Evaluating Climate Change Planning for Longleaf Pine Ecosystems in the Southeast United States

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Abstract: Longleaf pine (LLP, *Pinus palustris*) has been reduced to 3–5% of its original range, but may be particularly resilient to conditions associated with climate change including drought, severe storms, and increased prevalence of pests. Despite the critical role of LLP in building climate resilient ecosystems, little is known about how landscape managers in the region have considered climate change in planning efforts. We gathered 83 publicly accessible natural resource management plans from the southeastern United States that included management of LLP ecosystems between 1999 and 2016. We used document analysis to identify how plans addressed climate change threats on LLP, considered climate change in identification of LLP ecosystems, and linked climate change to planned conservation actions for LLP ecosystems. Newer plans and plans from state agencies tended to include greater consideration of climate change than older plans, federal plans, and those developed by nongovernmental organizations (NGO) or Joint Venture partnerships. Additionally, state wildlife action plans and forest action plans tended to score higher than other types of plans, such as plans from the Department of Defense, U.S. Forest Service, and NGOs. Considering climate vulnerability in planning efforts of LLP ecosystems is an opportunity because LLP represents a hopeful context for conserving vulnerable wildlife species as ecosystems adapt and evolve. Limited consideration of climate change as a criterion for identifying or evaluating LLP ecosystems by agencies may result from climate discourse focusing on ecosystems most vulnerable, versus resilient to, climate change. A stronger focus on climate change in longleaf pine community restoration may help forest managers promote sustainable forests and more hopeful conservation planning in the Southeast United States.

Key words: longleaf pine, policy, planning, climate change, management

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Climate change presents important challenges for ecosystem management and planning in the southeastern United States. A lack of information regarding impacts of climate on Southeast ecosystems, as well as uncertainties about climate risks, have presented challenges for climate change adaptation planning (Measham et al. 2011). Institutional limitations, including inertia to change, conflicting internal agency priorities relative to climate change, and variation of climate and emissions scenarios make it difficult to adequately address climate change in planning activities (Jantarasami et al. 2010, Measham et al. 2011). Lack of resources, including funding and personnel as well as stakeholder conflicts and public opposition (Lachapelle et al. 2003, Jantarasami et al. 2010, Ellenwood et al. 2012) increase the difficulty of planning for climate change.

Longleaf pine (LLP; *Pinus palustris*) ecosystems provide a relatively unique planning context as this specific landscape may be more resilient than others to environmental changes projected to occur in association with climate change in the Southeast such as severe storms (Stanturf et al. 2007, Johnsen et al. 2009), droughts (Samuelson et al. 2012), wildfire (Costanza et al. 2015), and insect and disease outbreaks (Hodges et al. 1979, Martinson et al. 2007). This resilience to climate-related hazards and LLP's potential for generating extra income from sawtimber and pine straw make this slower growing pine species more attractive for landowners than it has been in the past (Jose et al. 2006).

Longleaf pine ecosystems were historically the dominant land cover in much of the Southeast (Frost 1993). Longleaf pine once covered 37 million hectares, spanning from Texas to Virginia. How-

ever, lack of natural fire regimes, fragmentation, conversion of land for agriculture, urban development, and expanding pine plantations resulted in loss of most LLP (Oswalt et al. 2012). The remaining 3–5% of original LLP forests provide critical habitat for a host of endangered or threatened wildlife species including red-cockaded woodpeckers (*Leuconotopicus borealis*), frosted flatwoods salamanders (*Ambystoma cingulatum*), and gopher tortoises (*Gopherus polyphemus*; Gibbons et al. 2000, Alavalapati et al. 2002, Kirby et al. 2017). In addition, LLP provides habitat for many species of reptiles and amphibians of high conservation concern in the Southeast. These include species such as the eastern indigo snake (*Drymarchon couperi*; Means 2006) and the Carolina gopher frog (*Rana capito*) that particularly are associated with fire-maintained LLP ecosystems (Roznik et al. 2009).

Despite the opportunity for multiple benefits for using LLP in building climate resilient ecosystems, little is known about how landscape managers in the region have incorporated climate change adaptation into planning efforts. Given the need to understand climate change-associated planning for LLP, we evaluated LLP planning documents to assess how different agencies and organizations have integrated climate change into management plans and how those plans have changed over time. We evaluated seven types of plans from three types of agencies using a three-pronged framework. Our framework focused on whether plans considered climate change impacts on LLP, how plans considered climate change in identification and evaluation of LLP ecosystems, and how plans linked climate change to planned conservation actions for LLP. We hypothesized that:

Plan quality (measured in terms of greater consideration of climate change impacts on LLP ecosystems, greater consideration of climate change in identification and evaluation of LLP ecosystems, and explicitly linking climate change to planned conservation actions for LLP ecosystems), would improve over time;

Governmental agency plans (federal and state) would score higher than nongovernmental organizations in the context of addressing climate change; and

Plan quality would vary by plan type (e.g. Forest Action Plan, State Wildlife Action Plan, etc.).

Hypothesis 1 emerged from previous studies on natural resource planning that indicate planning has improved in recent decades due to the implementation of planning mandates (Fontaine 2011) as well as the availability of planning best practices (Berke 1994, Baer 1997). We expected climate change planning for LLP ecosystems would improve for similar reasons and because climate change planning has emerged as important for many government agencies in the last decade (Wentz 2017). Hypothesis 2 is based in understanding that state and federal agencies operated under planning mandates, such as the Department of Agriculture's National Forest System land management planning rule (also known as the 2012 Planning Rule; National Forest System Land Management Planning 2012) and the National Wildlife Refuge System Improvement Act of 1997 (Meretsky et al. 2006). Policy science often posits that since federal agencies have more personnel and budgets than states, they should have better capacity for planning and implementation (Cubbage et al. 2017). Hypothesis 3 reflects the recognition that different plan types have different objectives, some of which focus on comprehensive planning (e.g., individual national forest plans; Cubbage et al. 2017) with others focusing on conserving land and water (e.g., The Nature Conservancy).

Methods

Data Collection

We gathered publicly available natural resource management plans that included content explicitly addressing LLP ecosystems from federal agencies, state agencies, and nongovernmental organizations (NGOs) during the period of June to August 2016. Plans were collected directly from agency/organization websites or through internet searches using the following keywords: longleaf pine, planning, policy, and natural resource management. Eighty-three total plans were collected from diverse sources including the U.S. Fish and Wildlife Service ($n = 29$), U.S. Forest Service ($n = 10$), Department of Defense ($n = 10$), America's Longleaf ($n = 1$), the Nature Conservancy ($n = 9$), joint ventures (e.g., Lower Mississippi Valley Joint Venture; $n = 3$), and state natural resource agencies ($n = 21$). Year of publication spanned from 1999 to 2016.

We analyzed all state wildlife action plans ($n = 9$) and forest action plans ($n = 9$) from states in the current range of LLP (Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas). We also incorporated a random sample of 27 of the remaining 65 plans. The final sample ($n = 45$) included 4 national forest plans and 9 forest action plans from the Forest Service, 4 integrated natural resource management plans from the Department of Defense, 9 state Wildlife Action Plans, 13 comprehensive conservation plans from the Fish and Wildlife Service, 3 ecoregional plans from the Nature Conservancy, 2 joint venture plans, and 1 plan from America's Longleaf (Appendix 1).

Plan Evaluation Tool

We used a mixed method approach blending quantitative and qualitative data. We developed an evaluation tool (Table 1) that allowed us to assess certain elements of the plans using a binary scoring system. The tool included seven indicators to evaluate the following three aspects of plans: (1) considering climate change impacts on LLP (hereafter Considering Climate Impacts on LLP),

(2) considering climate change in identification and evaluation of LLP ecosystems (e.g., when a land manager uses climate change to identify or evaluate LLP ecosystems that occur on the land being managed; hereafter, Considering Climate in Identification/Evaluation of LLP Ecosystems), and (3) explicitly linking climate change to planned conservation actions for LLP (hereafter Linking Climate to LLP Actions). The possible coding responses for each indicator were scores of 0 or 1 and were categorized as 0 = not identified or not included; and 1 = identified or included (Table 1). We adopted mixed methods (Tashakkori and Teddlie 1998) by using both quantitative coding data and direct quotations from plans to illustrate patterns in planning documents (Table 1).

In order to promote trustworthiness (a qualitative equivalent of reliability comprised of credibility, transferability, dependability, and confirmability), the research team discussed disagreements, clarified any sources of confusion, and arrived at a consensus judgment for coding of the indicators in the evaluation tool (Lincoln and Guba 1985). Throughout the coding process, communication between members of the research team supported unbiased interpretation of the evaluation instrument. Our coding team included four members from universities (authors Clark, Chin, Lackstrom, and Dow) and one member from a nongovernmental organization (Patty Glick, National Wildlife Federation). Chin, Lackstrom, Dow and Glick evaluated the nine state wildlife action plans. Clark evaluated all 45 plans in the sample.

Data Analysis

We calculated the raw total score for each category by summing the scores from all indicators. Because each category varied in the number of indicators, we standardized categorical scores by summing individual scores for each category, dividing by the total number of points possible in that category and multiplying by 100. We calculated the total evaluation score by summing the raw category scores and standardizing them using the same method.

We used the Kruskal-Wallis test to test for differences in scores among agencies and plan types and then used pairwise Wilcoxon signed rank tests to test each pairwise difference between agency types. Given the small sample size ($n = 45$), an alpha level of 0.10 was adopted for all tests. We grouped plans into three types of agencies: federal, state, and nongovernmental organizations/joint venture partnerships. We also conducted a linear regression analysis to identify the relationship between year of publication and plan score, where total evaluation score was the dependent variable and publication year was the independent variable. In addition, we conducted linear regression analyses for plan publication year as a function of each category, using separate models for each of the three categories. A Chi-square test of independence was cal-

Table 1. Evaluation tool used to score how longleaf pine (*Pinus palustris*) management plans address climate change in the southeastern United States. With categories for plan quality, possible scoring for each category, and guidance used for scoring indicators in each category.

Category	Indicator	Possible scores	Guidance
Category 1: Considering Climate Impacts on LLP	Does plan include a stand-alone climate chapter or section?	0	Plan did not include a stand-alone chapter or section devoted to discussion of climate change
		1	Plan included a stand-alone chapter or section devoted to discussion of climate change
	Is climate change integrated into particular chapters or sections?	0	Plan did not integrate climate change as a theme or component into an already established chapter or section
		1	Plan integrated climate change as a theme or component into an already established chapter or section that was not devoted specifically for climate change
	Is climate change considered or included in discussions of monitoring and/or evaluation?	0	Plan did not include climate change in discussions of monitoring and/or evaluation
		1	Plan explicitly included climate change in discussions of monitoring and/or evaluation
Category 2: Considering Climate in Identification/Evaluation of LLP ecosystems	Does plan indicate if climate change was explicitly considered in the identification and/or evaluation of LLP ecosystems?	0	Plan did not indicate that climate change was considered in identifying or evaluating LLP ecosystems
		1	Plan explicitly indicated that climate change was considered in identifying or evaluating LLP ecosystems
	Were formal climate change vulnerability assessments conducted of LLP ecosystems?	0	Plan did not indicate that a formal vulnerability assessment was conducted of LLP ecosystems
		1	Plan indicated that a formal vulnerability assessment was conducted of LLP ecosystems
	Was LLP included as a result of its climate change related	0	Plan did not indicate climate-related vulnerabilities or resilience ((i.e. responses to drought, heat, or hurricanes) of LLP ecosystems
		1	Plan indicated climate-related vulnerabilities or resilience of LLP ecosystems
		0	Plan did not include conservation actions that included explicit language relating to climate change
		1	Plan included conservation actions that included explicit language relating to climate change

culated to compare the frequency of plans from each state in the LLP range. Data was analyzed using Stata 14.2 software.

Results

Number of plans varied significantly by state ($c^2 = 14.29$, df = 8, $P = 0.08$). There were more plans from North Carolina ($n = 9$), South Carolina ($n = 12$), Florida ($n = 12$), and Alabama ($n = 8$) than expected, and less plans from Virginia ($n = 5$), Mississippi ($n = 4$), Louisiana ($n = 3$) and Texas ($n = 3$) than expected. Total evaluation scores ranged from 0 to 85.7 with a mean of 36.2 (SD = 26.1; Table 2). The lowest scoring indicator was whether the plan included a formal climate change vulnerability assessment for LLP ecosystems, with all plans scoring a 0. Few plans considered climate change in the identification and evaluation of LLP ecosystems (Table 2).

Almost half of the plans included explicit discussion of climate change with regard to conservation actions, making it the highest scoring indicator ($\bar{x} = 54.3$; SD = 50.5). The Florida Forest Resource Statewide Strategies plan, for example, included a list of goals aimed to "seek better understanding of the likely effects of climate change on longleaf pine ecosystems as well as the role longleaf pine ecosystems management and restoration could possibly play in mitigating or adapting to climate change" (Florida Department of Agriculture and Consumer Services 2010). Other plans, such as the Lake Wales Ridge National Wildlife Refuge Comprehensive Conservation Plan in Florida, were broader with their goals: "Understand the impacts of climate change on refuge resources to plan for and adapt management as necessary to protect rare, threatened, and endangered species; ridge habitats; and cultural resources of the refuge." (USFWS Southeast Region 2010).

The second highest scoring category was Considering Climate Impacts on LLP ($\bar{x} = 48.6$; SD = 37.3), which included an indicator on inclusion of monitoring and/or evaluation of climate change in LLP ecosystems. Just over half of the plans included a stand-alone section or entire chapter on climate change. For example, some plans included climate change sections in chapters such as "Taking Conservation Action" (The Nature Conservancy and NatureServe 2003), "Environmental Consequences" (USFWS Southeast Region 2009a, USFWS Southeast Region 2006), and "Overarching Issues" (South Carolina Forestry Commission 2010). Twelve plans included climate change in discussions of monitoring or evaluation. Tyndall, Florida, Air Force Base's plan included possible adaptation approaches for natural resource management on their land, which included "Monitor trends in ecological systems to assess changes in reference conditions [of climate change], especially longleaf pine regeneration and ground cover responses" (Tyndall Air Force Base 2015). ACE Basin National Wildlife Refuge offered more broad strategies for the issue of climate change, including training "all staff and volunteers to look for and document any notable change in wildlife and/or wildlife habitat" and continuing "to monitor refuge plans" (USFWS Southeast Region 2009b). The Carolina Sandhills Comprehensive Conservation Plan (USFWS Southeast Region 2009a) contained a climate change strategy that included plans to "monitor forest health related to climate change."

Table 2. Average scores for federal ($n = 21$), state ($n = 18$) and NGO/Joint Venture ($n = 6$) longleaf pine (*Pinus palustris*) management plans in the southeastern United States from 1999 to 2016. Agency comparisons made using Wilcoxon signed rank test. Different letters represent statistically significant differences in total evaluation scores between agency type.

Agency level	Considering Climate Impacts on LLP	Considering Climate in Identification/ Evaluation of LLP Ecosystems	Linking Climate to LLP Actions	Total Evaluation Score
State	68.5	16.7	66.7	46.8 A
Federal	44.4	12.7	42.9	30.6 B
NGO/joint venture	33.3	11.1	33.3	23.8 B
Mean	52.6	14.1	51.1	36.2
Std. Deviation	37.3	23.0	50.6	26.1

The lowest scoring category was Considering Climate in Identification/Evaluation of LLP Ecosystems ($\bar{x} = 15.2$; SD = 24.7). Sixteen plans indicated that climate change was explicitly considered in the identification or evaluation of LLP ecosystems or included LLP as a result of its climate-related resilience. The management plan for Francis Marion National Forest stated, "Longleaf pine-dominated woodlands, savannas and flatwoods are highly diverse and resilient to the effects of climate change, wildland fire and hurricanes" (US Forest Service Southern Region 2015). South Carolina's Wildlife Action Plan referred to longleaf pine as the "wonder tree due to its ability to take the heat… Not only is it a prime candidate in the Southeast for carbon sequestration efforts, but it is more tolerant to drought, overly wet conditions, fire, beetle infestations, forest pathogens, and hurricane-force winds" (South Carolina Department of Natural Resources 2014). However, the Florida Forest Resources Statewide Strategies Plan stated,

"The potential effects of climate change on longleaf ecosystems, including effects on structure, function, the herbaceous layer, pollinators, animals, non-native invasive plants and carbon storage have received insufficient scientific investigation.… This is a serious research gap in light of the complex interactions that occur with prescribed fire, the potential changes in range given the possible affirmative role of longleaf pine in climate change mitigation, and the suggestion that longleaf pine could play a role in mitigating climate change and in carbon storage" (Florida Department of Agriculture and Consumer Services 2010).

Management plans from state agencies scored highest overall

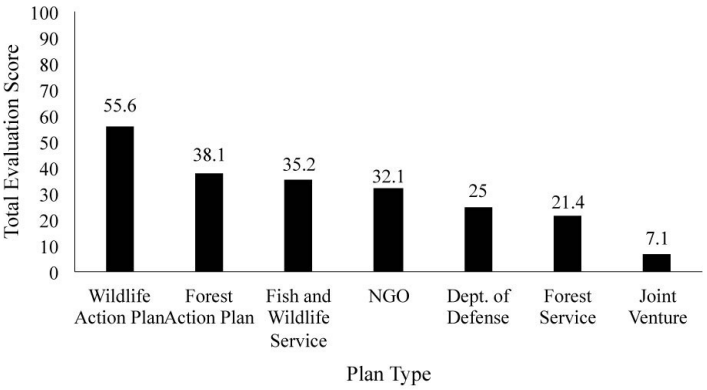

Figure 1. Mean total evaluation scores of Longleaf Pine (*Pinus palustris*) management plans in the Southeast United States from 1996 to 2016, by plan type. Scores based on greater consideration of climate change impacts on LLP ecosystems, greater consideration of climate change in identification and evaluation of LLP ecosystems, and explicitly linking climate change to planned conservation actions for LLP ecosystems in plans.

followed by federal plans and plans from NGOs and joint ventures (Table 2). State-level plans had the highest mean scores in the categories for Considering Climate Impacts on LLP and Linking Climate to LLP Actions, whereas federal-level plans had the highest mean score in the category for Considering Climate in Identification/Evaluation of LLP Ecosystems (Table 2). Differences in total evaluation scores were statistically significant by agency type ($c^2 = 5.54$, df = 2; $P = 0.063$; Table 2). Federal plans ($Z = -1.929$, df = 2; $P = 0.053$) and plans from nongovernmental organizations and joint ventures ($Z = 2.072$, df = 2; $P = 0.063$) both had significantly lower scores than plans from state agencies. These differences largely reflected state wildlife action plans and forest action plans that have the highest scores (Figure 1). However, we did not find significant differences in total evaluation scores by plan type (e.g., Forest Action Plan, Department of Defense plans; ($c^2 = 9.41$, df = 6; $P = 0.15$).

Year of plan publication was a positive predictor of total evaluation scores ($P < 0.001$; $R^2 = 0.406$). The regression analysis provided the following regression equation: $Y = -7924.901 + 3.963x + \epsilon$. The positive coefficient for publication year (3.963) indicates newer plans tended to have higher total scores than older plans. Publication year was also a positive predictor of scores within in each of the three categories in our assessment (Table 3).

Table 3. Relationships between total and categorical scores and publication year of Longleaf Pine (*Pinus palustris*) management plans in the southeastern United States from 1996 to 2016. Relationships were determined through individual linear regression models.

Planning Scores	Intercept	β	*P*	R^2
Total	3.27	0.564	<0.001	0.319
Considering Climate Impacts on LLP	4.86	0.589	<0.001	0.347
Considering Climate in Identification/Evaluation of LLP Ecosystems	1.57	0.309	0.039	0.095
Linking Climate to LLP Actions	2.98	0.266	0.078	0.178

Discussion

As hypothesized, we did find that plan quality improved over time. However, state plans were rated higher than federal plans, which was unexpected. This could be because the state plans were generally newer and more likely to be attuned to climate change as a salient issue in the 2010s than in previous decades. It also could reflect that even the state forest and wildlife action planning processes often received substantial federal funds for and direction in their development, and indeed had the new contemporary federal climate change guidelines in writing those plans. The lower scores for the NGO plans probably reflect a somewhat lesser organizational capacity and less detail than the government plans, which often are very extensive particularly when linked to ongoing or proposed management actions. Similarly, government planning is often constrained by NEPA (National Environmental Policy Act) whereas most NGO planning is not (Cubbage et al. 2017).

Our results suggesting vulnerability was rarely considered in planning efforts specifically for LLP ecosystems may reflect a prevalent belief that predicted conditions in association with climate change may be more favorable for LLP (Rogers and McCarty 2000). Not including this resilience in planning documents, however, may represent a missed opportunity for several reasons. Public support for conservation actions responding to climate change is often limited by misunderstanding, despair, or denial (Smith and Leiserowitz 2014), but LLP represents a hopeful context, and hope appears to be a key ingredient in motivating actions responding to climate change (Stevenson and Peterson 2015). Conserving LLP may have cascading effects for many wildlife species vulnerable to other forms of global change. For example, land conversion in Louisiana and Florida has resulted in habitat destruction of the gopher tortoise and as LLP ecosystems are a key element of gopher tortoise habitat in the area, conservation of LLP may further aid gopher tortoise conservation (Diemer 1986). As managers attempt to promote restoration of LLP, it is important to emphasize that establishment of LLP ecosystems may aid climate change adaptation in areas where other species or whole ecosystems may be negatively impacted by climate change.

Limited consideration of climate change as a criterion for identifying or evaluating LLP ecosystems may emerge from LLP being resilient to, versus threatened by, climate change. This resilience, which is more positive in nature compared to most other climate change messages, offers hope in the face of impending negative impacts from climate change (Samuelson et al. 2012). Climate change information is often disseminated through fear-based messages (O'Neill and Nicholson-Cole 2009). Research has shown, however, that positive framing of climate change can produce stronger intentions to act, even when individuals have higher uncertainty re-

garding the effects of climate change (Morton et al. 2011). Climate change impacts will have strong, lasting effects on natural ecosystems and landscapes (Rogers and McCarty 2000); however, LLP's tolerance of projected climate change-related conditions, such as drought or heat stress, are important attributes of the species and ecosystem and should be considered during long-term planning processes. There are, however, other compelling reasons for managers to support LLP management or restoration, including the 97% reduction in LLP range and the role of LLP in supporting endangered species (Frost 1993, Alavalapati et al. 2002). These salient reasons have been used to justify LLP for several decades, and may have obviated the need to stress climate change as a criterion for identifying or evaluating LLP ecosystems.

Although nearly half of LLP planning documents included climate change in their action planning for LLP, climate change actions and goals ranged in specificity. For example, South Carolina's Statewide Forest Action Plan (South Carolina Forestry Commission 2010) aimed to manage and restore LLP forests in order to adapt to climate change, whereas Carolina Sandhills National Wildlife Refuge Comprehensive Conservation Plan (USFWS 2009a) planned to develop partnerships with other agencies in order to research specific aspects (i.e., transpiration rates) of LLP in order to model potential effects on terrestrial and aquatic ecosystems. Increased resilience of ecological systems can be achieved through generic actions as well as specific measures aimed at recovery of particular populations. Successful adaptation to climate change relies on collective individual action combined with public policy intervention (Adger et al. 2005). Action planning in natural resource plans may encounter barriers due to inadequate goal definition, lack of trust, procedural obligations (i.e., mandated public involvement) and inflexibility including in time, funding, and lack of personnel resources (Lachapelle et al. 2003, Smit and Wandel 2006). However, managers should aim to include climate change in their action planning for LLP as action is required to enhance resilience (Adger et al. 2003).

The tendency for state plans and wildlife conservation plans to score highest may reflect mandates to consider climate change in some way within state wildlife action plans and forest action plans. State wildlife action plans are mandated by the U.S. Fish and Wildlife Service State Wildlife Grant Program. Forest action plans are mandated by the Food, Conservation, and Energy Act (Farm Bill; Food, Conservation, and Energy Act 2008). These mandates include specific planning requirements that could have led to these plans scoring higher in our evaluation. State wildlife action plans must identify species of greatest conservation need (SGCN) and describe the need for conservation action for those species, provide data and information to document the current status of the SGCN, and detail expected results and benefits of the activities for targeted SGCN or their habitats. Plans must include quantifiable and verifiable objectives to be accomplished and describe how the state will monitor program objectives. The most recent notice of funding opportunity for the wildlife grant program supported projects that significantly incorporated climate change considerations in the project design (USFWS 2016).

Forest action plans, also known as Statewide Forest Resource Assessments and Strategies, are required to include "conditions and trends of forest resources in the state, threats to forests, any areas or regions in the state that are priority, and any multi-state areas that are a regional priority." States must also submit long-term statewide forest resource strategies that include strategies for addressing threats to forest resources in the state and a description of resources necessary to address the statewide strategy (Food, Conservation, and Energy Act 2008). Although federal plans scored lower than state plans in our study, it is important to note that the federal government required revisions of state wildlife action plans to address climate change, likely improving state level scores. Nongovernmental organizations and some regional partnerships are more limited in resources and funds which may affect the quality of plans being produced by these agencies (Ryan et al. 2006). In addition, plans by NGOs and regional partnerships may include goals that differ than those of governmental agencies, such as fundraising. Furthermore, these plans may have less constraints than governmental agencies in their planning. For example, NGOs may not prioritize involvement of the public in their planning efforts, whereas many government agencies aim to encourage public awareness and participation through required public comment processes (Berke 1994). Nongovernmental organizations may be able to improve the quality of their plans by seeking additional technical and financial assistance (Berke 1996) and engaging with stakeholders (Vierros et al. 2006).

Plans improved over time due to establishment of best practices in planning. Not only are state wildlife plans now required to consider climate change (USFWS 2016), but land use plans have experienced rapid growth in formation of best practices, particularly over the last two decades (Berke and Godschalk 2009). Natural resource planners now have resources for planning best practices that have only been at their disposal for a couple decades, including evaluation rubrics and guidelines (Baer 1997, Berke and Godschalk 2009). Forest management is often distinguished by long planning horizons, resulting in plans being updated infrequently (Wilson and Baker 2001). Plan improvements over time, however, may partially reflect more frequent inclusion of climate change terminology, which may have limited impacts on action. Fortunately, our results suggest climate change related action planning

improved alongside merely considering climate impacts on LLP. As best practices in natural resource planning continue to improve and grow in number, agencies and organizations should consider updating their plans in order to improve plan quality.

An evaluation of a larger sample of plans may provide a more representative view of differences in plan quality among plans from federal agencies, state agencies, and nongovernmental organizations or joint venture partnerships. Additionally, future studies with larger sample sizes would facilitate more rigorous multivariate analyses exploring dynamics of climate change planning for LLP. Future research could adapt the evaluation tool from this study to facilitate evaluation of species specific wildlife management plans that target LLP-obligate species. Similarly, modifying the evaluation tool to measure addressing climate change issues on LLP ecosystems versus conducting vulnerability assessments, which no plans in our study did, may yield more nuanced results.

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Appendix 1. Publication year, agency level and plan type for longleaf management plans evaluated in this study.

Plan name	Year of publication	Agency level	Plan type
ACE Basin National Wildlife Refuge Comprehensive Conservation Plan	2009	Federal	U.S. Fish and Wildlife Service
Alabama Wildlife Action Plan	2016	State	State Wildlife Action Plan
Alligator River National Wildlife Refuge Comprehensive Conservation Plan	2008	Federal	U.S. Fish and Wildlife Service
Camp LeJeune Integrated Natural Resource Management Plan	2015	Federal	Department of Defense
Carolina Sandhills National Wildlife Refuge Comprehensive Conservation Plan	2009	Federal	U.S. Fish and Wildlife Service
Chassahowitzka National Wildlife Refuge Comprehensive Conservation Plan	2012	Federal	U.S. Fish and Wildlife Service
Choctaw National Wildlife Refuge Comprehensive Conservation Plan	2006	Federal	U.S. Fish and Wildlife Service
Croatan National Forest	2002	Federal	U.S. Forest Service
Draft Environmental Assessment and Finding of No Significant Impact for B-3 Battle Area Improvements at Ft. Stewart	2015	Federal	Department of Defense
Eglin Air Force Base Integrated Natural Resource Management Plan	2010	Federal	Department of Defense
Eufaula National Wildlife Refuge Comprehensive Conservation Plan	2008	Federal	U.S. Fish and Wildlife Service
Forests at the Crossroads: Alabama's Forest Assessment and Resource Strategy	2010	State	Forest Action Plan
Florida Forest Resources Statewide Strategies	2010	State	Forest Action Plan
Florida Peninsula Ecoregional Assessment	2005	NGO/JV	Nongovernmental Organization
Florida's State Wildlife Action Plan	2012	State	State Wildlife Action Plan
Francis Marion National Forest	2015	Federal	U.S. Forest Service
Georgia Statewide Assessment of Forest Resources	2015	State	Forest Action Plan
Georgia State Wildlife Action Plan	2015	State	State Wildlife Action Plan

(*Appendix 1 continues*)

(*Appendix 1 continued*)

Plan name	Year of publication	Agency level	Plan type
Grand Bay National Wildlife Refuge Comprehensive Conservation Plan	2008	Federal	U.S. Fish and Wildlife Service
Lake Wales Ridge National Wildlife Refuge Comprehensive Conservation Plan	2010	Federal	U.S. Fish and Wildlife Service
Louisiana Forest Action Plan	2010	State	Forest Action Plan
Louisiana Wildlife Action Plan	2015	State	Wildlife Action Plan
Mattamuskeet National Wildlife Refuge Comprehensive Conservation Plan	2008	Federal	U.S. Fish and Wildlife Service
Mid-Atlantic Coastal Plain Ecoregional Assessment	2001	NGO/JV	Nongovernmental Organization
Mississippi's Assessment of Forest Resources and Forest Resource Strategy	2010	State	Forest Action Plan
Mississippi's Wildlife Action Plan	2015	State	State Wildlife Action Plan
National Forests in Alabama	2004	Federal	U.S. Forest Service
National Forests in Florida	1999	Federal	U.S. Forest Service
North Carolina's Forest Resources Assesment	2010	State	Forest Action Plan
North Carolina Wildlife Action Plan	2015	State	State Wildlife Action Plan
Pocosin Lakes National Wildlife Refuge Comprehensive Conservation Plan	2007	Federal	U.S. Fish and Wildlife Service
Range-wide Conservation Plan for Longleaf Pine	2009	NGO/JV	Nongovernmental Organization
Savannah Coastal Refuges Complex National Wildlife Refuge Comprehensive Conservation Plan	2011	Federal	U.S. Fish and Wildlife Service
South Atlantic Coastal Plain Ecoregional Assessment	2002	NGO/JV	Nongovernmental Organization
South Atlantic Migratory Bird Initiative Implementation Plan	2002	NGO/JV	Joint Venture
South Carolina State Wildlife Action Plan	2015	State	State Wildlife Action Plan
South Carolina's Statewide Forest Resource Assessment and Strategy	2010	State	Forest Action Plan
St. Marks National Wildlife Refuge Comprehensive Conservation Plan	2006	Federal	U.S. Fish and Wildlife Service
Texas Statewide Assessment of Forest Ecosystem Services	2013	State	Forest Action Plan
Texas Wildlife Action Plan	2012	State	State Wildlife Action Plan
Tyndall Air Force Base Integrated Natural Resource Management Plan	2015	Federal	Department of Defense
Upper East Gulf Coastal Plain Ecoregional Assessment	2003	NGO/JV	Joint Venture
Virginia Statewide Assessment of Forest Resources	2010	State	Forest Action Plan
Virginia's 2015 Wildlife Action Plan	2015	State	State Wildlife Action Plan
Waccamaw National Wildlife Refuge Comprehensive Conservation Plan	2008	Federal	U.S. Fish and Wildlife Service