance.

EXECUTIVE SUMMARY

Introduction and Background

The southeastern United States (SE U.S.) is currently experiencing what is likely the world's most rapid growth in the development of woody biomass energy facilities. Expansion of this new industry is prompting wide-ranging discussion about opportunities and risks that biomass energy demands may pose for SE forest lands. This study, commissioned by the National Wildlife Federation and Southern Environmental Law Center with funds provided by Doris Duke Charitable Foundation, was developed to help inform and guide this emerging body of basic and applied forest research.

Growth in the woody biomass energy sector has emerged due to a variety of state, national, and international policy initiatives designed to encourage renewable energy generation. A large percentage of the new demands for woody biomass in the SE U.S. is associated with the manufacturing of wood pellets for export to European Union (EU) nations. This industry is being driven by EU directives and subsidy programs that promote biomass energy as a strategy for meeting greenhouse gas reductions, as mandated for signatories of the Kyoto Protocol to the United National Framework Convention on Climate Change.

In the U.S., Renewable Portfolio Standards (RPS) that phase in mandated utility purchase of renewable energy sources have served as an important driver for development of woody biomass demand in some states, including the SE states of North Carolina and Virginia. In other SE states that do not have RPS programs, recent construction of woody biomass electrical generating facilities has been prompted by various other local, state, and federal incentives that promote development of biomass energy projects.

The research in this report represents one of the first efforts to develop spatially explicit analyses of long-term woodshed sourcing for biomass energy facilities in the SE U.S. Sourcing models were developed using advanced geographic information systems (GIS) methodologies that incorporate biomass travel distances, woodshed competition, and various environmental factors known to influence forestry biomass sourcing practices. Sourcing models were then coupled with information on existing land cover types, protected lands, imperiled forest community types, and species habitat information to develop comparative assessments of potential impacts that different biomass sourcing practices may have across a range of SE forest ecosystems and wildlife species. These assessments provide information that is highly relevant for ongoing development of biodiversity protection criteria in sustainable forestry biomass certifications, as well as highlighting areas of future scientific research and monitoring needs.

Goals and Methodology

The goals of this study were fourfold:

1. To develop spatial analyses that provide specific information about the likely land cover base for long-term feedstock sourcing for six woody biomass facilities.

2. To analyze potential effects of biomass sourcing scenarios on a selection of native wildlife species identified as having high conservation concern.
3. To review state, national, and international policies related to deployment of biomass-based energy, with specific focus on sustainable sourcing criteria that pertain to wildlife habitat and biodiversity maintenance.
4. To synthesize the land cover analyses, wildlife assessments, and policy review as a guide for future research focus and associated policy development.

Facility Selections

A total of six woody biomass facilities distributed across the Coastal Plain, Piedmont, and Mountain provinces of the SE U.S. were selected for this analysis:

1. Georgia Biomass, LLC, a wood pellet manufacturing facility located near Waycross, GA in the lower Atlantic Coastal Plain.
2. Enviva Pellets Ahoskie, a wood pellet manufacturing facility located in Ahoskie, NC in the upper Atlantic Coastal Plain.
3. Piedmont Green Power, a biomass fired electrical generating unit located near

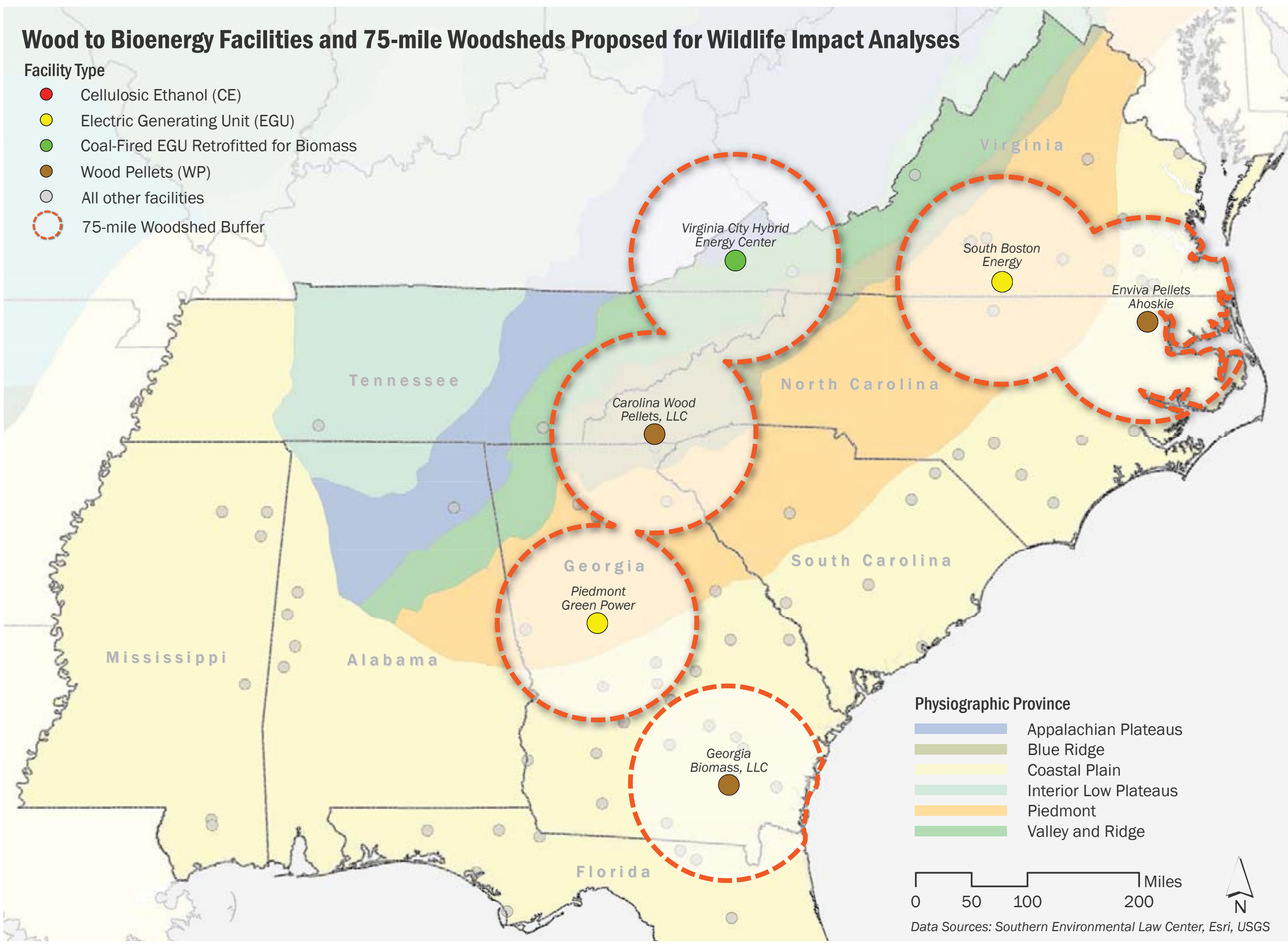

Figure 1. The six facilities chosen to model land use change and habitat impact risks

Barnesville, GA in the southern reaches of the Piedmont province.

4. South Boston Energy, a biomass fired electrical generating unit located in South Boston, VA and in the northern reaches of the Piedmont province.
5. Carolina Wood Pellets, a wood pellet manufacturing facility located in Otto, NC and in the southern Appalachian mountains.
6. Virginia Hybrid Energy Center, a co-fired coal and biomass electrical generating unit located in St. Paul, VA and in the southern Appalachian mountains.

These selections were intended to represent a wide cross-section of the different types of biomass sourcing practices and diverse biodiversity conservation concerns associated with these different practices across the SE U.S.

Biomass Sourcing Models

Using a comprehensive geographic information systems (GIS) work flow, we developed biomass sourcing models for each facility based that take into account two primary spatio-economic factors: 1) Road transport distance of biomass material from the forest to the facility; and 2) Competition with other woody biomass consumers in the woodshed sourcing area. Sourcing models assumed that facilities will preferentially source from woodshed areas that minimize costs through less road transport distance, while also minimizing bid pressure from competing biomass facilities. For softwood sourcing, additional modeling consideration was given to soil type, elevation, slope, and distance to road factors that influence land owner decisions for establishing plantation pine across the landscape. The spatially explicit integration of these disparate factors into biomass sourcing models is a novel research contribution provided by this study.

Land cover information for all sourcing models was based on the United States Geological Survey's 2011 Gap Analysis Program (GAP) National Land Cover dataset. This dataset is designed for use in conservation planning and assessments, which can include large-scale evaluations of biomass and renewable energy sourcing from forest ecosystems.

A series of customized "scenario screens" were run for each facility to simulate sourcing under different sets of sourcing constraints that reflect various protocols for sustainable forest management criteria. Woodshed areas with public ownership status or conservation easements that exclude extractive timber harvests were removed from consideration for all sourcing model scenarios.

Softwood sourcing

For plantation pine-based biomass, a series of five scenario screens were applied for softwood sourcing on private lands. These ranged from the most permissive criterion of allowing conversion of any upland land cover with the exception of row crops and developed areas, to the most restrictive of only sourcing biomass from existing plantation pine forestry land covers.

Ecosystem and wildlife habitat overlap assessments for softwood sourcing were performed on a subset of two intermediate scenario screens: 1) a permissive scenario that allowed for conversion of natural upland forest stands into plantation pine based on landscape factors, while assuming no conversion of agricultural (i.e., row crop and pasture), developed lands, or wetland areas into plantation pine; and 2) a restrictive scenario that limited the resource base of softwood sourcing to existing plantation pine and other disturbed lands (i.e., harvested, cleared, and ruderal succession) that are presumed to form the existing resource base for extractive softwood forestry.

Hardwood sourcing

Two scenario screens were applied for hardwood sourcing on private lands. The permissive screen for hardwood forestry assumed no restriction against sourcing from wetland and riparian forests. A more restrictive screen limited all sourcing to upland hardwood forests, and thus allowed no sourcing from forested wetlands. All hardwood sourcing screens excluded agricultural (including pasture and row crop) and developed land covers from the forestry biomass resource base. In two woodsheds with large areas of land held publicly by the U.S. Forest Service, an additional screen that allowed for sourcing from all non-Wilderness National Forest lands was compared to a scenario screen that prohibited all sourcing from National Forests.

Risk Assessments by Ecosystem Class

Facility biomass demands and literature-based estimates of local forestry productivity provided the basis for calculations of minimum landscape area sourcing requirement, which corresponds to 100% biomass allocation to the facility at the time of forestry harvest. From this minimum sourcing area, actual sourcing scenarios were distributed across a consistent set of harvest intensity and biomass allocation scenarios for each facility. These scenarios ranged from intensive sourcing of pulpwood quality forestry material (50% biomass allocation) to a residuals-only sourcing practice (10% biomass allocation). Sourcing model results based on each of these biomass allocation assumptions are translated into maps of relative landscape risk for biomass harvest.

Five landscape risk classes were defined through this approach: 1) High; 2) Moderately high; 3) Moderate; 4) Moderately low; and 5) Low. Areas that were predicted to contribute to biomass sourcing under the lowest landscape area requirement (i.e., 50% biomass allocation) were classified as High risk, while those only predicted to contribute to biomass sourcing under a residuals-only landscape area requirement (i.e., 10% biomass allocation) were classified as Low risk. Higher risk in this context is technically defined as having a higher relative suitability for biomass sourcing based on model factors, and does not necessarily imply vulnerability to an adverse biodiversity impact from this sourcing.

Sourcing models for each facility were intersected with the 2011 GAP National Land Cover dataset to develop area-based calculations of relative conversion or harvest risk for forest ecosystems assumed to serve as potential supply sources for biomass energy. These area calculations are spatially explicit by risk class, and are comparable across woodsheds due to the standardized land units defined by the 2011 GAP National Land Cover dataset.

Identification of At-Risk (G1-G3) Ecosystems

Through a partnership with NatureServe, an additional intersection procedure was performed to identify lists of forest vegetation types (ecological associations) classified as critically imperiled (G1), imperiled (G2), or vulnerable (G3). These intersection analyses were performed for each facility woodshed with known conservation areas excluded from consideration.

Identification of such at risk (G1-G3) associations for the purpose of avoiding adverse impacts on forests of high conservation value is a component of most sustainable forest management certifications. However, spatial resolution of G1-G3 ecological community data is currently not sufficient to support landscape-level analyses explicit to the risk classes identified by the biomass sourcing models. Lists of at risk associations in each woodshed are also not directly comparable across different facility woodsheds due to highly variable data availability and quality within and among the SE states.

Indicator Species

Through literature reviews and dialogue with regional wildlife experts, a list of sixteen wildlife species of known conservation concern and with forest habitat dependence was developed for the SE region. Based on data availability, formal geo-spatial analyses using species distribution models available through the National Gap Analysis Program (GAP) were developed for a sub-selection of nine species. The list of indicator species analyzed through formal geo-spatial overlays includes:

Mammals

1. Eastern spotted skunk (*Spilogale putorius*)
2. Long-tailed weasel (*Mustela frenata*)

Figure 2. Eastern spotted skunk
Spilogale putorius Photo credit: NPS

Birds

3. Brown-headed nuthatch (*Sitta pusilla*)
4. Northern bobwhite (*Colinus virginianus*)
5. Prothonotary warbler (*Protonotaria citrea*)
6. Swainson's warbler (*Limnothlypis swainsonii*)

Figure 3. Brown-headed nuthatch
Sitta pusilla. Photo credit: http://www.flickr.com/photos/vickisnature/3297971410/

Figure 4. Prothonotary warbler
Colinus virginianus. Photo credit: Jeff Lewis

Amphibians

7. Gopher frog (*Lithobates capito*)
8. Northern cricket frog (*Acris creitans*)

Reptile

9. Timber rattlesnake (*Crotalus horridus*)

Figure 5. Swanson's warbler *Limnothlypis swainsonii***.** Photo credit: http://www.flickr.com/photos/juliom/7158750123/

Figure 6. Northern cricket frog *Acris crepitans*. Photo credit: http://www.flickr.com/photos/pcoin/369987905/

The GAP species distribution models for these species provide spatially explicit predictions of species habitat suitability, and correspond directly to the National GAP Land Cover dataset used as the basis for all biomass sourcing models. Thus, risk-based overlay area calculations for each species provide a consistent basis for comparing the relative potential for habitat impact based on different biomass sourcing scenarios.

Modeling Limitations

It is important to note that the biomass sourcing models and scenario screens in this study were developed using static assumptions about landscape risk, the local forestry base, and facility sourcing practices. First, models do not account for other private landowner values (e.g., hunting leases, or aesthetic enjoyment) that may be associated with holding natural stands of forest in uses not associated with bioenergy production and/or competing extractive practices (e.g., pulp and paper production). Second, comparative risk assessments of ecosystems and species utilize conservative assumptions regarding complete maintenance of agriculture and pasture lands in existing uses (i.e., no demand-driven conversion into forestry). Third, because models are strictly based on existing forestry supply chains and known sourcing practices, they do not consider the potential for novel deployment of short rotation woody crops (SRWC) such as hybrid poplar (*Populus* sp.) as a supply response for facilities with large hardwood demands. While the results in this study do provide an objective basis for relative landscape risk comparison under the given scenario assumptions, more complex landscape decision and stochastic options modeling studies are warranted as additional data become available.

Results by Modeled Facility

Georgia Biomass, LLC, located in the Coastal Plain province near Waycross, GA, is a wood pellet facility with an estimated output of 750,000 Mg/yr. This facility currently demands 100% softwood material, which is currently sourced from local plantation pine forestry operations. Most pellets from this facility are exported from the Port of Savannah, GA to markets in Europe for power generation.

The sourcing model for Georgia Biomass suggests that approximately 43,500 hectares of extant native forests, including over 34,000 hectares of native longleaf pine and other pine savannah forest types, may be at high risk of conversion into plantation forestry over the life time of the facility. The current land cover base for plantation pine forestry in this facility's woodshed appears sufficient for meeting long-term softwood demands if biomass sustainability criteria that prohibit natural forest stand conversion are adopted.

The softwood sourcing model for Georgia Biomass suggests that approximately 43,500 hectares of native forests could be at high risk of conversion into plantation pine forestry when assuming the permissive scenario screen that provides no restriction against natural stand conversion. Over 34,000 hectares of this high risk area is classified as longleaf pine and other upland pine forest ecosystems. Due to large-scale historic conversion of longleaf and other upland pine forests into agricultural, forestry, and developed land covers, remaining examples of these ecosystem types in the SE region are widely recognized for the high conservation value provided to many native animal and plant species.

Most indicator species analyses showed higher areas of impacted habitat under scenarios where natural stand conversion was allowed as compared to scenarios where sourcing was constrained to the existing forestry land cover base. Particularly high amounts of relative habitat risk were shown for the eastern spotted skunk, gopher frog, timber rattlesnake, brown-headed nuthatch, and Swainson's warbler, all of which may be generally expected to show negative responses when natural upland forest habitat is converted into plantation pine. Results for northern bobwhite and long-tailed weasel were more ambiguous, which may reflect the higher adaptability of these species to plantation pine forestry landscapes.

A restrictive scenario screen that limits biomass sourcing to the existing base of plantation pine, disturbed, and ruderal forestry lands strongly suggests that the facility's long-term biomass demands can be met without primary sourcing or future conversion of extant natural forest stands. Due to the large existing base of plantation forestry lands in this woodshed, the full suite of sourcing model runs suggests that between 73%-76% of the facility's softwood biomass demand would be met by current plantation pine and disturbed forestry lands even when assuming no restriction against natural stand conversion.

Enviva Pellets Ahoskie, located in the Coastal Plain province near Ahoskie, NC, is a wood pellet facility with an estimated output of 350,000 Mg/yr. This facility reports a mixed sourcing of 80% hardwood and 20% softwood. Materials include lower quality stemwood and residual material associated with local logging operations. Based on the existing resource base, low quality stemwood and residuals from naturally regenerating forest stands are expected to provide the supply base for hardwood material. Softwood material will likely be

The land cover base and sourcing model in the Enviva Pellets Ahoskie woodshed suggest that between 46% - 63% of the long-term sourcing area for hardwood biomass will be composed of forested wetlands. Over 68,000 hectares of wetland forest in this woodshed may be at high risk of biomass sourcing and may be at risk over the facility life time.

composed of low quality stemwood from local pine plantation forestry operations. Most pellets from this facility are exported from the Port of Chesapeake, VA to markets in Europe for power generation.

A sourcing model based on 80% hardwood and 20% softwood was developed for the Enviva Pellets Ahoskie facility. Results for the hardwood component of the model suggest that between 46%-63% of the biomass sourcing area would be composed of forested wetlands under the scenario screen where wetland forests are assumed as available for bioenergy supply. Forested wetland ecosystems predicted to have the highest risk for bioenergy sourcing include over 48,000 hectares of riverine floodplain forests and almost 21,000 hectares of isolated basin swamps not directly associated with river systems.

Hardwood models that assumed no wetland sourcing for the Enviva Pellets Ahoskie facility suggest that long-term biomass demands likely cannot be met through a residuals-only sourcing strategy (i.e., 10% - 12.5% biomass harvest allocation) that relies solely upon existing stands of natural upland hardwood forests. Afforestation with fast growing hardwood biomass crops, such as hybrid poplar (*Populus* sp.), on marginal pasture and crop lands may be a potential strategy for long-term supply of this facility if a no wetlands sourcing policy is required.

Although comparison of indicator species overlay areas under the "wetlands allowed" and "no wetlands" sourcing screens showed a large amount of differences, these area differences are generally related to wetland vs. upland habitat preferences. For example, the prothonotary warbler and Swainson's warbler showed much higher habitat area overlays under wetland sourcing scenarios, which is a direct function of these taxa showing strong fidelity to bottomland forest habitat in the Enviva Ahoskie woodshed area. Similarly, higher habitat overlays under no wetland sourcing scenarios for the brown-headed nuthatch, northern bobwhite, and long-tailed weasel reflect the upland habitat preference of these species.

Literature for most indicator species suggests a number of habitat degradation concerns related to increased sourcing of primary and residual biomass from hardwood forests, particularly on wetland sites. However, selective thinning of overstory and understory hardwoods on upland sites was identified as a potential strategy for enhancing habitats for both the northern bobwhite and brown-headed nuthatch. Direct and secondary impacts to aquatic ecosystems, as well as unpredictable climate interactions with forest regeneration, are additional concerns associated with wetland forest harvesting. Specific habitat changes in wetland and upland harvest practices specifically associated with biomass energy sourcing in the Enviva Pellets Ahoskie woodshed will require additional research to resolve more fully.

The softwood component of the model suggests that a little over 1,600 hectares of native forests could be at high risk of conversion into plantation pine forestry when assuming a permissive scenario screen that provides no restriction against natural stand conversion. Almost 1,500 hectares of this high risk area is classified as mesic hardwood forests, with less than 30 hectares classified as longleaf pine. Based on these results, it was determined that the softwood demands of Enviva Pellets Ahoskie likely do not pose a major conservation concern for natural upland forest stands within the local woodshed area.

Piedmont Green Power, located in the Piedmont province near Barnesville, GA, is a 60.5 MW electric generating unit. Electrical production by this facility is entirely for use in the local and regional utility market. This facility sources low quality stemwood and residual material from local logging operations. Based on local forestry practices and the existing resource base, plantation pine-based softwood material is expected to provide the long-term biomass supply for this facility.

The sourcing model suggests that approximately 48,500 hectares of extant native forests may be at high risk of conversion into plantation forestry over the life time of the Piedmont Green Power facility. The current land cover base for plantation pine forestry in this facility's woodshed appears sufficient for meeting long-term softwood demands if biomass sustainability criteria that prohibit natural forest stand conversion are adopted.

The softwood sourcing model for Piedmont Green Power suggests that approximately 48,500 hectares of native forests could be at high risk of conversion into plantation pine forestry when assuming a permissive scenario screen that provides no restriction against natural stand conversion. Almost 41,000 hectares of this high risk area is classified as southern piedmont dry oak forest types, with the remainder composed of southern piedmont mesic forest. Historic and ongoing conversion of piedmont hardwood forests into plantation pine forestry is a conservation concern in this woodshed.

The brown-headed nuthatch, Swainson's warbler, eastern spotted skunk, and timber rattlesnake showed substantially higher areas of impacted habitat under scenarios where natural stand conversion was allowed to occur. All of these species can be expected to show negative responses when natural upland forest habitat is converted into plantation pine. By contrast, the northern bobwhite consistently showed relatively higher areas of impact under scenarios where sourcing was restricted to plantation pine and disturbed forestry lands. This result is likely reflective of the northern bobwhite's preference for relatively open overstory and understory conditions. Results for the long-tailed weasel and northern cricket frog were ambiguous, perhaps reflecting the adaptability of these species to plantation pine forest landscapes.

A restrictive softwood scenario screen that limits biomass sourcing to the existing base of plantation pine, disturbed, and ruderal forestry lands indicates that the facility's biomass demands can be met without conversion of natural forest stands. However, the full suite of sourcing model runs suggests that a little less than half (45%-49%) of softwood biomass would be met by the existing base of plantation pine and disturbed forestry lands when assuming no restriction against natural forest stand conversion. While this conversion model likely overstates absolute risk due to other landowner values associated with holding forest land in hardwood forest, this result is nevertheless suggestive of potential long-term land cover change without adoption of sourcing criteria that are protective against the conversion of existing natural stands of piedmont forest.

South Boston Energy, located in the Piedmont province near South Boston, VA, is a proposed 49.95 MW power facility. Feedstocks are expected to include low quality stemwood, slash, wood wastes, and wood chips and slash. Based on the existing forestry resource base in the woodshed, a mixture of 50% hardwood from natural stands and 50% softwood from pine plantations is assumed as the long-term biomass sourcing strategy for this facility. Therefore, a sourcing model based on 50% hardwood and 50% softwood was developed for the South Boston Energy facility.

The land cover base for the South Boston Energy facility suggests a 50% hardwood to 50% softwood sourcing strategy. The sourcing model suggests that approximately 5%-6% of the hardwood resource base could be composed of wetland forests, but that sufficient upland hardwood area is available if sustainability criteria that exclude wetland sourcing are adopted. The model suggests that approximately 6,700 hectares of extant native forests may be at high risk of conversion into plantation forestry to meet softwood demand. However, sufficient areas of extant plantation pine are available in the woodshed to source this facility if biomass sustainability criteria that prohibit natural forest stand conversion are adopted.

Results for the hardwood component of the model suggest that between 5%-6% of the biomass sourcing area would be composed of forested wetlands under a scenario screen where wetland forests are assumed as available for bioenergy supply. The highest risk areas for bioenergy sourcing include approximately 4,900 hectares of piedmont floodplain forests. Hardwood sourcing models that assumed no wetland sourcing for the South Boston Energy facility suggest that long-term hardwood biomass demands can be readily met through a residuals-only sourcing strategy (i.e., 10% - 12.5% biomass harvest allocation).

Comparison of indicator species overlay results showed the potential for substantially higher habitat impacts for the Swainson's warbler, northern cricket frog, and timber rattlesnake under scenarios where wetland sourcing was allowed. Each of these species, and various other riparian-dependent species, would generally be expected to react negatively to intensive biomass sourcing from wetland forest habitats in this region of the piedmont province. Other taxa with upland preferences showed little difference in overall habitat area overlays between "wetland allowed" and "no wetlands" sourcing scenarios. While biomass thinning practices on upland hardwood forests may potentially have habitat enhancement benefits for northern bobwhite and brown-headed nuthatch, species-level responses to upland harvest practices associated with biomass energy sourcing in the South Boston Energy woodshed will require additional research to resolve more fully.

Results for the softwood component of the model results suggest that approximately 6,700 hectares of native forests could be at high risk of conversion into plantation pine forestry when assuming a permissive scenario screen that provides no restriction against natural stand conversion. Almost 6,400 hectares of this high risk area is classified as southern piedmont dry oak forest types, with the remaining 300 hectares classified as southern piedmont mesic forest. However, the restrictive softwood scenario screen that limits biomass sourcing to the existing base of plantation pine, disturbed, and ruderal forestry lands indicates that the facility's biomass demands can very likely be met without further conversion of natural forest stands. Sourcing models suggest that between 78%-84% of the softwood biomass would be met by the existing base of plantation pine and disturbed forestry lands even when assuming no restriction against natural stand conversion.

The brown-headed nuthatch, Swainson's warbler, and timber rattlesnake showed substantially higher areas of impacted habitat under scenarios where natural stand conversion was allowed to occur. All of these species can be expected to show negative responses when natural upland forest habitat is converted into plantation pine. Similar to the results for Piedmont Green Power, overlays for the long-tailed weasel and northern cricket frog showed ambiguous differences between the conversion allowed and no conversion scenarios.

Carolina Wood Pellets, located in the Mountain province near Otto, NC, is a wood pellet facility with an estimated production of 68,000 Mg/yr. This facility sources 100% hardwood material from low quality stemwood, logging residual materials, and waste material from construction sources. All stemwood and residual materials are assumed to come from natural hardwood stands. Most hardwood pellets from this facility are bagged and sold in the domestic U.S. market for use in home heating stoves.

The sourcing model for the Carolina Wood Pellets facility suggests that this facility's demands can be met with residual hardwood biomass from the local woodshed, including in scenarios where all wetlands and U.S. Forest Service lands are assumed as unavailable. Avoidance of riparian areas appears particularly important for biodiversity protection, as it is expected that the northern cricket frog and other amphibian species in this woodshed would show significant negative responses to biomass sourcing from riparian forest habitats along mountain streams. Other wildlife and biodiversity concerns for this facility relate to uncertain taxa and landscape responses to increased residual harvest pressure for biomass sourcing from Appalachian forests. These issues require additional field research to resolve more fully.

The hardwood sourcing model for the Carolina Wood Pellets facility suggests that between 1%-3% of the biomass sourcing area would be composed of forested wetlands under a scenario screen where wetland forests are assumed as available for bioenergy supply. Somewhat larger areas of potential riparian wetland forest impact are predicted for scenarios where sourcing is excluded from all Natural Forest lands, with approximately 780 hectares of Mountain riparian wetlands and 20 hectares of Piedmont riparian wetlands identified as having high risk. Because of this facility's comparatively low biomass demand, hardwood sourcing models that assumed no wetland sourcing for the Carolina Wood Pellets facility indicate that long-term hardwood biomass demands can be readily met through a residuals-only sourcing strategy (i.e., 10% - 12.5% biomass harvest allocation) on upland forests only.

The northern cricket frog is the only indicator species that shows a consistent effect of higher overlay areas under scenarios where wetland sourcing is allowed. It is expected that the northern cricket frog and other amphibian species in the Carolina Wood Pellets woodshed would show significant negative responses to biomass sourcing from riparian forest habitats along mountain streams.

As with other facilities, forestry thinning practices associated with biomass extraction on upland hardwood forests may potentially have habitat enhancement benefits for northern bobwhite and brown-headed nuthatch. However, species-level responses to increased removal of residual material, particularly downed woody matter (DWM), from Appalachian forests is a noted habitat concern that will require additional research to resolve more fully.

The sourcing models suggest that exclusion of non-Wilderness National Forest stands from the biomass sourcing land base for the Carolina Wood Pellets could have the effect of transferring much of the facility's hardwood supply to piedmont forests. This result was surprising, and may be an artifact of the transport model not including increased fuel costs associated with up-gradient elevation.

Differences in areal overlays for ecosystem and indicator species in scenarios that allowed for non-Wilderness National Forests versus those that excluded all National Forests are largely a function of ecological differences between piedmont and mountain ecosystems. Further research will be needed to provide additional insights into the stand-level and landscape tradeoffs between sourcing strategies that may include National Forests as compared to those that are restricted to private landholdings.

Virginia City Hybrid Energy Center, located in the Mountain province near St. Paul, VA, is a 585 MW electrical generation unit operated by Dominion Virginia Power. This facility is designed to co-fire up to 20% biomass in its coal-fuelled electric production facility, although is operationally running on a 10% biomass capacity (~59 MW). Electrical production by this facility is entirely for use in the local and regional utility market. This facility sources low quality stemwood and logging residues from the local area. Based on the existing forestry resource base, it is likely that most sourcing will be composed of low quality stemwood and residuals from naturally regenerating hardwood stands.

The sourcing model for the Virginia Hybrid Energy Center facility suggests that less than 1% of the biomass sourcing area would be composed of forested wetlands under scenarios where wetland forests are assumed as available for bioenergy supply. These results are generally consistent among scenarios where non-Wilderness Natural Forest lands are assumed as available for harvest, as well as scenarios where all National Forest lands are excluded.

> *The sourcing model for the Virginia City Hybrid Energy facility suggests that biomass demands can likely be met with residual forestry from the local woodshed, including in scenarios where all wetlands and U.S. Forest Service lands are assumed as unavailable. Avoidance of riparian areas for sourcing this facility appears particularly important for biodiversity protection due to relative rarity of these habitats in the local landscape, as well as the potential for severe stream erosion and habitat degradation effects with riparian logging practices in the Appalachian Mountains. Other wildlife and biodiversity concerns for this facility relate to uncertain taxa and landscape responses to increased residual harvest pressure for biomass sourcing from Appalachian forests. The relatively high biomass demands of this facility compared to other Appalachian biomass energy sites make such concerns especially notable.*

Likely due to this very low area of riparian habitat overlay, wildlife indicator species showed little difference in scenarios where wetland harvest was allowed as compared to those restricted to upland forestry areas. However, it is generally expected that high intensity biomass harvest from riparian areas in this woodshed could have high habitat and biodiversity impacts, particularly due to the relative rarity of these habitats within the local landscape.

Inclusion of non-Wilderness National Forest in the biomass sourcing area resulted in somewhat higher areas of predicted overlay impact for the Swainson's warbler. While this species can be attracted to small-scale disturbances, it generally prefers disturbances found within the context of otherwise unfragmented hardwood mountain forest habitats. Residuals-only sourcing demands for the Virginia Hybrid Energy Center suggest potential long-term impact on over 50% of the Swainson's warbler habitat in this woodshed. Monitoring of potential impacts from different biomass harvest practices may be particularly warranted for the Swainson's warbler in this woodshed.

Exclusion of non-Wilderness National Forests from the biomass sourcing area consistently resulted in somewhat higher areas of predicted overlay impact for the northern bobwhite and long-tailed weasel. This result is most directly related to increased percentages of piedmont forests serving as a supply source for this facility when National Forests are excluded. While increased biomass harvest on private forestry lands may potentially have habitat enhancement values for northern bobwhite, potential effects on long-tailed weasel populations are less clear and would require additional research. As noted previously, species-level responses to increased removal of residual material, and particularly downed woody matter, from Appalachian forests is a noted concern that will require additional research to resolve more fully.

Policy Summary

The European Commission is currently debating sustainability certification directives for all bioenergy pathways being implemented under the Kyoto Accord. Draft proposals and current policy discussions suggest that Sustainable Forestry Management (SFM) standards may be required for all imported forestry biomass utilized in EU electrical generation.

Maintenance and enhancement of biodiversity through forestry sourcing is a fundamental objective in SFM definitions applied in EU nations. Because of the increasing importance of EU demands on the biomass energy market in the SE U.S., European SFM standards may have significant influence on the development of SFM for other biomass energy procurement in this region.

> *The EU broadly defines SFM as use of forest lands in a way that "maintains their biodiversity, productivity, regenerative capacity, vitality and their potential to fill, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels" (European Commission 2013, pg. 11).*

The U.S. forestry sector has a number of existing sustainable forest management (SFM) certification programs, including the Forest Stewardship Council (FSC), Sustainable Forestry Initiative (SFI), American Tree Farm System (ATFS), and the Program on the Endorsement of Forest Certification (PEFC). These programs are voluntary for forest landowners, and only 17% of SE forestry lands are presently certified through one of the major sustainability certification programs. FSC certifications are generally regarded as the most protective of remaining natural forest stands and associated wildlife habitat in the working forestry landscape, although all of the major SFM certification programs in the U.S. do contain specific biodiversity protection criteria. There currently is no SFM certification in the U.S. that specifically applies to bioenergy production. However, recommendations for minimizing biomass energy sourcing impacts on wildlife habitat have recently been developed by the Forest Guild.

State level best management practices (BMPs) that provide specific guidance for federal regulatory compliance are widely applied throughout the SE forestry industry. While such BMPs are implemented on a voluntary basis, they are specifically designed to prevent erosion and sedimentation violations of the Clean Water Act that are more likely to occur if BMPs are not followed in forestry operations. South Carolina is the first SE state to develop specific BMP criteria for forestry bioenergy sourcing, and forestry commissions in other SE states are considering similar BMP approaches for biomass energy. The South Carolina BMPs provide general assurances against Clean Water Act violations, but are not designed or intended to maintain overall forest biodiversity and wildlife habitat at either the stand or landscape level. Forest Guild guidance for minimizing the impacts of forest biomass sourcing on biodiversity is included as a voluntary set of recommendations in the South Carolina BMP manual.

Synthesis and Conclusions

This study represents one of the first detailed analyses of biodiversity and habitat concerns associated with forestry biomass energy in the SE U.S. region. Because of the regional nature of this study and the idiosyncratic or even unknown responses of wildlife taxa to variable sourcing practices, it is important to note that it not possible to make firm conclusions of impact that would apply to all sites, species, and harvest practices. However, the results of this study do support several generalizations that can inform policy discussions and research priorities for promoting increased sustainability of forestry biomass energy moving forward.

1. The primary conservation concern for softwood biomass sourcing in the SE Coastal Plain and Piedmont provinces is land cover change away from existing natural forest stands into plantation pine forestry. Such conversion is historically known as a primary factor in the loss or degradation of much wildlife habitat in the SE U.S., including for many species of conservation concern. Using existing land cover as a base, woodsheds with relatively large extant areas of plantation pine and ruderal forestry lands generally pose less concern for future biodiversity impacts as compared to those with relatively large areas of natural forest stands.

2. Biomass thinning for energy production may in many cases provide wildlife habitat enhancement within the extant plantation pine forestry landscape in the Coastal Plain and Piedmont, particularly in cases where lack of other markets has resulted in landowner neglect of planted forests. Such thinning practices can provide some structural and functional simulation of longleaf pine ecosystems that were historically a dominant upland habitat throughout the SE.

3. In the Coastal Plain, the most biologically productive hardwood forests are generally located in bottomland areas, including riparian floodplain and isolated basin wetland systems. Large-scale hardwood biomass sourcing within the Coastal Plain sites therefore will generally imply substantial logging pressure on natural wetland forests. While wetland forestry BMPs such as streamside riparian buffers and erosion control measures are available in the SE U.S., unique challenges associated with degradation of wildlife habitat, local and downstream water quality impacts, and uncertainties of natural stand regeneration after intensive harvests of SE bottomland and floodplain forests are all documented within the ecological literature. However, sourcing of upland hardwood biomass in the Coastal Plain may in some cases have habitat enhancement effects, particularly on sites that have experienced hardwood succession away from pines due to fire exclusion.

4. In the Piedmont and Mountain provinces, relatively low amounts of hardwood forest land are contained within wetland forests. There are substantial concerns regarding erosion, sedimentation, and wildlife habitat impacts associated with riparian and wetland forest harvesting in both the Piedmont and Mountain provinces. Avoidance of such wetland areas for biomass sourcing through riparian buffer strips can be recommended with minimal effects on overall hardwood biomass supply in the Piedmont and Mountain provinces.

5. Moderate biomass sourcing of upland hardwood biomass from the Piedmont and, to a lesser extent, the Mountains may in some cases have habitat enhancement effects, particularly when coupled with understory thinning. However, biomass harvest practices that result in large-scale reductions of cavity trees, snags, and downed woody matter are a habitat concern for a wide variety of wildlife taxa found in Piedmont and Mountain hardwood forests.

6. Specific field research is required to better understand long-term habitat responses associated with different biomass management regimes, and to compare these responses to control regimes that are not sourced for biomass. Such research will be critical for the long-term co-management of SE forestry ecosystems for both wildlife habitat maintenance and sustainable bioenergy production.

7. State-level BMP guidelines for forestry operations are not designed for the enhancement or maintenance of biodiversity at stand or landscape levels, but instead to ensure compliance with federal regulations related to the Clean Water Act. Biomass sustainability policies that aspire to be protective or restorative of landscape biodiversity and native forest vegetation types of high conservation value are likely to require additional certification regimes and compliance procedures beyond those provided by BMP guidelines.

8. The U.S. forestry sector has a number of existing sustainable forest management (SFM) certification programs, including the Forest Stewardship Council (FSC), Sustainable Forestry Initiative (SFI), American Tree Farm System (ATFS), the Program on the Endorsement of Forest Certification (PEFC),

and more recently the Roundtable on Sustainable Biomaterials. These programs are voluntary for forest landowners, and only 17% of SE forestry lands are presently certified through one of the major sustainability certification programs. There currently is no SFM certification in the U.S. that specifically applies to bioenergy production.

9. While all of the major SFM certification programs in the U.S. contain biodiversity protection criteria, FSC certifications are generally regarded as the most protective of remaining natural forest stands and associated wildlife habitat in the working forestry landscape. In particular, the FSC Controlled Wood and Forest Management Standards provide restrictions against conversion of extant natural stand forests into plantation forestry. If adopted for softwood sourcing biomass energy facilities that rely upon plantation pine feedstocks, these FSC standards would be expected to offer a high level of protection against biodiversity degradation associated with natural stand conversions to plantation forestry.

10. Biomass energy sourcing from natural stands of hardwood forests poses a more complex set of potential impacts for wildlife habitat and associated forest sustainability certification regimes. Specific recommendations for reducing habitat impacts from biomass sourcing in natural hardwood stands have recently been developed by the Forest Guild (2012). These recommendations generally focus on retaining sufficient snags, cavity trees, and downed woody matter to maintain opportunities for wildlife habitat regeneration. However, rates of voluntary compliance with these practices are currently unknown, as are specific wildlife responses to recommended and actual biomass harvest practices across different habitat and ecosystem types. Additional research will be required to more fully resolve these questions, and thus provide adaptive guidance for the long-term protection of biodiversity and wildlife resources under sustained forestry biomass sourcing.