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What risks matter? Public views about assisted migration and other climate-adaptive reforestation strategies

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Abstract
The world's forests play an important role in regulating climate change through their capacity to sequester carbon. At the same time, they are also increasingly vulnerable to the impacts of climate change. In the western Canadian province of British Columbia, changes in temperature, precipitation, and disturbance regimes are already impacting forests. In response to these observed and anticipated changes, adapted reforestation practices are being developed and proposed as a means to help forest ecosystems adjust to changing climatic conditions. One such practice under consideration is assisted migration—planting species within or outside of the native historical range into areas that are anticipated to be climatically suitable in the future. We used a survey of British Columbia's population at large ($n = 1923$) to quantify levels of support for a range of potential reforestation options (including assisted migration) to adapt to climate change, and to explore what factors can help predict this support. Our findings reveal that the likely location of potential public controversy resides not with the potential implementation of assisted migration strategies per se, but rather with assisted migration strategies that involve movement of tree species beyond their native range.

1 Introduction

While the world's forests play an important role in regulating climate change through their capacity to sequester carbon (FAO 2016), they are also increasingly vulnerable to the impacts of climate change (Settele et al. 2014). In the western Canadian province of British Columbia (BC), climatic change threatens the health and productivity of most of the 55 million hectares of forested land (Fettig et al. 2013; Winder et al. 2011), 95% of which is publicly owned (BC

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MFLNRO 2013). Changing climatic regimes have been linked to an increase in the frequency and severity of extreme weather and natural disturbances including drought, forest fires, and insect and disease outbreaks (Fettig et al. 2013; Kurz et al. 2008a). These impacts are forecasted to increase within the next decades (Kurz et al. 2008b). Additionally, climate-driven impacts on the distribution and range of tree species are expected. Some tree species (e.g., Douglas fir, ponderosa pine) are expected to colonize northward and upward in elevation (Wang et al. 2012). Others (e.g., coastal western hemlock in mountain ecosystems) may be unable to colonize into areas of suitable climate due to barriers to movement, competition from other species, and/or a lack of suitable habitat (Swift and Ran 2012).

In response to these observed and anticipated changes, scientists and decision-makers are increasingly considering the use of novel management strategies intended to increase the adaptability of forests to climate change (Hagerman and Pelai in press). These include adapted reforestation practices, such as planting species into new areas that are anticipated to be climatically suitable in the future (Aubin et al. 2011; Park and Talbot 2012). This approach, known as assisted migration (AM) and defined in forestry as "the intentional anthropogenic movement of individuals and populations" (Aitken and Whitlock 2013, p. 369; see also Ste-Marie et al. 2011), is often coupled with proposals to use genomic diagnostic tools to identify climate-adaptive traits (e.g., drought and heat tolerance) at the molecular level (Aubin et al. 2016). Once identified, these individuals—assumed to be genetically better adapted to anticipated future climatic conditions (ONeill et al. 2017)—are targeted for seed selection and, ultimately, reforestation in regions within or beyond the native range of the seed source. Here, we distinguish between two types of AM based on spatial distribution. While different names are used in the literature (Ste-Marie et al. 2011), we distinguish between *AM within natural range* (sometimes called assisted gene flow) and *AM outside of natural range* (sometimes called assisted colonization).

In the context of Canadian forests, proponents of AM argue that this strategy has the potential to avoid species extinction and support the economic benefits associated with market-based goods, such as timber and other ecosystem services (Aubin et al. 2011; Pedlar et al. 2012). Opponents highlight the risks of human-facilitated species movement, including potential maladaptation (i.e., failure of the planted tree species to establish) and the potential for introductions to become invasive or introduce pests and/or diseases (Park and Talbot 2012; Pedlar et al. 2012; Winder et al. 2011). In addition to the potential ecological risks of actively facilitating transitions, AM poses a philosophical threat to prevailing commitments to a resource management paradigm rooted in assumptions of ecological stability and management objectives oriented towards historical baselines (Hagerman and Satterfield 2014; Hewitt et al. 2011). This is especially true in BC and Canada, where management is based on reforestation with native species rather than establishing plantations of exotics (as occurs in other parts of the world).

Previous studies underscore these tensions showing that support for genomics and other interventions for climate adaptation and pathogen mitigation are deeply contested (Davidson et al. 2003; Hagerman et al. 2010), rapidly changing (Hagerman and Satterfield 2014), and dependent on context, problem framing, and stakeholder group (Hajjar et al. 2014). In their public survey of acceptance of different reforestation strategies, including AM, Hajjar and Kozak (2015) identified diverging levels of acceptance amongst the public in Western Canada for different reforestation strategies, with rejection of AM in segments of the population who favor biodiversity conservation or distrust decision-makers. Since that survey was conducted 5 years ago, forest decision-makers in BC have moved forward with preliminary policies and actions to support the use of AM in reforestation (Government of BC 2017).

Given this policy momentum and the fact that BC's forests are largely held in the public domain, it is crucial to understand current and potentially evolving views of the BC public as concerns the potential risks and benefits of AM relative to other management options. Taking public values and perceived risks into account when considering decisions about public lands is essential to the policy debate as it recognizes the diverse ways in which publics may view (and experience) the risks and benefits, as well as anticipate potential controversy or objections, that may be associated with implementation. With the urgency of climate change increasingly at the forefront of the Canadian public's consciousness (Mildenberger et al. 2016), and the impacts on forests increasingly evident, we examine current public views on this topic using a Web-based survey.

2 Perceptions of environmental and forest-related risks

Decades of social science research on perceptions of environmental risks broadly identify the role of values-based factors (Capstick et al. 2016; Ziegler 2017), including cultural norms or ethical positions (Kahan et al. 2012; van der Linden 2015; Wildavsky and Dake 1990), and governance-related factors, such as trust in managing authorities (Siegrist et al. 2006), as influencing perceptions of risk and levels of policy support. In the context of novel policy options where uncertainty is high, such as AM, individual decision-making processes may tend to default to "psychological biases" (Gregory et al. 2016), with values-based and trust-related factors becoming particularly salient in shaping public responses.

The role of these factors in shaping public attitudes is well-established in forest-specific contexts. For example, *environmental values*, defined here as orientations towards the environment (in our case, forests), have been shown to influence preferences for forest management (McFarlane and Boxall 2003; McFarlane et al. 2006; Vaske and Donnelly 1999). Environmental values are often appraised on a continuum scale ranging from biocentric to anthropocentric positions (McFarlane and Boxall 2003; Steel et al. 1994; Vaske and Donnelly 1999). The former reflects the normative view that nature and forests have intrinsic value regardless of their usefulness to humans, while the latter reflects the view that nature and forests can and should be used and modified for human needs and well-being. Considering this, values-based ethical views about how humans ought to interact with non-human nature (e.g., whether or not to pursue genomic-based interventions in managing forests in this instance) are posited to contribute to perceptions of risk and overall levels of support for new policy alternatives. Additionally, previous studies in the forest domain have shown that public trust influences levels of acceptance for forest management strategies and is essential for successful implementation (McFarlane et al. 2012; Winter et al. 2004).

A final consideration for this study is the potential role of knowledge in influencing perceived environmental risks and levels of policy support. The empirical evidence on this is mixed. Decades of risk scholarship highlights that perceptions are not easily shifted in response to new information (Satterfield et al. 2009), and that higher degrees of science literacy and technical reasoning capacity are not necessarily associated with greater concerns for climate change (Kahan et al. 2012). Some previous forest-specific studies found no or inconclusive relationships between knowledge and public preferences (Hajjar and Kozak 2015; McFarlane 2005; McFarlane and Boxall 2000). In contrast, others demonstrate that greater knowledge about forest practices and their consequences can increase public acceptability (Bliss et al. 2006). Given the likely roles of values-based, trust, and knowledge factors in shaping public perceptions, we quantify current perceptions of risk and levels of support associated with a range of potential reforestation options in BC's broader population (including AM), and explore the influence of environmental values, trust, and knowledge in shaping this support.

3 Methods

3.1 Data collection: online survey

We used an online survey to better understand public views about current and potential new options for reforestation strategies to adapt to climate change in BC. The survey comprised 71 questions, including continuous interval and Likert scales, ranking questions, multiple choice questions, and open-ended questions. We used FluidSurveys software (http://www.fluidsurveys.com) to create an online version of the survey that was then distributed to BC's general public by a digital data collection company (ResearchNow, https://www.researchnow.com). We programmed quotas based on the latest population census (2011) in terms of age (19–34 years, 27%, and 35–54 years, 36%), gender (female, 52%), and urban population (Vancouver and Victoria, 69%) to avoid an overrepresentation of segments of the population within the panel sample.

After pre-testing, we collected a total of 1926 completed surveys between May 15 and May 30, 2017. Because the focus of this study is on climate change adaptation, this total excludes surveys that were filled by respondents who do not believe that climate change is happening ($n = 26$, 1.3% of total completed surveys). While the survey was not purposefully targeted to avoid "non-believers" in climate change, the low observed percentage compared to other studies in Canada (Mildenberger et al. 2016) and the USA (Leiserowitz et al. 2016) may be explained by a low response rate to invitations to the survey by non-believers due to lack of interest in the subject (i.e., climate change adaptation). In order to eliminate low-quality responses, we also excluded surveys that were completed in less than 8 min ($n = 174$, 8.2% of total completed surveys), the minimum time deemed necessary during pre-testing to meaningfully read and answer all questions.

The first section of the survey included a brief tutorial stating that climate change is already impacting BC's forests. Respondents were then introduced to six different reforestation options for adapting to changing climate conditions with the help of simple illustrations (shown in Fig. 1), accompanied by short descriptions. The strategies were grouped into three categories designed to represent a continuum from business-as-usual to technologically intensive interventions. The first pair of strategies, which are already being implemented in BC, included options aimed at reforesting with native species to reproduce historical ecosystem dynamics (hereafter "conventional strategies"). The second pair comprised AM strategies that are currently being considered for implementation in BC: AM within and outside of natural range. The third pair included the introduction of non-native species from other continents and the use of genetically modified organisms or GMOs (hereafter "unconventional strategies"). This spectrum allowed us to evaluate how AM is perceived relative to other more or less conventional and invasive management actions, and to measure dissimilarities, if any, in levels of public support for reforestation practices that transgress historical species boundaries.

We asked respondents to rate two variables for each of the six reforestation strategies (Table 1): (i) levels of support using a 5-point continuous scale, and (ii) ethical views using a 3-

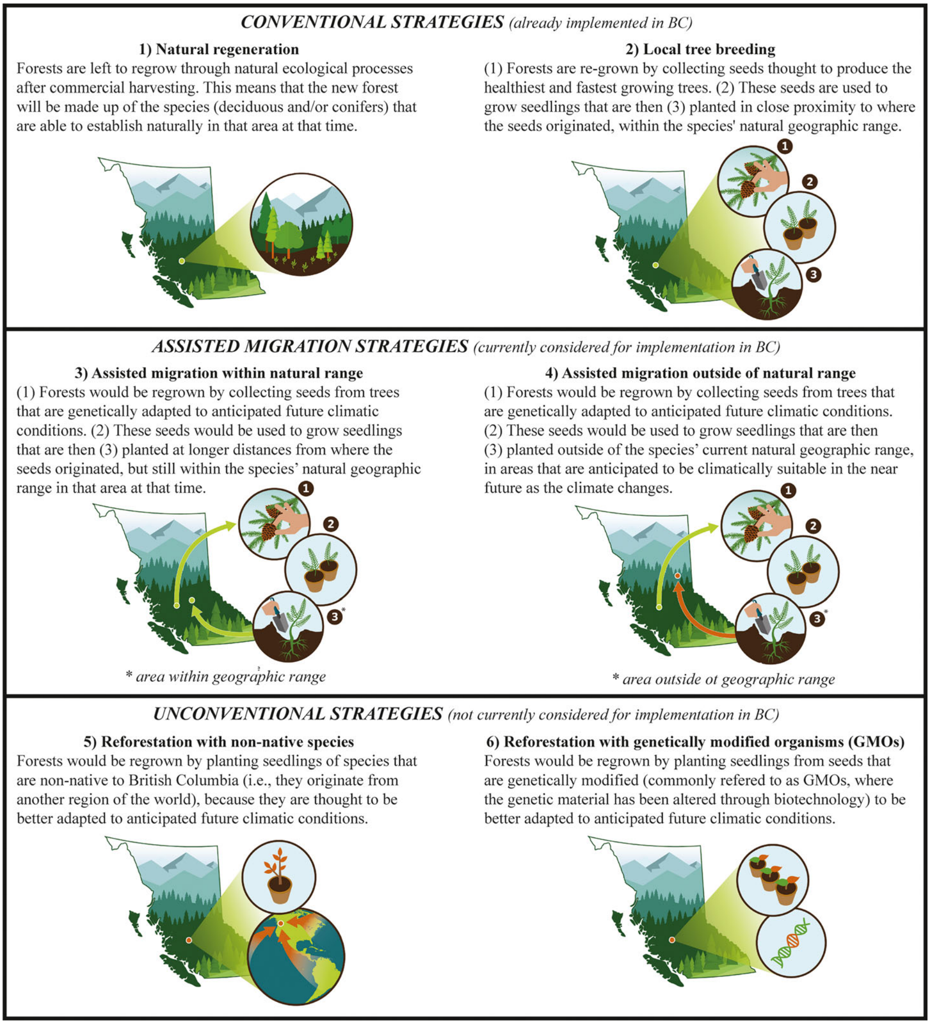

Fig. 1 Description of the six reforestation strategies to adapt to climate change in BC's publicly owned forests as presented to respondents in survey

point continuous scale. Levels of support were used as the dependent variable in a subsequent regression analysis, while ethical views were used as supplemental information. We assessed the influence of demographic and explanatory variables on levels of support for the strategies. In addition to the three categories of explanatory variables identified in the previous section (values, trust, and knowledge), we used an index of participants' perceived risk associated with climate change. Table 1 describes each of the variables, how they were presented in the online survey (see Online Resource 1 for complete set of questions), and how they were operationalized in the regression analyses.

We also asked a question specifically about the two AM strategies to distinguish between levels of public support for AM within versus outside of natural range. Respondents were asked to identify which of the following three statements best describe their views on the implementation of each AM strategy: (i) it should be implemented right now with ongoing

Table 1 Dependent and independent variables

Variables	Measurement scale	Index used in regression analysis
Dependent		
Levels of support	One 5-point continuous interval question per strategy	Numerical index created by averaging the identified level of support (from − 2 to 2) for each strategy that loaded on the factors identified by the factor analysis
Independent—explanatory variables		
Knowledge		
1. Knowledge of the cause of climate change	One multiple choice question	Binary variable with two factors: (1) respondents who believe climate change is caused mostly by human activities or (2) others
2. Knowledge of forestry in BC	Ten true or false questions	Average summation (out of 10) of the score of each of the 10 questions, where correct answer = 1 and wrong answer = 0
Environmental value		
1. Environmental value orientation	Ten 5-point continuous interval questions	Average of the score of each statement that loaded on each of the factors (2) extracted using a factor analysis: (1) biocentric and (2) anthropocentric
2. Preferred outcome of forest management	Distribution of 10 points between three outcomes: environmental, socio-cultural, and economic	Binary variable with three factors based on K-means solution: (1) balanced preference, (2) economic preference, or (3) environmental preference
Trust		
1. Trust in different actors	Seven 5-point continuous interval questions	Binary variable with three factors based on K-means solution: (1) trust coalition, (2) distrustful, or (3) trustful
Perceived risk of climate change		
1. Risk perception index	Seven 5-point continuous interval questions	Average summation of the score of each of the seven questions
Independent—demographic variables		
1. Age	One open-ended question with numerical answer	Numerical value
2. Gender	One multiple choice question	Binary variable with two factors: (1) male or (2) female
3. Education	One multiple choice question	Binary variable with two factors: (1) higher education (some university/college or higher) or (2) lower education (vocational/technical school or lower)
4. Employment in forest sector	One multiple choice question	Binary variable with two factors: (1) employed (direct and indirect) or (2) not employed
5. Political orientation	One 11-point continuous interval question	Binary variable with three factors: (1) left orientation (score 0 to 3), (2) center (score 4 to 6), or (3) right (score 7 to 10)
6. Region	One multiple choice question	Binary variable with three factors: (1) rural, (2) suburban, or (3) urban
Additional questions		
Ethical views	One 3-point continuous interval question per strategy	Not used in regressions, but for explanatory purposes only
Additional question on AM within and outside of natural range	Two multiple choice questions	Not used in regressions, but for explanatory purposes only

research and monitoring, (ii) we need further research before being able to implement it, and (iii) it should be avoided because there will always be too many unknowns.

3.2 Data analysis

We performed all statistical analyses in R Studio (version 1.0.153). We treated data from continuous interval scales as ordinal, thereby employing non-parametric statistical tests (e.g., Mann–Whitney *U* test, chi-square test of independence), whereas we used parametric statistics (e.g., Student's *t* test) for interval data originating from Likert scale questions (Clason and Dormody 1994). Descriptive statistics, such as means and frequencies, were used throughout to summarize the variables under study.

We factor analyzed (with varimax rotations) the results of the individual Likert items for environmental values, levels of support, and ethical views about the different strategies, to cluster them into reduced factors. We extracted factors until the eigenvalue fell below 1 and used a minimum loading of 0.40 to allocate an item into a factor. We then created indices to be used in the regression analyses by averaging the score of each statement that loaded on each factor. We also used K-means clustering to group respondents based on their (i) trust in different actors and (ii) preferred outcome of forest management. In both cases, we first identified the potential number of clusters by carrying out hierarchical clustering with the Ward method. Finally, we ran individual binary logistic regressions for each individual reforestation strategy to evaluate the influence of the independent variables on levels of support (Table 1).

4 Results

4.1 Explanatory variables

An overview of respondents' demographic data can be found in Online Resource 2. In terms of *knowledge about the cause of climate change*, 54.1% of respondents ($n = 1057$) believed that climate change is caused mostly by human activities. The remaining respondents, which were all considered "others" (Table 1), believed that climate change was either caused equally by natural changes in the environment and human activities (34.8%, $n = 680$) or caused mostly by natural changes in the environment (7.2%, $n = 141$), with 2.5% ($n = 48$) not knowing. The results from our *risk perception of climate change* index (mean = 3.52, standard deviation = 0.88, $\alpha = 0.94$) indicated that respondents are concerned about the various risks caused by climate change.

With respect to knowledge of forestry in BC, respondents answered an average of 4 correct answers out of 10 questions (standard deviation = 2.20; Online Resource 3). There was a high variability in our pool of respondents' knowledge on forestry, with scores ranging from no correct answers to perfect scores. When asked about the most important outcomes associated with forests in BC, respondents distributed, on average, the greatest portion of 10 points to maintaining environmental benefits, followed by economic and socio-cultural benefits (Online Resource 4). A K-means solution identified three different clusters that were used in the regression analysis:

1. "Balanced preference" cluster (1147 respondents)—similar values for the three different categories
2. "Economic preference" cluster (198 respondents)—preference for economic benefits
3. "Environmental preference" cluster (581 respondents)—preference for environmental benefits

Factor analysis of the environmental values scale (Online Resource 5) revealed a two-factor solution corresponding to biocentric and anthropocentric orientations. On average, respondents showed a significantly higher biocentric (mean = 1.22, standard deviation = 0.67, $\alpha = 0.79$) than an anthropocentric orientation (mean = − 0.87, standard deviation = 0.85, $\alpha = 0.79$; $t(1843) = -44.90$, $p < 0.001$).

Finally, results indicate variable levels of trust in different actors to provide accurate information about the implications of climate change for forest management (Online Resource 6), with scientists, environmental groups and professional foresters being the most trusted, and governments and forest industry the least. A K-means solution identified three different clusters:

1. "Trust coalition" cluster (604 respondents)—high trust for scientists, environmental groups, and First Nations
2. "Distrustful" cluster (562 respondents)—low trust for all actors
3. "Trustful" cluster (760 respondents)—high trust for all actors

4.2 Views on reforestation strategies

Respondents' levels of support for, and ethical views about, the six reforestation strategies are illustrated in Fig. 2. BC's public respectively indicated very high levels of support and favorable ethical views for the two conventional strategies (i.e., natural regeneration and local tree breeding), as well as AM within natural range. Even though more than half of the respondents (53%) supported AM outside of natural range in principle, the strategy scored significantly lower than AM within natural range in terms of overall levels of support (Mann–Whitney $U = 1{,}624{,}500$, $p < 0.001$) and ethical views (Mann–Whitney $U = 1{,}624{,}500$, $p < 0.001$). Finally, a majority of respondents were ethically opposed to the implementation of the two unconventional strategies, with no significant differences observed.

4.3 Regression analyses

We used logistic binary regressions to evaluate the effects of the independent variables (Table 1) on levels of support for each of the six reforestation strategies (Table 2). We found significant relationships between levels of support for at least one of the strategies and knowledge of forestry, environmental values, trust in different actors, age, gender, education, political orientation, and employment in the forest sector.

4.4 Distinction between AM within and outside of natural range

Two factors were extracted from factor analyses of levels of support and ethical views of the six strategies (Online Resource 7). Factor 1 describes similar opinions on natural regeneration,

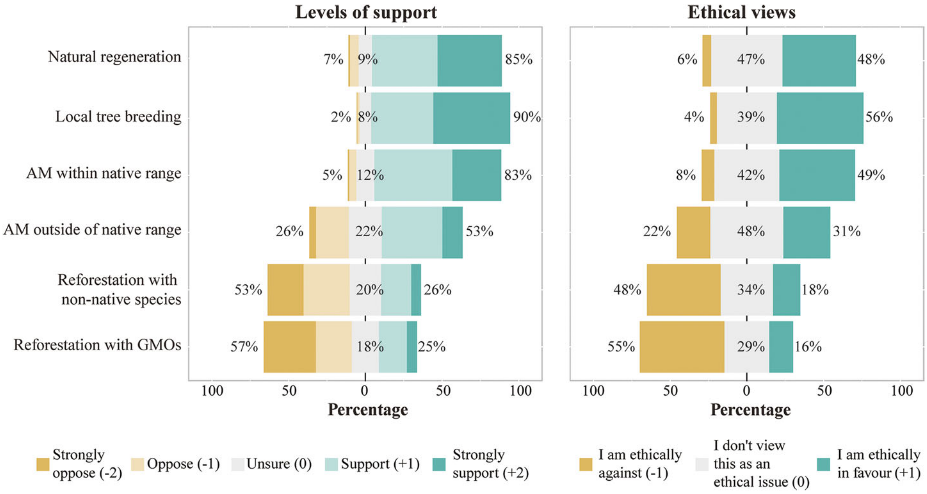

Fig. 2 Levels of support/opposition for, and ethical views on, the six reforestation strategies

local tree breeding, and AM within natural range whereas factor 2 combined assisted migration outside of natural range with the two unconventional strategies.

A chi-square test of independence was performed to compare the frequency of views on the implementation of AM within and outside of natural range (Fig. 3). A significant interaction was found ($\chi^2(2) = 417.8$, $p < 0.001$), indicating that respondents are more likely to believe that AM within natural range should be implemented immediately with ongoing research and monitoring (63%), whereas they predominantly consider that AM outside of natural range requires further research prior to implementation (56%).

5 Discussion

Results from this study provide new insights into the basis and levels of current support for novel reforestation strategies. Three key findings, discussed below, include (i) the identification of the locus of controversy around levels and basis of support for proposed assisted migration strategies; (ii) the roles of trust, environmental values, and knowledge in shaping public attitudes towards the strategies; and (iii) trends in public perceptions over time.

5.1 Contention in the assisted migration debate: within or outside of native range?

The observed differences in public views about the two AM strategies being considered by BC's government are notable. On the one hand, the high proportion of respondents who supported AM within natural range suggests that a large majority of BC's public is willing to see AM implemented in BC forests, as long as it abides by species' historical ranges. On the other hand, lower levels of support for AM outside of natural range indicate that the movement of species to other regions represents a contentious element that is, in the eyes of the public, somewhat comparable to the use of exotic species or GMOs. The relative lack of distinction between AM outside of natural range and long-range intercontinental species introductions observed here is consistent with previous research that identifies this issue as a barrier to public consensus in the assisted migration debate (Hewitt et al. 2011).

Table 2 Binary logistic regression results for each category of adaptation strategies

Variable	Natural regeneration	Local tree breeding	AM within species range	AM outside of species range	Reforestation with non-native species	Reforestation with GMOs
Intercept	−0.009 (0.98)	−0.13 (0.88)	0.47 (1.61)	−0.24 (0.79)	*−0.75* (0.47)*	*−1.27*** (0.28)*
Perceived risk of climate change						
Risk perception index	0.11 (1.12)	0.04 (1.04)	−0.07 (0.93)	−0.05 (0.95)	−0.06 (0.94)	−0.03 (0.97)
Knowledge						
Knowledge on the cause of climate change	−0.18 (0.83)	−0.13 (0.88)	−0.10 (0.90)	−0.003 (1.00)	0.17 (1.16)	0.06 (1.06)
Knowledge on forestry	*0.13*** (1.14)*	*0.29*** (1.34)*	*0.22*** (1.24)*	*0.06** (1.07)*	−0.04 (0.96)	*0.06* (1.06)*
Environmental values						
Anthropocentric	−0.07 (0.94)	*−0.21* (0.81)*	0.11 (1.11)	*0.26*** (1.30)*	*0.57*** (1.76)*	*0.33*** (1.38)*
Biocentric	*0.31** (1.36)*	*0.41** (1.50)*	*0.27* (1.32)*	0.13 (1.14)	0.16 (1.18)	−0.09 (0.91)
Preferred outcome (“balanced” cluster)	0.16 (1.17)	*0.39* (1.47)*	0.01 (1.01)	−0.01 (0.99)	−0.001 (1.00)	0.09 (1.09)
Preferred outcome (“economical” cluster)	−0.001 (1.00)	−0.01 (0.99)	0.07 (1.07)	−0.08 (0.92)	0.14 (1.16)	*0.52* (1.67)*
Preferred outcome (“environmental” cluster)	N/A	N/A	N/A	N/A	N/A	N/A
Trust						
Trust (“distrustful” cluster)	0.16 (1.18)	−0.19 (0.83)	*−0.38* (0.68)*	−0.15 (0.86)	0.04 (1.04)	−0.18 (0.84)
Trust (“trustful” cluster)	*0.42* (1.52)*	−0.04 (0.96)	0.09 (1.10)	*0.41*** (1.51)*	*0.48*** (1.61)*	*0.43** (1.54)*
Trust (“trust coalition” cluster)	N/A	N/A	N/A	N/A	N/A	N/A
Demographic						
Age	*0.01* (1.01)*	*0.02** (1.02)*	*0.02*** (1.02)*	*0.01* (1.01)*	*−0.01* (0.99)*	*−0.01* (0.99)*
Gender (male)	−0.22 (0.81)	0.04 (1.04)	−0.05 (0.96)	0.09 (1.09)	0.09 (1.09)	*0.40*** (1.50)*
Education (high)	0.01 (1.01)	0.30 (1.35)	0.06 (1.06)	0.11 (1.12)	−0.04 (0.96)	0.20 (1.23)
Sector (employed in forestry)	0.14 (1.15)	0.47 (1.60)	0.27 (1.31)	0.29 (1.34)	0.28 (1.33)	*0.49* (1.63)*
Political (left)	−0.13 (0.87)	−0.32 (0.72)	−0.11 (0.90)	−0.18 (0.84)	0.18 (1.20)	−0.08 (0.92)
Political (right)	*0.38* (1.47)*	0.36 (1.44)	0.20 (1.23)	0.12 (1.13)	*0.35* (1.42)*	0.15 (1.16)
Political (center)	N/A	N/A	N/A	N/A	N/A	N/A
Region (rural)	−0.23 (0.79)	−0.33 (0.72)	−0.28 (0.76)	−0.29 (0.75)	−0.08 (0.92)	0.11 (1.12)
Region (urban)	0.16 (1.18)	−0.11 (0.90)	−0.11 (0.89)	−0.02 (0.98)	0.08 (1.08)	−0.006 (0.99)
Region (suburban)	N/A	N/A	N/A	N/A	N/A	N/A
Nagelkerke R^2	0.06	0.13	0.09	0.06	0.10	0.10
Classification table: proportion correct	0.85	0.91	0.83	0.58	0.75	0.76

$^*p \leq 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

In part, public perceptions of risk of AM outside of natural range are also consistent with expert assessments that similarly note increased ecological risks with spatial distance (Mueller and Hellmann 2008). Many of the risks associated with AM outside of natural range do not necessarily apply to AM within natural range (e.g., no chance of creating exotic invasive species; Hewitt et al. 2011). On the other hand, other experts argue that limiting AM to within-range movements risks failing to adapt to expected future climates (Pedlar et al. 2012; Winder et al. 2011).

Despite relatively low levels of support for AM outside of native range, this strategy was supported in principle by more than half of respondents. However, the majority (69%) believe that more research is needed before AM outside of natural range can be implemented (Fig. 3), thereby confirming the general sense that current uncertainties make its acceptance extremely challenging. The possibility that uncertainties can be reduced through further research (Aitken and Whitlock 2013; Vitt et al. 2010) opens the door to a conceivable decline in public opposition, if and when conclusions demonstrate that the benefits of AM outside of natural range outweigh the risks.

5.2 Predicting who is likely to support or oppose different strategies

While the predictive powers of our regression models (Table 2) are not strong, the models themselves indicate significant relationships that are worth noting. To begin with, the observed effect of environmental values is consistent with the literature. Biocentric individuals may be compelled to accept AM outside of natural range if it prevents the extinction of a species, but they are generally more supportive—as found in this study—of less invasive strategies that limit human impact on nature and preserve key ecosystem processes (Aubin et al. 2011). In contrast, the support by anthropocentric individuals for unconventional strategies and AM outside of natural range is consistent with their assigned belief that human intervention is needed to maintain forest-related goods and services. Preferences for management outcomes only entered in two regression models, with the most significant being that preference for economic benefits is associated with support for reforestation with GMOs.

By showing the positive effects of trust on support for four strategies (i.e., natural regeneration, AM outside of natural range and both unconventional strategies) and the negative effect of distrust on AM within natural range, our results confirm the importance of trust in decision-makers and other important actors in shaping the acceptance of forest management strategies (McFarlane et al. 2012; Winter et al. 2004).

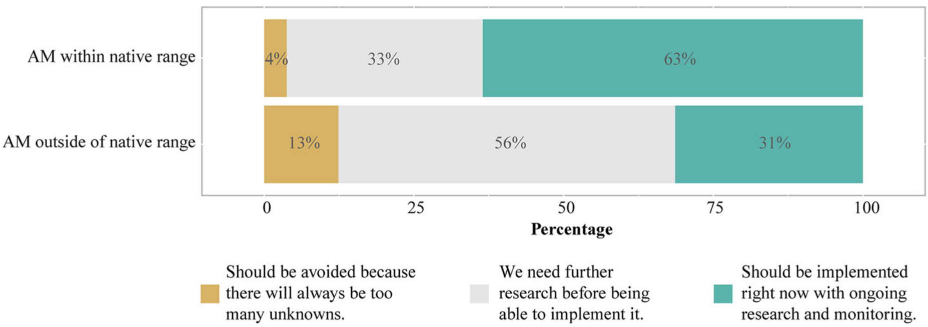

Fig. 3 Views on implementation of assisted migration within and outside of natural range in BC's forests

Even though knowledge about the cause of climate change did not have a significant impact in the models, greater knowledge of forest management was associated with greater support for all the strategies except for reforestation with non-native species. Our results suggest that greater knowledge of forestry (and indirectly of the increasing impacts of climate change) may translate into greater willingness to act (Bliss et al. 2006). This observed positive relation contrasts with other studies that have suggested that increased knowledge of forestry reduces risk perception and, thereby, reduces support for responsive management strategies (McFarlane et al. 2012; McFarlane et al. 2006).

Men generally showed greater levels of support for the use of GMOs. Other studies have also found that men are generally less risk-averse towards forestry activities (McFarlane 2005) and the use of GMOs in reforestation (Hajjar and Kozak 2015). In contrast, politically conservative individuals were shown to be more supportive of natural regeneration, but also for reforestation with non-native species, which confirms previous findings regarding their inclinations towards more intensive forest management strategies (Steel et al. 1994). Older individuals were more sympathetic to conventional and assisted migration strategies, and also more likely to oppose the implementation of unconventional strategies (i.e., reforestation with non-native species or GMOs). The question now becomes whether this points to deepening perceptions of risks for reforestation strategies by older individuals, or to increasing acceptance by the younger generation. Respondents who indicated being directly or indirectly employed in the forest sector were more likely to support the use of GMOs. One potential explanation is that these individuals are more likely to experience the recent negative impacts of climate change on BC's forests, thus making them more supportive of unconventional approaches.

5.3 Trends in levels of support for forest management interventions over time

Our findings indicate that public acceptance of AM strategies has been fairly stable over time when compared to results of a previous study in the same jurisdiction (Hajjar and Kozak 2015). However, we found different levels of support for the other reforestation practices (i.e., conventional and unconventional). Notable differences include lower levels of support for reforestation with non-native species and GMOs and higher levels of support for natural regeneration detected in this most recent survey. A number of potential explanations explain this temporal variation.

First, there seems to be a marked preference for strategies that preserve as much of the natural structure of forest ecosystems as possible. Out of the 262 comments about forestry practices left in the open-ended sections of the survey, 84 (32%) indicated a preference for such strategies. The predominance of a conservation management paradigm focused on maintaining historical ecological balance is often identified in the literature as a barrier to the acceptance of AM even more unconventional interventions such as reforestation with exotic species or GMOs that, because they modify the natural states of forests, are often perceived as "unnatural" and even "unethical" (Hewitt et al. 2011; Park and Talbot 2012).

Second, while BC's public clearly perceives the risks associated with climate change and its impact on forests, our results suggest that they may be even more preoccupied by the potential risks associated with unconventional strategies, particularly when they involve GMOs or exotic species. Public dissatisfaction and cynicism towards industrial forest management (Cashore et al. 2001) could partly explain this observed distrust of unconventional approaches that may be moving us away from an "ecological approach to forestry" (Park and Talbot 2012).

Third, the different ways in which the natural regeneration strategies were presented in the two surveys may have influenced respondents' perception. While the two surveys referred to similar approaches to natural regeneration, the previous definition emphasized the “do nothing” aspect of the strategy, whereas the current description focused on the natural ecological processes of species establishment. This underlines the importance of problem framing. Presenting adaptation strategies in different ways may considerably influence public perception. This may be further exacerbated in the specific case of AM, as a variety of existing definitions, coupled with a general lack of knowledge, could act as significant barriers to its acceptance (Hewitt et al. 2011).

6 Conclusions and insights for decision-makers

Risk scholars working on environmental issues ranging from nanotechnology to fracking to geoengineering underscore the importance of engaging citizens early or at the emergence of an issue (e.g., Gregory et al. 2016; Satterfield et al. 2009; Thomas et al. 2017) so as to better anticipate controversies, as well as address potential concerns. As government agencies responsible for resource management on public lands consider the widespread application of new climate-adaptive strategies for reforestation, current priority should be to better understand how citizens interpret this issue. Our findings reveal three main insights into the views of the public on these adaptive strategies.

First, decreasing levels of support across the six strategies from conventional to unconventional options—and specifically the split between conventional and AM within native range strategies versus unconventional and AM outside of native range strategies—underscore the main conclusion of this study. That is, the likely location of potential public controversy resides not with the potential implementation of AM strategies per se, but rather with AM strategies that involve movement of tree species beyond their native range. Put simply, the risks that matter in the eyes of the public are not specifically associated with application of genomics to reforestation, but rather with the transgression of native boundaries.

Second, results from the regression analyses highlight the importance for decision-makers to earn the trust of the public if new reforestation strategies are to be supported, and specifically the need for transparency and accountability. Increasing public knowledge and science literacy would allow the public to understand the associated risks and benefits of different forest management options, thereby leading to more informed opinions. Our study also underlines the influence of the framing, definition, and description of assisted migration and other adaptation strategies in influencing public perceptions.

Third, and related to the insights above, our results reveal that a relatively high proportion of respondents feel that AM outside of range either should not proceed until further research is conducted or should be avoided outright due to too many uncertainties (Fig. 3). This should give decision-makers pause, considering that the views and support of potentially affected publics (including the BC public surveyed here) are crucial for ensuring the legitimacy of newly pursued strategies. This finding also points to the need for more in-depth consideration of stakeholder views—including participatory consultation processes—so as to better explore the complexities and potential malleability of support or opposition, and to foster informed dialog on this issue. Ultimately, gaining a better understanding of the views of publics, such as those provided here, is a crucial first step in considering the potential application of new reforestation strategies.

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