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Perceptions on Climate Change Correlate with Willingness to Undertake Some Forestry Adaptation and Mitigation Practices

Melanie Lenart and Christopher Jones

Results from a survey taken anonymously by 1,029 US-based respondents in forest management and academia highlight how individuals' perceptions about climate change correlated with their willingness to consider management prescriptions for forest ecosystems. About two-thirds of respondents identified themselves as having a professional land management role, and most of the remainder specialized in research or education. In most cases, respondents' willingness to try specific adaptation or mitigation measures related to the degree to which they agreed that "climate change is occurring because of human activities that release greenhouse gases to the atmosphere." The survey results are considered with a focus on which proposed practices and types of climate information received the most acceptance or resistance. For instance, respondents across the spectrum of climate change perceptions supported efforts to thin overly dense forests and opposed options to sequester carbon by promoting the woody invasion of grasslands or ignoring biodiversity.

Keywords: climate change, adaptation, mitigation, climate records, forest management

US forests and wood products sequestered about 730 million tons of carbon a year between 2005 and 2008 (Heath et al. 2011), after accounting for carbon released in prescribed fires, wildfires, and biomass energy use. That amounted to roughly 14% of annual US carbon emissions for the period ending in 2011 (US Environmental Protection Agency 2013). However, their ability to continue sequestering carbon at this rate could be disrupted by disturbances and extreme events related to both natural variability and climate change, including hotter droughts (Anderegg et al. 2013), large-scale pest infestations, and crown fires (Fettig et al. 2013).

Because of this concern about climate change impacts to ecosystems and the potential release to the atmosphere of some of the carbon stored in forests, forestry researchers and professionals in the USDA Forest Service, National Park Service, and other agencies have been called on to produce planning documents that address climate change and recommend ways to adapt to it and mitigate it (Joyce et al. 2009, National Park Service 2010, Heath et al. 2011, USDA Forest Service 2011, Melillo et al. 2014). Private forest owners also are beginning to consider whether and how climate change might affect their land holdings and how they might adapt (American Forest Foundation 2009).

Adaptation considerations gained importance as it became clear that international policy efforts were not going to prevent climate change (Intergovernmental Panel on Climate Change [IPCC] 2007, 2013, Solomon et al. 2009). The scientific literature on climate change adaptation increased 5-fold or more over the decade ending in 2005 (Janssen 2007). Despite this, the general consensus is that scientists and managers are in the early stages of understanding adaptation science (Kerr 2011). Lemieux et al. (2013) tested perceptions by resource managers at two public lands agencies and found that internal performance on climate change adaptation was perceived as low, and Petersen et al. (2013) found that Great Lakes resource managers reported far more feasible climate change adaptation actions than those they identified as being undertaken by their agencies. The latter also found that managers gave many different definitions for

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Affiliations: *Melanie Lenart (mlenart@e-mail.arizona.edu), University of Arizona, Department of Soil, Water and Environmental Science, Tucson, AZ. Christopher Jones (ckjones@cals.arizona.edu), University of Arizona, Gila County Cooperative Extension, Globe, AZ.*

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climate change adaptation. For our purposes, we used the definition by Millar et al. (2007) that natural resource adaptation strategies were "actions that help ecosystems accommodate changes adaptively" and that mitigation strategies were "actions that enable ecosystems to reduce anthropogenic influences on global climate."

Even as US foresters managing public lands consider climate change adaptation and mitigation in planning decisions, some Americans continue to vacillate in their concern about climate change and whether they consider it anthropogenic (Leiserowitz et al. 2010, 2013). Although several research articles explored potential management practices that might help forests adapt to and mitigate climate change (Spittlehouse and Stewart 2003, Millar et al. 2007, Joyce et al. 2009, Keskitalo 2011, Littell et al. 2012, Olander et al. 2012, Fettig et al. 2013), few studies have tested whether forest managers' perceptions on climate change might affect their adaptation and mitigation management decisions (Labriole and Luzadis 2011). One exception is Blennow and Persson (2009), who found a significant positive association ($P < 0.0001$) between Swedish forest owners' strength of belief in climate change and whether they had adapted their forest management to consider climate change.

Research on possible connections between climate change perceptions and forest adaptation and mitigation management among Americans should be useful for US forest managers and for scientists and educators working in the boundary/interface organizations serving them (Osmond et al. 2010), such as the Cooperative Extension system, climate science programs, and other science translators. To gather information that could help identify which adaptation and mitigation practices respondents might be willing to consider or implement, we administered an anonymous survey (see Supplemental Material S1).[S] Jones and Lenart (2014) compare results by sector, whereas in this article we focus on comparing results through a filter of respondents' perceptions on whether or not climate change is anthropogenic. We hypothesized that climate change perceptions would correlate with respondents' expressed willingness to engage in proposed management practices.

It might seem obvious that forest managers' perceptions about whether climate change is anthropogenic—and thus that the ongoing temperature rise and related changes are likely to continue long into the future as human activities change the atmospheric composition of greenhouse gases (IPCC 2014)—would affect their willingness to implement management decisions designed to adapt to and mitigate anthropogenic climate change. However, the scientific literature testing this correlation is sparse. We also report our results concerning climate change perceptions, climate records and information, and climate model projections. These findings are discussed in the context of their potential influence on respondents' willingness to consider forest adaptation practices.

Because risk management analysis has been recommended as a robust means for considering climate change (e.g., Kunreuther et al. 2013, IPCC 2014), our results for adaptation are considered in the context of a framework for communicating risk management developed by Wood (2010). Wood placed the findings from a meta-analysis of hundreds of risk management studies (Wood et al. 2012, Bourque et al. 2013) into the context of climate change, recommending that communicating risk works best when those involved follow a number of rules, including the following:

1. Focus on actions people can take.
2. Explain the beneficial consequences of the recommended actions.
3. Use evidence-based approaches.
4. Use multiple sources of information.
5. Convey what other people have done.

Even though we use a risk management communication framework to evaluate our adaptation results, we recognize that forest managers operate in complex institutional and social environments that do not lend themselves to simplistic management prescriptions (Archie et al. 2012, Bierbaum et al. 2013). Jantarasami et al. (2010) found that institutional barriers limited agency ability to take adaptation action. Still, knowledge and communication of knowledge will be crucial to managers' capacity to take action on forest adaptation options when opportunity permits. The results described here can give forest managers insights about how their colleagues' perceptions on anthropogenic climate change might relate to their willingness to undertake specific management practices and also on the types of climate records and information considered most useful.

Methods

For our survey population, we targeted forest managers, researchers at universities and government agencies, and Cooperative Extension educators. We distributed the survey as an electronic link to the members of the Association of Natural Resource Extension Professionals (about 460 members, with 87 responding) and the Society of American Foresters (about 14,000 members), with the survey open from May 17 to 25, 2011. About 90% of respondents filled out the electronic survey ($n = 926$), and the remaining 10% filled out the survey manually during the Society of American Foresters-sponsored National Workshop on Climate and Forests held in Flagstaff, Arizona, from May 16 to 18, 2011. The downloaded data were analyzed using statistical programs

Management and Policy Implications

The results reported here might give forest managers insight about which specific adaptation and mitigation practices are likely to be supported (or not) by their colleagues in relation to or regardless of stance on climate change. The forestry and research community surveyed generally supported some practices that can improve the resiliency of forests to weather extremes and climate change, such as conducting thinning treatments and prescribed burns and detecting and removing exotic invasive species. These are logical program areas regarding climate change adaptation and mitigation to support and to request support for. The results were mixed for increasing landscape connectivity and encouraging natural and assisted species migration, but most respondents were at least willing to learn more about these practices. Supporting research and developing best management practices for these and related practices might help forests and the many species they support adapt to long-term climate change.

[S] Supplementary data are available with this article at http://dx.doi.org/10.5849/jof.13-051.

developed by the Statistical Analysis System and IBM SPSS, Inc.

Survey respondents were self-selected in a nonrandom sampling of target groups. Whereas purposive sampling accepts respondents up to a certain number (Singleton and Straits 1999), our sampling effort adopted a related approach of accepting respondents during a prespecified time frame. Petty and Cacioppo (1996) suggest that researchers can forego the use of a randomly selected population when their intent is mainly to test a theory about whether two variables are related, as it was here.

Our hypothesis was that respondents' perceptions on whether climate change is anthropogenic would influence their level of willingness to consider adaptation or mitigation responses to climate change and perceptions of specific climate records. Most of the adaptation and mitigation questions posed to respondents were based on practices suggested by Millar et al. (2007) and Joyce et al. (2009). To test our hypothesis, we compared one variable—respondents' perceptions on whether climate change was "occurring because of human activities that release greenhouse gases to the atmosphere," known here as whether climate change was anthropogenic—with a series of other variables relating to the following:

- Climate change perceptions (Table 1).
- Forest adaptation management options (Table 2).
- Mitigation management options (Table 3).
- Confidence in specific climate and proxy records (Table 4).
- The potential need for specific climate information (Table 5).

Tables 1–5 list the questions as they were administered in the survey, including the bold formatting (column 1), but questions are presented in order of highest to lowest level of overall acceptance based on the mean of all respondents (column 2). χ^2 tests were used to consider whether responses regarding adaptation and mitigation practices and climate records and information were related to respondents' level of confidence that climate change was anthropogenic. For the latter question, options included "not at all confident," "slightly confident," "confident," "very confident," and "extremely confident" that climate change was anthropogenic. The comparison tested the probability of the null hypotheses that the two variables were independent ($\alpha = 0.05$). Because both categories compared in the cross-tabulation were ordinally ranked, Kendall's *tau-b* was used (columns 3 and 4 of Tables 1–5). Kendall's *tau-b* test considers whether correlations show a trend for anthropogenic climate change perceptions (based on all five groups of responses) with individual questions.

In addition, we used Tukey honestly significant difference (HSD) *t*-tests to identify significant differences between groups. Whereas the Kendall's *tau-b* test considers statistical significance based on how all the responses correlate to each other, the Tukey *t*-test indicates when a category registers a statistically significant response from at least one other category. The Tukey *t*-test results for all five categories (available on request) generally showed a consistent trend, so because of space considerations, we report the results for only three of the five categories: those who are "not at all confident" that climate change is anthropogenic (column 5); those who are "confident" it is (column 6); and those who are "extremely confident" that it is (column 7).

We identified proposed management measures or climate records/needs as "potentially polarizing" when at least one group registered a statistically significant response ($\alpha = 0.05$ for the Tukey HSD *t*-test) that put members on the opposite side of supporting a measure than those with a different stance on whether climate change is anthropogenic.

Results and Discussion

About 91.4% of total respondents (n = 1,029) indicated the degree to which they considered climate change anthropogenic, if at all. Of these, about two-thirds identified themselves as having a professional land management role (n = 608), whereas most of the remainder specialized in research or education. Respondents who reported their geographic information came from around the nation, with 38.4% from the Northeast (n = 368), 25.9% from the Southeast (n = 248), 19.3% from the Northwest (n = 185), and 16.4% Southwest (n = 157).

Perceptions

One-ninth (11.1%) of respondents rejected the statement that "climate change is really occurring," whereas one-third (33.0%) rejected the statement that "climate change is occurring because of human activities that release greenhouse gases to the atmosphere." Regarding the 986 respondents who answered this latter question (excluding those who answered "I don't know or not applicable to me" and including those with roles beyond forest manager, researcher or extension educator), respondents were distributed across all five categories of perceptions: "not at all confident" (n = 329); "slightly confident" (n = 165); "confident" (n = 131); "very confident" (n = 180); and "extremely confident" (n = 181) that climate change was anthropogenic.

For comparison with other research, we note that the full spectrum of results found that about 33% of respondents rejected anthropogenic climate change ("not at all confident"), 30% were "slightly confident" or "confident" it was occurring, and 37% were convinced it was occurring ("extremely" or "very" confident). In comparison, 29% of those randomly polled by Leiserowitz et al. (2010) were "doubtful" or "dismissive," 27% were "cautious," and 39% were "alarmed" or "concerned." Thus, even though our sample was not randomly selected, our respondents approximately conformed to patterns identified by researchers who did randomly sample Americans. Similarly, Carlton et al. (2014) found about 30% of the Great Lakes state foresters surveyed (n = 76) expressed disinterest in learning about forestry practices that could increase resilience to climate change, which suggests they are doubtful or dismissive or otherwise unconvinced that climate change poses a threat.

The results reported here cross-tabulate respondents' stance on whether climate change is anthropogenic to their responses to the following categories: climate change perceptions (Table 1); forest adaptation management options (Table 2); mitigation management options (Table 3); confidence in specific climate and proxy records (Table 4); and perceived need for specific climate information (Table 5).

These results apply only to the population of respondents. It would take additional research to test whether these results apply to the US population as a whole (Yeager et al. 2011). However, it is worth mentioning that when differences among respondents' willingness to consider or accept specific adaptation management practices were tested by role, comparing university-affiliated respondents to forestry practitioners, perceptions transcended role; when statistically significant differences registered, they related to respondents' stance on whether climate change was anthropogenic rather than their professional role (results of this comparison

Table 1. Foresters' perceptions of climate change.

Questions. Means relate to the responses for "Please rank the following regarding the amount of confidence you have for each question." Responses were: 0 = "not at all confident," 1 = "slightly confident," 2 = "confident," 3 = "very confident," and 4 = "extremely confident."	Mean for all groups	Kendall's *tau-b*		Categories relating to confidence that climate change is anthropogenic		
		Correlation	*P*	Not at all	Confident	Extremely
P1. How confident are you that **climate change is really occurring?**	2.65	0.670	0.000	1.34*	2.68*	3.97*
P2. How confident are you that **you have enough information** to form a valid opinion about whether climate change is occurring?	2.26	0.484	0.000	1.70	1.95	3.71*
P3. How confident are you that the **majority of scientists** think climate change is occurring because of human activities?	2.13	0.732	0.000	0.52*	2.27*	3.66*
P4. How **worried** are you about climate change? (Note: The answers to this question were improperly worded, as here, but respondents seemed to compensate.)	1.87	0.702	0.000	0.37*	1.98*	3.27*
P5. How confident are you that you **understand what natural resources are likely to be affected** by climate change?	1.87	0.155	0.000	1.80	1.74	2.40*
P6. How confident are you that you have **observed** climate change or its impacts firsthand?	1.70	0.530	0.000	0.65	1.78*	2.94*
P7. How confident are you that you **know the right questions to ask** about climate change?	1.63	0.111	0.000	1.80	1.37*	2.22*
P8. How confident are you that **you know where to find the necessary resources** to answer questions you have on climate change?	1.62	0.183	0.000	1.55	1.41	2.24*
P9. How confident are you that you **know what mitigation actions to take** regarding climate change?	1.19	0.091	0.002	1.30	0.98	1.65*
P10. How confident are you that you **know what adaptation efforts to make** regarding climate change?	1.16	0.024	0.414	1.39	0.99	1.47

* Value is statistically significant from all other responses, using a Tukey *t*-test and (α = 0.05).

are available on request). Because of this finding, the results reported here use the 2011 sample size of all respondents rather than narrowing the sample size to the approximately two-thirds of respondents who indicated that their role included land management.

In most cases, the results bore out our hypothesis that the degree to which respondents agreed that climate change was anthropogenic would relate in a statistically significant way to their willingness to consider specific adaptation or mitigation measures (Tables 2 and 3) and perceptions on climate change, climate records, and climate information (Tables 1, 4, and 5). For the Tukey HSD *t*-test results reported in Tables 1–5 (columns 5–7), the level of acceptance for each category typically increased along the spectrum of confidence that climate change is anthropogenic. As indicated by the *P* values for Kendall's *tau-b* (column 4, Tables 1–5), we were able to reject the null hypothesis that the two variables were independent in all but 6 of 72 cases (P10, A1, M1, M2, M12, and M14 in Tables 1–3). Of these, it is notable that confidence that climate change was anthropogenic had no relation to confidence that the respondents knew what adaptation efforts to pursue (Table 1, P10, $P = 0.414$). This result conforms to literature reports that the science of climate change adaptation remains mostly untested (Kerr 2011, Bierbaum et al. 2013).

Adaptation

Several management practices that potentially could help forests adapt to climate change were widely accepted, whereas others were rejected by respondents across a broad set of beliefs (Table 2). Respondents across the spectrum of perceptions supported efforts to thin overly dense forests (A1; see also Figure 1). The overall mean of 3.21, with 3 representing "very willing," was close to the mean in each category of climate change stance, and we could not reject the null hypotheses that the two variables were independent ($P = 0.086$). The practice with the next highest amount of support, conducting prescribed burns (A2), was also popular but not independent ($P = 0.048$). Another fire-related management tool—the practice of constructing fire breaks (A7, more accurately called fuel breaks)—registered among the seven practices that received an overall rank of 2 ("willing" to adopt or advise on it) or above, but responses correlated significantly with anthropogenic climate change perceptions ($P = 0.0006$).

Another theme that emerged as widely supported was handling of exotic invasive species. Creating early detection programs (A4) and conducting rapid removal programs on newly detected species considered invasive (A6) received support from all groups. Meanwhile, only those who were "extremely confident" that climate change was anthropogenic generally supported the concept of allowing the invasion of "neonative" species (A15), defined here as species "that seem likely to be suited to changing climate conditions."

Two other adaptation practices generally embraced by respondents involved fostering connected landscapes (A3) and its corollary, lowering fragmentation of the landscape (A5). However, even though these practices ranked above 2 ("willing" to adopt or advise on it) overall, they were potentially polarizing by our definition; the group of respondents who were "not at all confident" that climate change was anthropogenic averaged below "willing" for both practices, whereas those who were "extremely confident" were more enthusiastic than other respondents.

Four other questions addressing adaptation for species protection also were considered potentially polarizing by our standards: creating local refugia for endangered species (A9); augmenting local endangered species populations via captive-bred populations (A11); and moving species into noncolonized areas that might be more climatically suitable given ongoing climate change, whether following disturbance (A17) or as a means of expanding endangered species populations (A19).

Another theme in the adaptation questions—whether to expand seed-collecting efforts beyond local species—fell midway between 1 ("willing to learn more about it") and 2 ("willing" to adopt or advise on it). Most respondents were generally supportive of the standard practice of stocking soil with seeds from local plants only (A8). Only those who were "extremely confident" about anthropogenic climate change were, in general, willing to augment genetic diversity by collecting seeds from adjacent zones (A16) or to stock soils with seeds from different

Table 2. Foresters' willingness to adopt adaptation responses to climate change.

Questions. Means relate to the responses for "How willing would you be to adopt or advise on the following adaptation practices as part of your management toolbox?" Responses were: 0 = "not at all willing," 1 = "willing to learn more about it," 2 = "willing," 3 = "very willing," and 4 = "extremely willing—it's a primary tool."	Mean for all groups	Kendall's *tau-b*		Categories relating to confidence that climate change is anthropogenic		
		Correlation	*P*	Not at all	Confident	Extremely
A1. Thin trees out of overly dense forests to reduce the risk of large-scale stand mortality from drought and/or wildfire.	3.21	−0.049	0.086	3.30	3.14	3.24
A2. Conduct prescribed burns in forests in an effort to restore or retain natural fire cycles.	2.93	0.055	0.048	2.82	2.74	3.18
A3. Foster connected landscapes, such as by retaining or gaining protection of riparian zones, to promote the natural migration of species.	2.56	0.386	0.000	1.68*	2.74	3.23*
A4. Create early-detection programs to **detect new invasions** of undesired exotic species.	2.49	0.287	0.000	1.99	2.53	3.04
A5. Enlarge management areas or otherwise **lower fragmentation of the landscape** to promote the preservation of species.	2.45	0.395	0.000	1.52*	2.57	3.16*
A6. Conduct **rapid removal programs** on newly detected species considered invasive.	2.44	0.191	0.000	2.12	2.51	2.80
A7. Construct fire breaks in key areas.	2.35	0.081	0.006	2.20	2.23	2.58
A8. Stock soils with seeds from local plants only (i.e., following the existing standard of using **local germplasms only**).	1.99	0.177	0.000	1.70	2.11	2.34
A9. Create local refugia for endangered species.	1.85	0.376	0.000	1.12*	1.97	2.38
A10. Consider adopting management practices even if they have a high level of uncertainty in some situations so they could **serve as experimental efforts**.	1.77	0.314	0.000	1.25*	1.81	2.27*
A11. Augment endangered species populations via introduction of captive-bred animals into the local area where they already exist.	1.75	0.293	0.000	1.25	1.82	2.37*
A12. Erect snow fences where early snowmelt could be a problem.	1.65	0.274	0.000	1.14	1.72	2.13
A13. Make an effort to **use redundancy** (such as also planting on sites that are historically non-optimal for a specific species or community) when restoring a site following disturbance.	1.57	0.339	0.000	1.05*	1.58	2.17*
A14. Stock soils with seeds from plants outside of the standard range (i.e., those from environments suitable to future climate)—**using different genotypes of the same species that exist locally**.	1.56	0.237	0.000	1.21	1.56	1.99*
A15. Allow the invasion of "neo-native" species—in effect, those that seem likely to be suited to changing climate conditions.	1.53	0.230	0.000	1.20	1.53	1.97*
A16. Relax genetic management guidelines to include the option of augmenting genetic diversity by collecting from adjacent seed zones or populations for restoration projects.	1.52	0.132	0.000	1.34	1.52	1.81
A17. Promote the expansion—**following major disturbance**—of plants or animals into different locations that may be climatically suitable for them.	1.50	0.306	0.000	1.01*	1.56	1.90*
A18. Consider "**re-aligning**" the system with different species if it has been pushed too far out of historic conditions—whether by manipulation or disturbance—when considering restoration.	1.49	0.277	0.000	1.08	1.51	1.87
A19. Promote the **expansion of endangered species populations** by introducing animals into a new area deemed suitable for them because of changed climate.	1.37	0.384	0.000	0.77*	1.40	1.95*
A20. Stock soils with seeds from plants outside of the standard range (i.e., from environments more suitable to future climate)—**using species that do not currently occur** in the local area.	1.13	0.190	0.000	0.85	1.26	1.38

* Value statistically significant from all other responses, using a Tukey *t*-test and ($\alpha = 0.05$).

Figure 1. The ponderosa pine stand on the right has received a thinning treatment to remove many of the smaller trees that can serve as fuel ladders to carry wildfire into the crowns of trees. The image on the left shows the overly dense "doghair thickets" of small trees common in untreated ponderosa pine forests throughout Arizona's White Mountains. Thinning treatments for overly dense dry forest was widely supported by respondents in a national survey on climate change adaptation and mitigation practices. Photos by Melanie Lenart.

Table 3. Foresters' willingness to adopt mitigation responses to climate change.

Questions. Means relate to the responses for "How willing would you be to adopt or advise on the following mitigation practices as part of your management toolbox?" Responses were: 0 = "not at all willing," 1 = "willing to learn more about it," 2 = "willing," 3 = "very willing," and 4 = "extremely willing–it's a primary tool."	Mean for all groups	Kendall's *tau-b*		Categories relating to confidence that climate change is anthropogenic		
		Correlation	*P*	Not at all	Confident	Extremely
M1. Thinning overly dense stands to reduce the risk of severe fire or stand-destroying disturbance.	3.25	−0.048	0.093	3.36	3.13	3.32
M2. Using forest **biomass to produce energy** when appropriate.	2.83	−0.037	0.212	2.92	2.59	2.88
M3. Change your **personal energy-consumption** habits to reduce your carbon footprint.	2.47	0.518	0.000	1.23*	2.56*	3.45*
M4. Enhance carbon sequestration in **wood** and aboveground biomass.	2.35	0.318	0.000	1.71*	2.32	3.01*
M5. Retain carbon stored in natural resources (wood, fiber, soil) by **protecting existing conservation areas**.	2.23	0.410	0.000	1.41*	2.24	3.13*
M6. Enhance carbon sequestration in soils and belowground biomass.	2.20	0.355	0.000	1.52*	2.07	2.97*
M7. Retain carbon stored in natural resources (wood, fiber, soil) **by designating additional conservation areas**.	1.86	0.488	0.000	0.82*	1.97	2.92*
M8. Speed rotation of timber harvesting in order to promote the transfer of carbon into forest products.	1.58	−0.099	0.001	1.80	1.55	1.49
M9. Consider manipulating local species within a forest stand to **favor species that promote carbon sequestration**.	1.40	0.235	0.000	0.96*	1.41	1.67
M10. Enhance carbon sequestration by **planting "neo-native"** species expected to thrive because of climate change.	1.22	0.288	0.000	0.77*	1.24	1.55
M11. Purchase carbon "credits" to help offset your personal carbon footprint.	1.03	0.481	0.000	0.26*	1.00	1.78*
M12. Allow or **promote woody invasion of grasslands** to enhance carbon sequestration in local locations where carbon storage increases with woody invasions.	1.01	0.026	0.383	0.92	1.05	1.01
M13. Enhance carbon sequestration in forests by **planting exotic species**.	0.69	0.067	0.026	0.56	0.69	0.80
M14. Overlook issues such as biodiversity and habitat value to promote carbon sequestration.	0.50	−0.10	0.738	0.46	0.54	0.49

* Value is statistically significant from all other responses, using a Tukey *t*-test and ($\alpha = 0.05$).

genotypes of existing species (A14). The proposed management tool of stocking soils with seeds of species from outside the local area (A20) received the lowest ranking overall in the adaptation questions.

Experimental adaptation efforts generally received little support from respondents. The two extremes were significantly different from other groups in their lack of support ("not at all confident" that climate change is anthropogenic) or overall support ("extremely confident") for adopting uncertain management practices as experimental efforts (A10), using redundancy that would include planting species that have been historically nonoptimal at a site (A13) and promoting the expansion of potentially suitable species following a disturbance (A17). None of these measures had much support except in the most convinced group, and even their support was relatively lackluster for the proposal to realign the system with different species if it has been pushed too far out of historic conditions (A18).

Mitigation

Respondents from all categories were highly supportive of efforts to thin overly dense stands for mitigation (Table 3, M1), much as they had supported a similar measure for adaptation purposes. Respondents also supported using forest biomass to produce energy "when appropriate" (M2), with no indication that their support was correlated to confidence in anthropogenic climate change ($P = 0.212$). On the other hand, it is possible that the groups would have quite different definitions of what should be considered appropriate, which was not defined here.

In response to the question about changing their personal energy-consumption habits (M3), the groups split into statistically different categories, with support for the concept increasing with conviction that climate change related to human activities. Respondents were less supportive of purchasing carbon credits to help offset their personal carbon footprints (M11), with an average response of willing only to learn more about it, although support increased somewhat as conviction about anthropogenic climate change did ($P < 0.0001$).

Management actions for sequestering carbon received varying levels of support. All groups except the one least convinced of anthropogenic climate change supported measures to enhance carbon sequestration in wood and aboveground biomass (M4), and in soils and belowground biomass (M6). Those with little or no confidence that climate change was anthropogenic showed weak support for two measures supported by the other groups: retaining carbon by protecting existing conservation areas (M5) and by designating additional conservation areas (M7).

No group provided support, beyond willingness to learn more about some of them, for efforts to enhance carbon sequestration by favoring some species over others (M9), planting "neo-native species" expected to thrive because of climate change (M10), planting exotic species (M13), allowing woody invasion of grasslands (M12), or overlooking biodiversity and habitat value to promote carbon sequestration (M14). For the latter two, Kendall's *tau-b* values suggest that results were independent of stance on whether climate change was anthropogenic (Table 3, column 4). The concept of speeding the rotation of timber harvesting (M8) received only lukewarm support, with a slight trend toward more support from those who were skeptical about anthropogenic climate change. As it happens, the science behind this concept remains unsettled; for instance, Maness (2009) suggests that extending rather than decreasing the rotation length of timber would sequester more carbon.

Climate Records and Perceived Needs

Confidence in 13 types of climate-related records (Table 4) and perceived usefulness of 14 types of climate information (Table 5) were also compared with the level

Table 4. Foresters' perceptions of climate records.

Questions. Means relate to the responses for "Please rank the following regarding the amount of confidence you have for each question." Responses were: 0 = "not at all confident," 1 = "slightly confident," 2 = "confident," 3 = "very confident," and 4 = "extremely confident."	Mean for all groups	Kendall's *tau-b*		Categories below relate to confidence that climate change is anthropogenic		
		Correlation	*P*	Not at all	Confident	Extremely
R1. Instrumental records of **precipitation** for the site of the weather station.	2.61	0.268	0.000	2.20	2.48	3.06
R2. Instrumental records of temperature for the site of the weather stations.	2.59	0.340	0.000	1.98*	2.54	3.17*
R3. Tree ring records of **fire cycles**.	2.43	0.217	0.000	2.16	2.30	2.84
R4. Pollen records of past species distribution.	2.23	0.296	0.000	1.80	2.26	2.65
R5. Sediment records using **charcoal to identify large wildfires** from the distant past.	2.16	0.270	0.000	1.79	2.18	2.61
R6. Ice core records of **carbon dioxide levels** (from air bubbles in the cores).	2.07	0.441	0.000	1.38	1.99*	2.87*
R7. Tree ring records of **precipitation**.	2.06	0.248	0.000	1.71	1.97	2.48
R8. Sediment records using **oxygen isotopes** to identify long-term **temperature** changes on the planet.	1.86	0.448	0.000	1.15	1.78	2.63
R9. Ice core records of local **temperature**.	1.86	0.406	0.000	1.24	1.79	2.59*
R10. Instrumental records of temperature when weather station data are extrapolated to provide continuous values across the landscape.	1.62	0.423	0.000	0.94*	1.59	2.30*
R11. Tree ring records of **temperature**.	1.60	0.340	0.000	1.09	1.51	2.29*
R12. Instrumental records of **precipitation when weather station data are extrapolated** to provide continuous values across the landscape.	1.58	0.363	0.000	1.03*	1.55	2.20*
R13. Tree ring records of **streamflow**.	1.24	0.284	0.000	0.82	1.20	1.83*

* Value is statistically significant from all other responses, using a Tukey *t*-test and ($\alpha = 0.05$).

Table 5. Foresters' interest in climate information.

Questions. Means relate to the responses for "Within this topic, how important is it to you to have more information on the following?" Responses were: 0 = "not at all important," 1 = "slightly important," 2 = "important," 3 = "very important," and 4 = "extremely important."	Mean for all groups	Kendall's *tau-b*		Categories below relate to confidence that climate change is anthropogenic		
		Correlation	*P*	Not at all	Confident	Extremely
N1. Records of changes in **average precipitation** from **weather stations**.	2.21	0.290	0.000	1.77	2.26	2.62
N2. Records of changes in **precipitation extremes** from weather **stations**.	2.14	0.314	0.000	1.67	2.09	2.75*
N3. Records of changes in **types of precipitation** from **weather stations**.	2.13	0.316	0.000	1.63	2.16	2.66
N4. Records of temperature extremes from **weather stations**.	2.07	0.310	0.000	1.58	2.05	2.69*
N5. Records of monthly average temperature from **weather stations**.	2.03	0.340	0.000	1.58	2.04	2.55*
N6. Projections of changes in **average precipitation** (monthly mean, seasonal changes) based on models.	1.86	0.464	0.000	1.03*	1.97	2.55*
N7. Longer proxy records of changes in **precipitation** extremes based on tree rings, geomorphological evidence and other natural archives.	1.85	0.384	0.000	1.18	1.91	2.50*
N8. Longer proxy records of changes in **average precipitation** from tree rings, sediment cores and other natural archives.	1.84	0.374	0.000	1.18*	1.99	2.41*
N9. Projections of changes in **precipitation extremes** (intensity and duration of extreme events such as drought or flood) based on models.	1.83	0.487	0.000	0.91*	1.85	2.67*
N10. Projections of changes in **types of precipitation** (rain versus snow, likelihood of hail) based on models.	1.82	0.511	0.000	0.88*	1.90	2.67*
N11. Projections of temperature extremes (highs, lows, heat waves, frost/thaws) based on models.	1.81	0.514	0.000	0.83*	1.89	2.64*
N12. Longer proxy records of temperature extremes based on tree rings and sediment cores and other natural archives.	1.80	0.390	0.000	1.09*	1.93	2.47*
N13. Longer proxy records of monthly average temperature based on tree rings, sediment cores and other natural archives.	1.78	0.403	0.000	1.08	1.91	2.47*
N14. Projections of monthly average temperature (mean, maximum, minimum) based on models.	1.67	0.438	0.000	0.90*	1.77	2.37*

* Value is statistically significant from all other responses, using a Tukey *t*-test and ($\alpha = 0.05$).

of conviction that climate change was anthropogenic. Many temperature records were potentially polarizing (see R9, R10, and R11 in Table 4 and N11, N12, N13, and N14 in Table 5); the difference among extremes was fairly wide even for some questions for which the overall rank indicated general acceptance (R2, N4, and N5). In all 10 cases, those who were "extremely confident" that climate change was anthropogenic significantly favored temperature records more than other groups. In half of these cases, those who were "not at all confident" were significantly less trusting of or interested in temperature records.

Respondents ranked tree-ring records of fire cycles (R3) as far more reliable than tree-ring records of temperature (R11) or streamflow (R13), or most other records, including records extrapolated from weather stations of temperature (R10) and precipitation (R12). The latter ranked below "confident" by all respondents except those most convinced that climate change was anthropogenic.

Regarding perceived needs, projections and proxy records ranked far below observational records from weather stations (Table 5). In fact, observational records from weather stations were the only climate data respondents considered "important" overall for management purposes (N1–N5). Carlton et al. (2014) also found that Great Lakes

Table 6. Broad categories of adaptation practices considered in a risk communication framework.

Risk communication traits	Thinning and fuel treatments	Efforts to manage invasive species	Movement of species to more suitable climates	Expanding landscape protection
1. Actions people can take specified.	Covington et al. (1997), Allen et al. (2002)	Brundu et al. (2001), DiTomaso et al. (2013)	Only in general terms so far	Lawler et al. (2010)
2. Beneficial consequences of actions explained.	Stephens et al. (2012)	Brundu et al. (2001), DiTomaso et al. (2013)	Not yet documented	Gilbert-Norton et al. (2010); benefits for targeted species explained
3. Evidence-based approaches used.	Covington and Moore (1994), Swetnam and Baisan (1996)	Brundu et al. (2001), DiTomaso et al. (2013)	Experiments in progress; Williams and Dumroese (2013) review efforts	Gilbert-Norton et al. (2010), Lawler et al. (2010)
4. Multiple sources of information given.	Above sources and Westerling et al. (2006), Allen et al. (2010)	Many of the chapters in the books cited in this column	Experiments in progress	Gilbert-Norton et al. (2010) analyzed 78 corridor studies, Lawler et al. (2010)
5. Actions other people have done conveyed.	Stephens et al. (2012)	Sheley and Petroff (1999), DiTomaso et al. (2013)	Introductions of novel species in past have caused problems (e.g., see Sheley and Petroff [1999], DiTomaso et al. [2013])	Gilbert-Norton et al. (2010) analyzed 78 corridor studies

state foresters listed historic climate records and trends in rainfall patterns and temperature shifts among responses to the open-ended question of what types of weather and climate information would help them do their jobs. Interestingly, projections of monthly average temperature based on climate models, which are the most reliable projections climate modelers have to offer (Bader et al. 2008), ranked at the bottom of our respondents' list of need priorities (N14).

Climate Change and Communicating Risk

The results bring forth useful information for considering how forest practitioners and researchers perceive adaptation and mitigation practices, as well as which climate records they tend to value. They highlight that, for the population surveyed, perceptions on climate change often correlate with willingness to try specific adaptation and mitigation practices, with some notable exceptions. Because the exceptions may help define the rule, it is worth considering what makes the most favored practice considered here—thinning trees from overly dense forests to reduce the risk of large-scale mortality from drought and/or wildfire—so highly ranked among these respondents, regardless of stance on anthropogenic climate change. Some respondents commented that this practice was useful regardless of changing climate, which may help explain its popularity. At the same time, thinning treatments clearly offer a means of adapting dry forests to ongoing climate change, which includes the potential for longer wildfire seasons and more big fires of 1,000 acres or more (Stephens et al. 2012). Westerling et al (2006) highlighted the role of warming temperatures in the big fire years of the West, finding that these years typically featured high spring temperatures and correspondingly early snowmelt.

To consider the reason that some proposed climate change adaptation measures were more accepted than others, we used the framework developed by Wood (2010) as described in the Introduction and summarized in Table 6 (column 1, with rules converted to traits). Supporting references or lack thereof (columns 2–5) are used to convey the presence or absence of the trait described for the adaptation measures considered in general terms.

We add two caveats for application of this framework to our adaptation research. First, regarding using "evidence-based approaches" (Table 6, trait 3), we turn to the results on climate records and perceived needs for insights. Respondents indicated that they considered observational records of temperature and precipitation generally more trustworthy (Table 4) and useful (Table 5) than records based on climate model projections, most proxy records, and extrapolations in general. The proxy records of fire cycles are considered trustworthy, but one should note that these are based on evidence (presence or absence) of a fire scar in an annual tree ring during a particular year; the results do not require extrapolation, whereas tree-ring reconstructions of temperature, precipitation, and streamflow are extrapolated from the width of full or partial tree rings.

Second, convey "what other people have done" (Table 6, trait 5) here refers to describing results of climate change adaptation practices as evaluated by observational studies, transplant experiments testing the success of varieties from difference provenances, or other controlled experiments. Experiments done with computer models would probably not suffice based on the mixed results concerning the usefulness of climate model projections (Table 5, N6, N9–11, and N14). In other words, conveying information about how climate change might affect forests is not the same as conveying how forests have responded to specific management practices.

Thinning Treatments

Thinning overly dense forests conforms to all five of the traits (Table 6) highlighted from Wood (2010). Evidence (trait 3) from multiple sources (trait 4), including well-accepted records of tree ring fire cycles (table 4, R3) has made it clear that many modern US forests have structural compositions (Covington and Moore 1994) and fire regimes (Swetnam and Baisan 1996) different from those in the past. These differences make them more susceptible to drought, stand-destroying fires (Westerling et al. 2006), and large-scale pest infestation (Allen et al. 2010, Martinez-Vilalta et al. 2012), which has led prominent fire ecologists to recommend taking action (trait 1) to conduct thinning treatments and prescribed burns. Finally, experimental and observational research showing "what others have done" (trait 5) reveal that surface fires in fire-adapted forests treated by thinning and prescribed burns are less likely to become stand-replacing crown fires.

Invasive Species versus Species Movement

The adaptation practices of detecting new invasions of undesired exotic species (Table 2, A4) and conducting rapid removal programs for invasive species (A6) were highly ranked among respondents. Using the matrix in Table 6, these practices appear to be considered actions (trait 1) with beneficial consequences (trait 2). There is evidence (trait 3) from multiple sources (trait 4) about the problems invasive species pose and documentation about what other people have done (trait 5) to combat invasive species.

Perhaps as a consequence, the potential risks that exist from actions to introduce nonnative species to new locations appear to concern many respondents. There was little overall support for measures that allowed nonnative species to colonize sites (A15 and A17 in Table 2 and M10 and M12 in Table 3) or for moving species around in general (A13, A15, A16, A17, A18, A19, and A20, all in Table 2). Even introduction of different genotypes of the same species (A14) was generally unpopular.

In the scientific literature, little effort has been made to distinguish between nonnative invasive species considered damaging and "neo-native" species moving in natural or assisted migration in response to changing conditions. In fact, scholars find it challenging to develop a definition for invasive species without referring to their effect on ecosystems, which can only be assessed after their introduction (Valéry et al. 2008). On the one hand, species composition at a site relates to climate gradients; if climate changes, species composition will need to do so as well (Fettig et al. 2013). On the other hand, some respondents' personal observations seem to suggest that even well-intended introductions of nonnative species often have unintended, sometimes drastic, consequences. As one respondent wrote:

> Not so willing with the 'neo-native' because we already have invasives problems and I'm not sure what the difference is. Also would take some research because we don't often know what the little changes do to the big ecosystem picture.

Forest managers have only just begun to consider assisted migration, so there is currently a dearth of information on assisted migration results (for a summary of ongoing studies and informal resource networks, see Williams and Dumroese [2013]).

The information pool regarding both natural and assisted migration will probably continue to grow in the decades to come, as transplant experiments test the responses of different tree populations and landscapers, individuals, and nonprofit groups move species around in planned and unplanned ways. Members of the Torreya Guardians have been moving the group's namesake pine from its native Florida to North Carolina in anticipation of a warming climate (Minteer and Collins 2010). In the meantime, the actions that people might take (Table 6, trait 1) are not necessarily beneficial (trait 2); at least, there is currently little evidence (trait 3) for beneficial consequences. Similarly, at this point there is no consensus on this management practice from multiple information sources (trait 4) regarding what other people have done (trait 5). In short, our findings on species movement support the findings by Bierbaum et al. (2013) that mechanisms for sharing information and best practices will need to be enhanced to advance these adaptation practices.

Expanding Landscape Protection

In the scientific literature, the practices of fostering connected landscapes (Table 2, A3) and lowering fragmentation of the landscape (A5) seem to be accepted as actions (trait 1) having beneficial consequences (trait 2). However, both of these practices registered statistically significant differences in willingness among respondents at both ends of the spectrum regarding perceptions on whether climate change was anthropogenic, as did mitigation efforts to protect existing conservation areas (Table 3, M5) or designate additional conservation areas (M7). Gilbert-Norton et al. (2010) published a meta-analysis of 78 corridor experiments that found a highly significant increase in species movement in the presence of corridors. This confirmation based on evidence (trait 3) will take time to work its way into the public sphere, however. Multiple groups are producing information (trait 4) on this research area, so it is possible to convey what others have done (trait 5).

Perhaps the main issue will be whether the results are considered beneficial (trait 2) to humans. The spread of species, particularly endangered species that might warrant protection that could interfere with property use, is a point of contention for some. We did not ask for political affiliation in this survey, but McCright and Dunlap (2011) found that liberals and Democrats tend to be more concerned about climate change than conservatives and Republicans. Private property rights tend to be a rallying point for conservatives, whereas support for endangered species protection is more often one for liberals. Adaptation efforts that involved endangered species were particularly unpopular with those who were "not at all confident" that climate change is anthropogenic (Table 2, A9, A11, and A19), lending support to the interpretation that political ideology may have influenced the results on expanding landscape protection.

It took many years and multiple sources of evidence in support of thinning treatments for conservatives and liberals to reach agreement that dense forests need such treatments (Lenart 2006). Thus, we might expect the issue of expanding landscape protection to facilitate species movement to take time and communication efforts, including conversations in professional networks (Jacobson et al. 2013) and science-focused collaborative partnerships (Littell et al. 2012) before it could gain comparable popularity among managers. Acceptance among managers and the public may well require the demonstration of a direct benefit not only to other species but also to humans, such as hikers, foragers, hunters, and youth educators.

Conclusion

Our results and analysis suggest that managers may be unlikely to systematically undertake some of the proposed adaptation and mitigation management activities until more research has been conducted not only on the potential risks posed by climate change but also, more specifically, on the observed benefits of undertaking the practices in question. The practices that received widespread support are those that have been tested over decades, such as thinning and prescribed burn treatments in overly dense forests, whereas many practices identified as potentially useful for climate change adaptation generated among respondents a lack of support or a potential for polarizing divisions.

Until the adaptation and mitigation scientific research can answer specific questions with definitive evidence about best practices for landowners and forest managers in a warming climate, some of these practices are likely to find lackluster support among many managers, particularly those who are not convinced that climate change is anthropogenic. In some cases, integration of management tools may require not only support from evidence-based research on how these adaptive practices apply in the field, but also an exchange of information (including verbal interactions) among managers through informal and professional networks as well as via scientific papers and technical reports and plans.

It is our hope that the findings in this study might help managers begin to prioritize adaptation and mitigation measures by providing insights on how their colleagues on different sides of the climate change perception divide responded when surveyed about specific practices. Our findings support other research showing that climate change remains a contentious issue among a significant minority of the population and that those who are not convinced that climate change is anthropogenic may in some cases be less likely to support climate change adaptation and mitigation measures in forests than those who are convinced its cause relates to human activities.

Literature Cited

Allen, C.D., A.K. Macalady, H. Chencouni, D. Bachelet, N. McDowell, M. Vennetier, T. Kizberger, et al. 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *For. Ecol. Manage.* 259:660–684.

Allen, C.D., M. Savage, D.A. Falk, K.F. Suckling, T.W. Swetnam, T. Schulke, P.B. Stacey, P. Morgan, M. Hoffman, and J.T. Klingel. 2002. Ecological restoration of southwestern Ponderosa pine ecosystems: A broad perspective. *Ecol. Appl.* 12(5):1418–1433.

American Forest Foundation. 2009. *Family forests & climate change.* Available online at www.pefc.org/images/stories/documents/external/AFF_FFCC_final.pdf; last accessed May 13, 2013.

Anderegg, W.R.L., J.M. Kane, and L.D.L. Anderegg. 2013. Consequences of widespread tree mortality triggered by drought and temperature stress. *Nat. Climate Change* 3:30–36.

Archie, K.M., L. Dilling, J.B. Milford, and F.C. Pampel. 2012. Climate change and western public lands: A survey of US federal land managers on the status of adaptation efforts. *Ecol. Soc.* 17(4):20.

Bader, D.C., C. Covey, W.J. Gutowski Jr., I.M. Held, K.E. Kunkel, R.L. Miller, R.T. Tokmakian, and M.H. Zhang. 2008. *Climate models: An assessment of strengths and limitations.* US Climate Change Science Program and the Subcommittee on Global Change Research Report, Department of Energy, Office of Biological and Environmental Research, Washington, DC. 124 p.

Bierbaum, R., J.B. Smith, A. Lee, M. Blair, L. Carter, F.S. Chapin III, P. Fleming, et al. 2013. A comprehensive review of climate adaptation in the United States: More than before, but less than needed. *Mitig. Adapt. Strateg. Glob. Change* 18:361–406.

Blennow, K., and J. Persson. 2009. Climate change: Motivation for taking measures to adapt. *Global Environ. Change* 19:100–104.

Bourque, L.B., R. Regan, M.M. Kelley, M.W. Wood, M. Kano, and D.S. Mileti. 2013. An examination of the effect of perceived risk on preparedness behavior. *Environ. Behav.* 45(5): 615–649.

Brundu, G., J. Brock, I. Camarda, L. Child, and M. Wade. 2001. *Plant invasions: Species ecology and ecosystem management*. Backhuys Publishers, Leiden, The Netherlands. 338 p.

Carlton, J.S., J.R. Angel, S. Fei, M. Huber, T.M. Koontz, B.J. MacGowan, N.D. Mullendore, N. Babin, and L.S. Prokopy. 2014. State service foresters' attitudes toward using climate and weather information when advising forest landowners. *J. For.* 112(1):9–14.

Covington, W.W., and M.M. Moore. 1994. Southwestern Ponderosa pine forest structure: Changes since Euro-American settlement. *J. For.* 92:39–47.

Covington, W.W., P.Z. Fulé, M.M. Moore, S.C. Hart, T.E. Kolb, J.N. Mast, S.S. Sackett, and M.R. Wagner. 1997. Restoring ecosystem health in Ponderosa pine forests of the Southwest. *J. For.* 95:23–29.

DiTomaso, J.M., G.B. Kyser, S.R. Oneto, R.B. Wilson, S.B. Orloff, L.W. Anderson, S.D. Wright, et al. 2013. *Weed control in natural areas in the western United States.* Weed Research and Information Center, University of California, Davis, CA. 544 p.

Fettig, C.J., M.L. Reid, B.J. Bentz, S. Sevanto, D.L. Spittlehouse, and T. Wang. 2013. Changing climates, changing forests: A western North American perspective. *J. For.* 111(3):214–228.

Gilbert-Norton, L., R. Wilson, J.R. Stevens, and K.H. Beard. 2010. A meta-analytic review of corridor effectiveness. *Conserv. Biol.* 24(3):660–668.

Heath, L.S., J.E. Smith, K.E. Skog, D.J. Nowak, and C.W. Woodall. 2011. Managed forest carbon estimates for the US greenhouse gas inventory, 1990–2008. *J. For.* 109: 167–173.

Intergovernmental Panel on Climate Change (IPCC). 2007. *Contribution of working group I to the fourth assessment report of the Intergovernmental Panel on Climate Change, 2007*, Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.). Cambridge University Press, Cambridge, UK. 996 p.

Intergovernmental Panel on Climate Change (IPCC). 2013. *Climate change 2013: The physical science basis. Working Group I contribution to the fifth assessment report of the Intergovernmental Panel on Climate Change*, Stocker, T.F., D. Qin, G.-K. Plattner, M.M.B. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P.M. Midgley (eds.). Available online at www.ipcc.ch; last accessed Dec. 30, 2013.

Intergovernmental Panel on Climate Change (IPCC). 2014. *Climate change 2014: Impacts, adaptation, and vulnerability.* Working Group II contribution to the fifth assessment report of the Intergovernmental Panel on Climate Change. Available online at www.ipcc-wg2.gov; last accessed on May 24, 2014.

Jacobson, C., A. Lisle, R.W. Carter, and M.T. Hockings. 2013. Improving technical information use: What can be learnt from a manager's perspective? *Environ. Manage.* 63:221–233.

Janssen, M.A. 2007. An update on the scholarly networks on resilience, vulnerability, and adaptation within the human dimensions of global environmental change. *Ecol. Soc.* 12(2) 1–18. Available online at www.ecologyandsociety.org/vol12/iss2/art9/; last accessed July 9, 2014.

Jantarasami, L.C., J.J. Lawler, and C.W. Thomas. 2010. Institutional barriers to climate change adaptation in US national parks and forests. *Ecol. Soc.* 15(4):33.

Jones, C.K., and M. Lenart. 2014. Forestry professionals and Extension educators vs. climate change: Implications for Cooperative Extension programming. *J. Exten.* 52(3):3FEA1.

Joyce, L.A., G.M. Blate, S.G. McNulty, C.I. Millar, S. Moser, R.P. Neilson, and D.L. Peterson. 2009. Managing for multiple resources under climate change: National forests. *Environ. Manage.* 44:1022–1032.

Kerr, R. 2011. Time to adapt to a warming world, but where's the science? *Science (News Focus)* 334:1052–1053.

Keskitalo, E.C.H. 2011. How can forest management adapt to climate change? Possibilities in different forestry systems. *Forests* 2:415–430.

Kunreuther, H., G. Heal, M. Allen, O. Edenhofer, C.B. Fields, and G. Yohe. 2013. Risk management and climate change. *Nat. Climate Change* 3:447–450.

Labriole, M.M., and V.A. Luzadis. 2011. New York Society of American Foresters' perceptions of climate change. *J. For.* 109:89–94.

Lawler, J.J., T.H. Tear, C. Pyke, M.R. Shaw, P. Gonzalez, P. Kareiva, L. Hansen, et al. 2010. Resource management in a changing and uncertain climate. *Front. Ecol. Environ.* 8(1):35–43.

Leiserowitz, A., E. Maibach, C. Roser-Renouf, G. Feinberg, and P. Howe. 2013. *Global warming's six Americas in September 2012.* Yale Univ. and George Mason Univ., Yale Project on Climate Change Communication, New Haven, CT. Available online at environment.yale.edu/climate/publications/Six-Americas-September-2012; last accessed July 9, 2014.

Leiserowitz, A., E. Maibach, C. Roser-Renouf, and N. Smith. 2010. *Climate change in the American mind: Americans' global warming beliefs and attitudes in June 2010.* Yale Univ. and George Mason Univ., Yale Project on Climate Change Communication, New Haven, CT. Available online at environment.yale.edu/climate-communication/files/ClimateBeliefsJune2010.pdf; last accessed Dec. 17, 2013.

Lemieux, C.J., J.L. Thompson, J. Dawson, and R.M. Schuster. 2013. Natural resource manager perceptions of agency performance on climate change. *J. Environ. Manage.* 114:178–189.

Lenart, M. 2006. Collaborative stewardship to prevent wildfires. *Environment* 48(7):8–21.

Littell, J.S., D.L. Peterson, C.I. Millar, and K.A. O'Halloran. 2012. US National Forests adapt to climate change through science-management partnerships. *Climatic Change* 110(1–2):269–296.

MANESS, T.C. 2009. Forest management and climate change mitigation: Good policy requires careful thought. *J. For.* 107(3):119–124.

MARTINEZ-VILALTA, J., F. LLORET, AND D.D. BRESHEARS. 2012. Drought-induced forest decline: Causes, scopes and implications. *Biol. Lett.* 8:689–691.

MCCRIGHT, A.M., AND R.E. DUNLAP. 2011. The politicization of climate change and polarization in the American public's view of global warming, 2001–2010. *Sociol. Q.* 52:155–194.

MELILLO, J., T. RICHMOND, AND G. YOHE (EDS.). (2014). *Climate change impacts in the United States: The third national climate assessment.* US Global Change Research Program. 841 p. Available online at nca2014.globalchange.gov/report; last accessed May 30, 2014.

MILLAR, C.I., N.L. STEPHENSON, AND S.L. STEPHENS. 2007. Climate change and forests of the future: Managing in the face of uncertainty. *Ecol. Appl.* 17(8):2145–2151.

MINTEER, B.A., AND J.P. COLLINS. 2010. Move it or lose it? The ecological ethics of relocating species under climate change. *Ecol. Appl.* 20(7):1801–1804.

NATIONAL PARK SERVICE. 2010. *Climate change and your National Parks*. National Park Service Climate Change Response Program, Fort Collins, CO. Available online at www.nps.gov/climatechange/docs/NPS_CCRS.pdf; last accessed Nov. 23, 2012.

OLANDER, L.P., D.M. COOLEY, AND C.S. GALIK. 2012. The potential role for management of US public lands in greenhouse gas mitigation and climate policy. *Environ. Manage.* 49:523–533.

OSMOND, D.L., N.M. NADKARNI, C.T. DRISCOLL, E. ANDREWS, A.J. GOLD, S.R. BROUSSARD ALLRED, A.L.R. BERKOWITZ, ET AL. 2010. The role of interface organizations in science communication and understanding. *Front. Ecol. Environ.* 8(6):306–313.

PETERSEN, B., K.R. HALL, K. KAHL, AND P.J. DORAN. 2013. In their own words: Perceptions of climate change adaptation from the Great Lakes region's resource management community. *Environ. Pract.* 15(4) 377–392.

PETTY, R.E., AND J.T. CACIOPPO. 1996. Addressing disturbing and disturbed consumer behavior: Is it necessary to change the way we conduct behavioral science? *J. Market. Res.* 33(1): 1–8.

SHELEY, R.L., AND J.K. PETROFF (EDS.). 1999. *Biology and management of noxious rangeland weeds*. Oregon State Univ. Press, Corvallis, OR. 438 p.

SINGLETON, R.A. JR., AND B.C. STRAITS. 1999. *Approaches to social research*. Oxford Univ. Press, Inc., New York. 618 p.

SOLOMON, S., G.-K. PLATTNER, R. KNUTTI, AND P. FRIEDLINGSTEIN. 2009. Irreversible climate change due to carbon dioxide emissions. *Proc. Natl. Acad. Sci. USA* 106(6):1704–1709.

SPITTLEHOUSE, D.L., AND R.B. STEWART. 2003. Adaptation to climate change in forest management. *BC J. Ecosyst. Manage.* 4(1):1–11.

STEPHENS, S.L., J.D. MCIVER, R.E.J. BOERNER, C.J. FETTIG, J.B. FONTAINE, B.R. HARTSOUGH, P.L. KENNEDY, AND D.W. SCHWILK. 2012. The effects of forest fuel-reduction treatments in the United States. *BioScience* 62(6):549–560.

SWETNAM, T.W., AND C. BAISAN. 1996. Historical fire regime patterns in the southwestern United States since AD 1700. P. 11–32 in *Fire effects in southwestern forest: Proc. of the 2nd La Mesa Fire Symposium, 1994 March 29–31, Los Alamos, New Mexico*, Allan, C.D. (ed.). USDA For. Serv., Gen. Tech. Rep. RM-GTR-286, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

USDA FOREST SERVICE. 2011. *National roadmap for responding to climate change*. USDA For. Serv., FS-957b, Washington, DC. Available online at www.fs.fed.us/climatechange/pdf/Roadmapfinal.pdf; last accessed July 9, 2014.

US ENVIRONMENTAL PROTECTION AGENCY. 2013. *Inventory of US greenhouse gas emissions and sinks: 1990–2011*. EPA 430-R-13-001. Available online on www.epa.gov/climatechange/emissions/usinventoryreport.html; last accessed Dec. 17, 2013.

VALÉRY, L., H. FRITZ, J.-C. LEFEUVRE, AND D. SIMBERLOFF. 2008. In search of a real definition of the biological invasion phenomenon itself. *Biol. Invas.* 10:1345–1351.

WESTERLING, A.L., H.G. HIDALGO, D.R. CAYAN, AND T.W. SWETNAM. 2006. Warming and earlier spring increases western US forest wildfire activity. *Science* 313:940–943.

WILLIAMS, M.I., AND R.K. DUMROESE. 2013. Preparing for climate change: Forestry and assisted migration. *J. For.* 111(4):287–297.

WOOD, M.M. 2010. *Motivating public readiness for disaster.* Presented at the Mountain Climate Research Conference, Blue River, Oregon. Available online at www.fs.fed.us/psw/cirmount/meetings/mtnclim/2010/talks/pdf/Wood_Talk2010.pdf; last accessed June 20, 2013.

WOOD, M.M., D.S. MILETI, M. KANO, M.M. KELLEY, R. REGAN, AND L.B. BOURQUE. 2012. Communicating actionable risk for terrorism and other hazards. *Risk Anal.* 32(4):601–615.

YEAGER, D.S., J.A. KROSNICK, L. CHANG, H.S. JAVITZ, M.S. LEVENDUSKY, A. SIMPSER, AND R. WANG. 2011. Comparing the accuracy of RDD telephone surveys and Internet surveys conducted with probability and nonprobability samples. *Public Opin. Q.* 75(4):709–747.