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Biomass harvesting guidelines (BHGs) have been developed to address concerns about the sustainability of harvesting woody biomass. Assessing preferences among BHG stakeholders is important for designing operationally feasible and socially acceptable standards in different contexts. We used choice modeling to determine how foresters, loggers, and landowners perceived the relative importance of stumpage price, wildlife habitat quality, percentage of coarse woody debris (CWD) remaining, and distribution of CWD in their choices of BHG scenarios. Responses (N = 718) indicated stumpage price was nearly double the importance of wildlife habitat quality, and three times more important than debris distribution and debris remaining.

KEYWORDS *woody biomass, guidelines, BHG, choice modeling, choice-based conjoint*

INTRODUCTION

Forest biomass has been identified as a means to meet the global demand for more carbon neutral energy and bolster slumping timber markets (Stupak et al., 2007; Conrad & Bolding, 2011). The use of mill wastes notwithstanding, converting forests to energy relies on harvesting woody biomass. Woody

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biomass is considered all tree and woody plant material in forests, rangelands, and woodlands (Evans & Finkral, 2009) and has numerous advantages over fossil fuels as a means to help meet global energy needs (Smeets, Faaij, Lewandowski, & Turkenburg, 2007; Bergman & Zerbe, 2008). The Southeast Bioenergy Roundtable, an outgrowth of the U.S. Department of Energy's Southeastern Biomass Energy Program (SERBEP), concluded that particular aspects of bioenergy development could have positive impacts ecologically, economically, and socially, but increased woody biomass harvesting could result in diminished ecosystem function and loss of biodiversity (Cook & Beyea, 2000). Harvesting woody biomass, in addition to roundwood, often removes more forest material than conventional forestry practices and could degrade soil productivity, water quality, forest biodiversity, wildlife habitat, and overall forest health (Herrick, Kovach, Padley, Wagner, & Zastrow, 2009; Abbas et al., 2011).

Stakeholders developed biomass harvesting guidelines (BHGs) to promote forest management practices that protect, maintain, and enhance biodiversity, wildlife habitat, and site productivity during biomass harvesting. Because forest practice guidelines did not address ecological impacts of woody biomass harvesting, BHG development began in the United States around 2007 (Fielding et al., 2012). Although seemingly progressive, BHGs in the United States are less intensive than similar guidelines in Finland, Sweden, and Denmark (Stupak et al., 2007). Considering the increasing demand for woody biomass and the absence of consistent standards at the state or national levels, scientifically informed BHGs are critical to ensure an ecologically sustainable woody biomass industry (Janowiak & Webster, 2010; Abbas et al., 2011).

Biomass harvesting guidelines have led to interest in new national standards, including within existing forest certification programs. All three major forest certification systems in the United States—The Sustainable Forestry Initiative (SFI), Forest Stewardship Council (FSC), and the American Tree Farm System (ATFS)—periodically revise their standards to ensure sustainable forest management (Wisconsin Division of Forestry, 2003). Revisions since 2010 have included discussions of biomass harvests and certification systems, which are likely crucial to Renewable Portfolio/Renewable Energy Standards approaches. Each of these certification revisions have sought and included stakeholder perspectives regarding specific indicators for BHGs.

Assessing BHG preferences among stakeholder groups that will be directly affected by biomass harvesting policies and markets is an important step toward designing BHGs that are operationally feasible and socially acceptable (Fielding et al., 2012). Key stakeholders include forest professionals and managers, nonprofit organizations, private landowners,

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and those who would implement BHGs on the ground—such as loggers, landowners, and professional foresters. Tyndall, Shulte, and Hall (2011) noted that landowners play an integral role in woody biomass harvesting policy development because their willingness to engage in woody biomass harvesting may dictate market size, forest availability, and ecological and social impacts. Stakeholder assessment and engagement have proven equally important for biomass energy development (Upreti & van der Horst, 2004). For instance, some forestry, ecology, and wildlife management studies demonstrated conservation programs tailored to the needs and perspectives of stakeholders improve compliance with regulations, trust in regulating agencies, motivation to engage in conservation programs, and acceptance of new power structures associated with regulations (Mangel et al., 1996; Burroughs, 1999; Côté & Bouthillier, 1999; Beierle & Konisky, 2000; Robertson & Hull, 2003).

Current BHG language suggests harvesting costs, percent course woody debris (CWD) remaining, and debris distribution are likely critical components, but empirical research has yet to address stakeholder attitudes toward these components (Fielding et al., 2012). Furthermore, qualitative research suggests perceptions of BHGs were mixed among forest managers, forest landowners, and loggers in North Carolina (Fielding et al., 2012). These groups were disinclined to support BHGs because they perceived the rules as redundant with forestry best management practices (BMPs), akin to regulations, and not supported by sufficient scientific data. We addressed the need for empirical assessment of stakeholder preferences for BHG attributes using a case study focused on key stakeholders in the southeastern United States.

The southeastern United States is heavily forested, with 201 million acres of productive forestland (Wear & Greis, 2002). Woody biomass from the region could contribute to the expansion of the biomass energy sector (Colnes et al., 2012). Nonindustrial private forest (NIPF) landowners own 70% of forestland in the Southeast (Jacobson, Abt, & Carter, 2000), and commercial timber crops can be produced from 93% of all forestland in the region (Wear & Greis, 2002). Further, the Southeast has thousands of forest professionals and forest managers and several nonprofit organizations engaged in the development of the woody biomass harvesting market, guidelines, and BMPs.

We used choice modeling to determine the perceived acceptability of BHGs among foresters, loggers, forest landowners, and environmental nonprofit organization employees in contexts with different stumpage prices. Specifically, we assessed the relative importance of percentage of CWD remaining after harvest; distribution of CWD after harvest; stumpage price received to harvest woody biomass material; and wildlife habitat quality after harvest.

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METHODS

Choice Models

Choice modeling assumes the choices people make equate to underlying preferences to measure the value of environmental goods (Holmes & Boyle, 2003). Conjoint analysis is a form of choice modeling used to determine which attributes presented to a "consumer" are most important in determining choice or purchasing behavior (Jervis, Lopetcharat, & Drake, 2012). Choice-based conjoint (CBC) is the most prominent of three types of conjoint analysis (Orme, 2010). It poses questions to consumers in a way that reflects how people make choices between products by asking the consumer to compare and then choose the most appealing product rather than by rating or ranking (Jervis et al., 2012) methods that provide limited information on changes in forest services (Holmes & Boyle, 2003). Although there is a possibility that this method could employ a different cognitive process than ranking or rating, thereby impacting convergent validity, choice modeling is emerging as a method ideally suited to provide decision makers with detailed estimations about public preferences for human-induced changes within forest ecosystems (Holmes & Boyle, 2003).

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Choice-Based Conjoint Survey

We used CBC to create choice scenarios designed to facilitate an attribute-based experiment (Holmes & Adamowicz, 2003). We created an online survey using SSI Web 6.6.18 (Sawtooth Software version 8.2.0, Orem, UT). Respondents chose between scenarios with varying levels of key attributes (Table 1). For instance, respondents faced choices where BHG configuration was linked with higher stumpage prices and other respondents had the same BHG configuration, but with lower prices. We identified key attributes and their levels based on the analysis of interview data reported by Fielding et al. (2012). We defined attributes and levels in the survey using a timber harvest scenario example that preceded the choice experiment (Figure 1).

The survey employed 12 choice tasks, with three options per task and an "I would not choose either of these" option for each choice task. Each choice task was a balanced combination of levels for each attribute with each

TABLE 1 Attributes and Levels for Conjoint Analysis of Forest Professionals and Landowners in Four Southeastern States in 2012

• Percentage of coarse woody debris remaining after harvest	10%; 20%; 30%
• Distribution of coarse woody debris after harvest	Spread out; piles in rows; scattered piles
• Stumpage price received for woody biomass material	\$0/ton; \$3/ton; \$6/ton
• Wildlife habitat quality after harvest	Low; medium; high

Now imagine that you are involved in a woody biomass harvest that will occur in conjunction with a conventional timber harvest. The site is a 100 acre tract located in the coastal plain with recommended biomass harvesting guidelines in place. The following 12 slides will depict two scenarios and you will be asked to choose the one you prefer most after considering each of the four (4) factors independently.

1. Retention of coarse woody debris—Leaving between 10 to 30% of harvestable coarse woody debris (limbs, tops, and snags) on a logging site following a harvest

2. A strategy for dispersion—Such as scattering debris across the site, placing the debris in small piles across the site, or piling the debris in rows (windrows) across the site

3. Stumpage price—Stumpage price that you will receive for the harvested woody debris

4. Quality of wildlife habitat—Overall quality of wildlife habitat on site after harvest

FIGURE 1 Choice scenario example given to forest professionals and landowners in four southeastern states prior to engaging the choice-based experiment.

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attribute represented in every choice. We used the default design parameters of a balanced overlap design[1] and 300 versions[2] of the survey without sacrificing efficiency or precision, respectively. The survey was constructed on an Internet web server hosted and maintained by North Carolina State University. To complement CBC findings, we supplemented analysis with 5-point Likert-scale questions (*Strongly disagree–Strongly agree*) from the larger survey on harvesting operations and economic and forest impacts, within which the CBC survey was embedded.

Sampling

We downloaded publically available databases and contacted state and national forest professionals and environmental nonprofit organizations, as well as university extension programs, to generate a list of registered foresters and loggers, environmental nonprofit organizations, and forest landowners in North Carolina,[3] South Carolina,[4] Virginia,[5] and Georgia.[6] From this information, we developed two sublists of potential participants: (a) individuals for whom we had email addresses and (b) organizations who would rather not share internal information, but agreed to send our emails directly to their members or staff on our behalf. Because numerous groups sent the survey to their members without sharing access to the actual lists, we estimate a minimum sampling frame of 4,000. Survey reminders were sent to individuals and organization contacts every week for 4 weeks or until survey completion (Dillman, Smyth, & Christian, 2009).[7] Notifications contained a web link that directed respondents to the survey.

We used the continuum of resistance model to evaluate potential for nonresponse bias. The continuum of resistance is based on the assumption that the level of effort required to elicit a response is indicative of the proclivity of individuals to respond and the underlying assumption is that late respondents are comparable to nonrespondents on the continuum of resistance (Kypri, Stephenson, & Langley, 2004). We divided respondents into three groups based on whether they submitted an early response (after the first email; $n = 210$), an intermediate response (after the first reminder and before the third reminder; $n = 418$), or a late response (after the third reminder; $n = 139$). We compared response waves for differences for three principal indicators to BHG development: Do they believe states should develop these guidelines?; Are they familiar with the concept of using woody biomass for energy?; Did they provide a response in the first CBC scenario? We performed an analysis of variance (ANOVA) to compare the means of the three groups and found no significant differences between groups.

Analysis

Choice Modeling/Conjoint Analysis

We excluded 239 respondents that did not complete enough choice scenarios to meet minimum program specifications to conduct conjoint analysis. To extract individual utility scores, we employed Hierarchical Bayesian (HB) estimation (Jervis et al., 2012). Scores were then rescaled using a zero-centered differences method to standardize all attribute utility scores and facilitate comparisons (Allenby, Arora, & Ginter, 1995; Childs & Drake, 2009; Orme, 2010). We analyzed the geometric mean of the predicted probabilities, or root likelihood (RLH) value, to remove respondents with an RLH value ≤ 0.333 to safeguard against underestimation (Jervis et al., 2012), eliminating one respondent. The RLH value is calculated by dividing 1 by the number of alternatives in each choice task. One attribute with four levels (the "none of these" option aside) should be predictable 25% of the time (0.250). We employed latent-class analysis to examine two-way interactions among attributes to determine if a single attribute, or combination of attributes, had an effect on choice (Orme, 2010; Jervis et al., 2012).

Importance scores measure the percent importance of the four attributes in the respondent's choice that was made. This score is calculated by dividing the utility score range for each attribute by the total utility range and then multiplying by 100 (Orme, 2010). Final steps of the analysis included a one-way ANOVA to determine whether zero-centered utility scores for the total usable population's preferences for the four attributes differed. We also employed ANOVA to test for differences among stakeholder groups.

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We excluded nonprofit staff from all group comparisons because we did not have a sufficient number of respondents to include them in the analysis. Fisher's least significant difference (LSD) post hoc tests were conducted to identify differences when ANOVAs were significant at the 0.05 level. We used XLSTAT version 2010.5.02 (Addinsoft, New York, NY) to conduct analysis of Sawtooth output.

Policy Simulation

We employed Sawtooth's online simulator software to explore hypothetical policy profiles. The program uses utility scores to calculate respondents' preferences for policy profiles. Results are interpreted as percent share of preferences. Preference simulations have been used to estimate support for policy profiles (Kruk, Paczkowski, Mbaruku, de Pinho, & Galea, 2009; Morgan-Davies & Waterhouse, 2010; Lüthi & Prässler, 2011). We crafted five policy profiles using the utility score data collected from the CBC survey that were practically and theoretically pertinent to BHG development. The five profiles were: (a) "BHG Wildlife" ($6/ton; high quality wildlife habitat; 30% CWD remaining, spread out distribution), (b) "Reduced Costs" ($6/ton; low quality wildlife habitat; 10% left, piled distribution), (c) "Theoretical Wildlife" ($6/ton; high quality wildlife habitat; 30% CWD remaining, piled distribution), (d) "Balanced 1" ($6/ton; medium quality wildlife habitat; 20% CWD remaining, piled distribution), and (e) "Balanced 2" ($6/ton; medium quality wildlife habitat; 20% CWD remaining, rows distribution). The "BHG Wildlife" option was indicative of current BHGs that place a preference for a spread out distribution (Fritts, Moorman, Hazel, & Jackson, 2014). The "Reduced Costs" option reflected the least cost-intensive option for loggers. "Theoretical Wildlife" was constructed from empirical data that indicated piles rather than a spread out distribution are best for achieving high quality habitat for wildlife that requires downed woody debris for cover (Fritts et al., 2014). The "Balanced 1" and "Balanced 2" options varied CWD distribution to represent a balance between the desire to minimize costs associated with harvesting (e.g., even distribution would mean higher costs and piles equate to lower costs because of the logistics involved) and simultaneously achieve ideal conditions for wildlife.

RESULTS

Sample Characteristics

Most respondents were from North Carolina ($n = 186$, 44%) and Georgia ($n = 159$, 37%), with fewer from Virginia ($n = 49$, 12%) and South Carolina ($n = 31$, 7%). Most respondents were foresters ($n = 247$, 56%), followed by loggers ($n = 92$, 21%), landowners ($n = 81$, 18%), and those affiliated with environmental nonprofit organizations ($n = 21$, 5%). The sample was skewed

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toward males (n = 400, 95%). The sample ranged from 24 to 84 years of age with an average age of 51. Most respondents were employed full time (n = 374, 90%), followed by retired (n = 21, 5%) and those employed part-time (n = 20, 5%). Most respondents had a bachelor's degree (n = 236, 33%) or graduate degree (n = 97, 14%) and had an average reported annual income of between US$75,000–99,999.

Utility and Importance Scores

Estimation of the part-worth utilities for the sample revealed stakeholders had different preferences for attributes and levels within the attributes (Figure 2). Calculation of percent importance scores for the sample revealed stumpage price received for woody biomass material (46.2%) was most important, followed by wildlife habitat quality after harvest (24.6%), distribution of CWD after harvest (16.0%), and lastly percentage of CWD remaining after harvest (13.3%).

Preference Difference Between Groups

We did not detect differences between loggers, foresters, and landowners for attributes (Figure 3) or levels of attributes (Table 2). Stumpage price was the

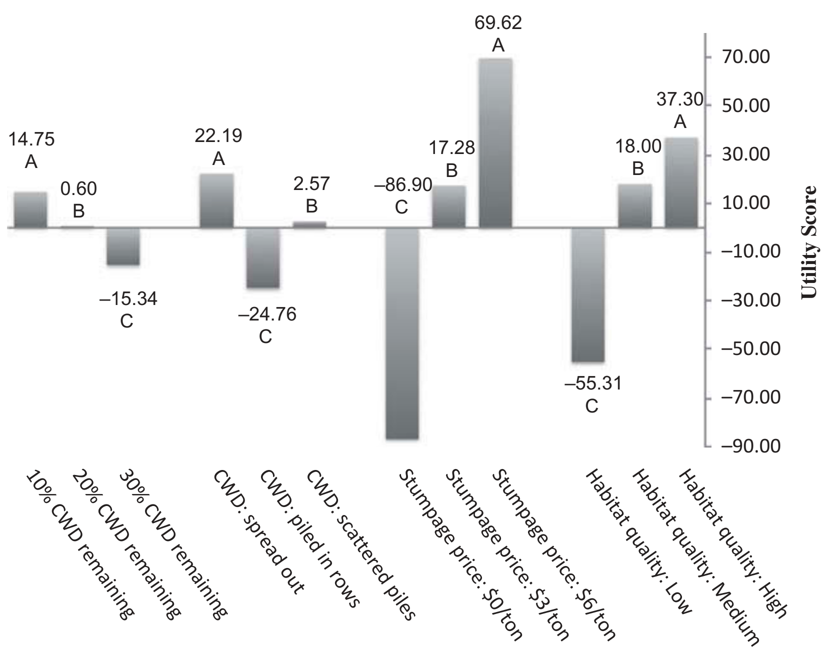

FIGURE 2 Total zero-centered utility values for attributes and levels for forest professionals and landowners in four southeastern states. Letters indicate significant differences (p < .05) within each attribute for total sample (n = 479). Only levels within an attribute can be compared.

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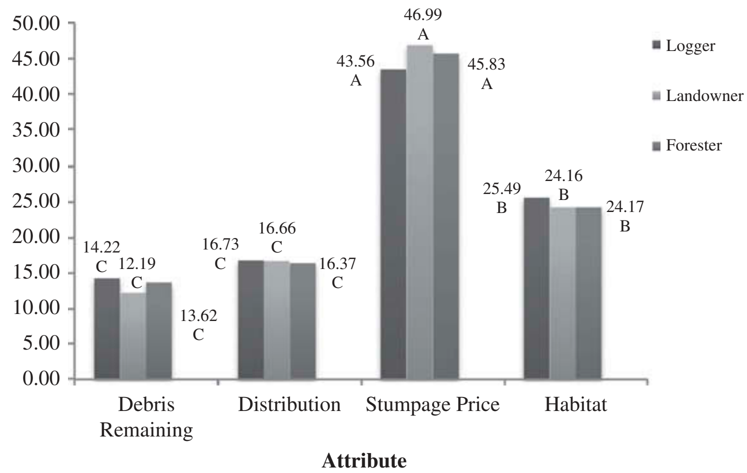

FIGURE 3 Attribute importance (%) scores for forest professionals and landowners in four southeastern states. Similar lettering signifies that significant differences ($p < .05$) within each attribute for total sample ($n = 479$) were not found.

TABLE 2 Utility Scores (%) for Segmented Forest Professionals and Landowners in Four Southeastern States in 2012

Debris left behind	%	Debris distribution	%	Stumpage price	%	Habitat quality	%
10%		*Spread out*		*$6/ton*		*High*	
Logger[A]	15.84	Logger[A]	23.30	Logger[A]	72.18	Logger[A]	39.54
Forester[A]	15.84	Forester[A]	20.13	Forester[A]	68.96	Forester[A]	37.45
Landowner[A]	14.15	Landowner[A]	28.60	Landowner[A]	74.59	Landowner[A]	36.93
20%		*Piles*		*$3/ton*		*Medium*	
Logger[B]	0.83	Logger[B]	2.30	Logger[B]	16.02	Logger[B]	18.03
Forester[B]	0.49	Forester[B]	3.48	Forester[B]	17.53	Forester[B]	16.68
Landowner[B]	0.74	Landowner[B]	−0.56	Landowner[B]	18.29	Landowner[B]	18.19
30%		*Rows*		*$0/ton*		*Low*	
Logger[C]	−16.68	Logger[C]	−25.60	Logger[C]	−88.19	Logger[C]	−57.56
Forester[C]	−16.33	Forester[C]	−23.61	Forester[C]	−86.49	Forester[C]	−54.13
Landowner[C]	−14.89	Landowner[C]	−28.04	Landowner[C]	−92.88	Landowner[C]	−55.12

Note. Only levels within an attribute can be compared. Different lettering signifies that significant differences ($p < .05$) within each level for total sample ($n = 479$) were found. Environmental nonprofit organizations were excluded.

most preferred attribute by all three groups. All three groups responded that BHGs would increase costs for loggers (62%). Landowners (65%) and loggers (65%) were more likely than the foresters (53%) to agree that harvesting woody biomass would benefit them financially. Collectively, 58% of foresters,

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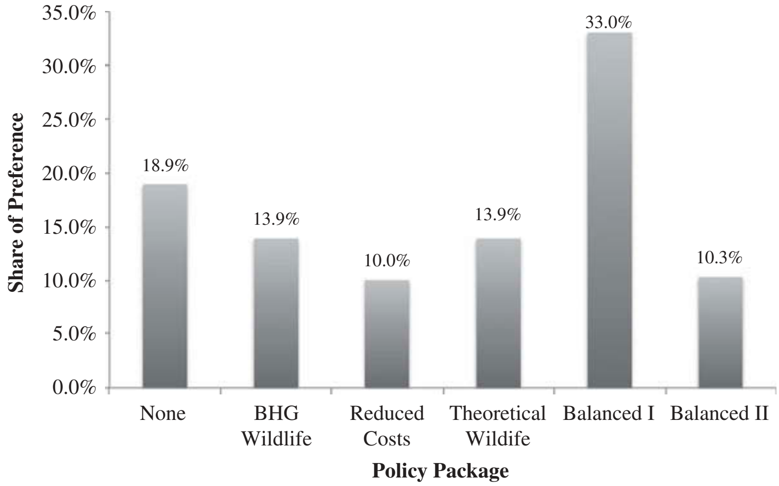

FIGURE 4 Sample preferences for BHG policy packages. Packages were: (a) "BHG Wildlife" ($6/ton; high quality wildlife habitat; 30% CWD remaining, spread out distribution), (b) "Reduced Costs" ($6/ton; low quality wildlife habitat; 10% left, piled distribution), (c) "Theoretical Wildlife" ($6/ton; high quality wildlife habitat; 30% CWD remaining, piled distribution), (d) "Balanced 1" ($6/ton; medium quality wildlife habitat; 20% CWD remaining, piled distribution), and (e) "Balanced 2" ($6/ton; medium quality wildlife habitat; 20% CWD remaining, rows distribution).

loggers, and landowners agreed they would benefit financially compared to only 15% who disagreed. These groups also preferred high wildlife habitat quality. However, foresters, loggers, and landowners were more likely to disagree (56%) than agree (13%) that harvesting woody biomass would damage wildlife habitat.

Policy Simulation

In a comparison of the five hypothetical policy profiles, the "Balanced 1" profile was the most preferred (32.8 ± 1.29%) and the second most preferred scenario was having no BHGs (Figure 4). This indicates that high stumpage price and BHGs that account for wildlife habitat quality best match subject preferences in this study and create the only context they preferred over having no BHGs.

DISCUSSION

Our results suggest that without a strong market for woody biomass the details of BHGs will be of little relevance. All groups in our study indicated stumpage price received to harvest woody biomass material was the most important factor when making BHG choices and preferred no BHGs to any other policy scenarios offered in this study. Stumpage price

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influences contractor and landowner profits, and could also influence logger wages. Stumpage prices are determined by harvesting and transportation costs, market value, and consumer demand (Ashton, Jackson, & Schroeder, 2007). Currently, however, costs for woody biomass removal remain high (Aguilar & Garrett, 2008; Conrad & Bolding, 2011), market opportunities for woody biomass are lacking (Evans & Finkral, 2009), and the dynamic nature of stumpage prices make predicting profitability difficult (Saunders, Aguilar, Dwyer, & Stelzer, 2012). Given that these trends have dictated woody biomass profits in the South, it makes sense that stumpage price—the measurable product of these trends and the antecedent of other BHG attributes in this study—was the most important attribute to all groups in our study.

Our results highlight the importance of wildlife habitat considerations in BHG development. The ecological effects of woody biomass harvesting on wildlife represent an important policy consideration (Reijnders, 2006). Our results suggest loggers, landowners, and foresters would support those attributes of BHGs designed to promote high quality wildlife habitat once identified, such as leaving at least some debris preharvest and postharvest to maintain ecosystem function and quality wildlife habitat (Abbas et al., 2011). Although stumpage price was the most important attribute in our study, respondents preferred scenarios where at least moderate wildlife habitat quality remains after harvest; our sample's preference for wildlife habitat is reinforced by our policy profile simulation where we observed three of the top four preferred profiles combine high stumpage price and high quality wildlife habitat. To better inform BHG development, our findings would need to be corroborated by future studies that examine more precise habitat characterizations and their aptness to specific wildlife species of interest and forest types.

Our choice modeling results suggest policy and guideline developers should consider BHG attributes in aggregate rather than in isolation. For example, when analyzed in isolation, a preference for BHGs requiring minimal amounts of CWD retention was identified. Similarly, strong preferences for spread out dispersions were expressed. These findings reflect previous research suggesting debris removal and distribution have important economic impacts (Ghaffariyan et al., 2011; Sullivan et al., 2011; Moskalik, Sadowski, Sarzyński, & Zastocki, 2013). Dispersion and removal, however, had almost no impact on BHG preference profiles when stumpage price and wildlife habitat quality were considered at the same time. Allocation and dispersion of debris were not influential in our policy profile simulation because wildlife habitat quality and stumpage price mattered much more. In fact, our sample preferred an increased quantity of debris retention and piled CWD in the most preferred policy profile. This result suggests that analyzing particular attributes of woody biomass harvesting in isolation may not be a suitable method for developing BHGs in many cases.

Our results apply to national standards and certification efforts that are informed by sustainability indicators telling us how, when, or where woody biomass removals should take place (Lal et al., 2011). Indicators, such as the attributes and their levels in this study or the 37 offered by Lal et al. (2011),[8] may indeed help achieve sustainability. However, comprehensive indicators may not suit every forest, region, or woody biomass market. In our case, it is possible that despite gleaning stakeholder perspectives across four states, our results would vary as ecological, economic, and social contexts differ. For standards and certification initiatives to account for these potential differences and better achieve representativeness, scholarly efforts should establish how indicators might change depending on variability within stakeholder perspectives as well as geographic and ecological contexts.

Finally, multiattribute assessments can play an important role in the push for carbon neutral energy and establishing sustainable timber markets. The findings of this study highlight a need for enhanced consideration for wildlife habitat, geographic and ecological context, and variability within stakeholder perspectives to develop a strong market for woody biomass in the southeastern United States. These findings were achieved with a choice modeling approach. Multiattribute studies can uncover previously overlooked relationships between attributes that make BHGs more likely to succeed in practice. Additionally, these studies can reveal overlooked stakeholder commonalities and differences to create viable wood-to-energy guidelines, codes, and policies (Aguilar & Saunders, 2011; Evans, Perschel, & Kittler, 2013) and advance our understanding of how actors in the wood-to-energy movement may gauge and attain the common interest to better meet energy, ecological, economic, and social objectives.

NOTES

1. Balanced overlap means the levels within a task are repeated to a moderate degree.
2. There was only one survey, but "the idea is to improve measurement of the effects of the attribute levels by ensuring a high degree of variability in the choice tasks across individuals" (Sawtooth Software, n.d., pp. 12–13).
3. NC: American Loggers Council; NC Woodlands; NC Roster of Registered Foresters*; American Tree Farm System; Society of American Foresters; NC Association of Professional Loggers*; Forest Guild; NC Forestry Association.*
4. SC: SC Registered Foresters*; SC Timber Producers*; SC Forestry Association; American Loggers Council; American Tree Farm System; Society of American Foresters; Forest Guild; SC Association of Consulting Foresters.
5. VA: American Loggers Council; VA Sharp Logger Program; Virginia Forest Landowner Education Program; American Tree Farm System; Society of American Foresters; Virginia Association of Consulting Foresters; Forest Guild; VA Loggers Association.
6. GA: American Loggers Council; GA Association of Consulting Foresters*; American Tree Farm System; Georgia Master Timber Harvesters*; Society of American Foresters; Forest Landowners Association; Forest Guild.

NOTE: *Denotes emails sent via direct email from the research team rather than by organization to its members.

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NOTE: Environmental nonprofit organizations are not listed per state because their participation is uncertain. We approached the National Wildlife Federation, TNC, Sierra Club, Southern Sustainable Resources, and Conservation Fund.

7. Three organizations used their periodic newsletters: American Tree Farm System; VA Sharp Logger; Virginia Forest Landowner Education Program.

8. Lal et al. (2011) discussed nine criteria and 37 indicators for woody biomass harvesting.

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