



# Wildlife habitat enhancements for grizzly bears: Survival rates of planted fruiting shrubs in forest harvests



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## ABSTRACT

Productive grizzly bear foraging habitats are lost as the prevalence of natural forest openings declines. We assessed the effectiveness of using wildlife habitat enhancements to increase food supply for grizzly bears in recent forest harvests by conducting planting trials of containerized shrub seedlings for three important late-season grizzly bear foods (fruiting shrubs): *Shepherdia canadensis* (Canada buffaloberry), *Vaccinium membranaceum* (mountain huckleberry), and *Amelanchier alnifolia* (saskatoon). We monitored seedling survival over two growing seasons and considered the effects of soil nutrient amendments, exclosures, initial seedling condition, and environmental factors (elevation and terrain). *A. alnifolia* had the highest survival rate, although it may not be as effective in the long term due to being preferred ungulate winter browse. Soil nutrient amendments reduced survival rates of all three species, perhaps due to competition with grasses, whereas exclosures increased survival rates. Survival rates across an elevation gradient for *S. canadensis* and *A. alnifolia* were inversely related to local occupancy rates, demonstrating that knowledge of their realized niche space is not consistent with early establishment rates of seedlings. As the amount of natural forest openings declines, wildlife habitat enhancements in disturbed sites with open canopies, including forest harvests, have the potential to locally increase late-season food supply for grizzly bears.

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## 1. Introduction

Grizzly bear (*Ursus arctos*) populations are under threat across much of their North American range, primarily due to anthropogenic habitat loss and habitat alterations, as well as increases in human-caused mortalities associated with increases in human access (Mattson and Merrill, 2002; Linke et al., 2013). Current management efforts to recover and sustain populations focus on reducing human-bear conflicts and human-caused mortalities, as well as identifying and maintaining grizzly bear habitats (Alberta Grizzly Bear Recovery Team, 2008). There is a growing need for strategies to improve habitat to balance habitat losses and habitat alterations (Nielsen et al., 2006). Along with human-caused mortality, food availability is a critical component of grizzly bear habitat quality (McLellan and Hovey, 1995, 2001; Merrill et al., 1999; Merrill and Mattson, 2003; Nielsen et al., 2010) and thus a central focus of strategies aimed at creating or improving habitat. Grizzly bears consume plant matter throughout much of their active period

(McLellan and Hovey, 1995; Munro et al., 2006), particularly during hyperphagia (late summer to early fall) when they forage on fruit-producing species to help accumulate fat reserves for hibernation (Martin, 1983; Hamer and Herrero, 1987; Hamer et al., 1991; Hamer, 1996; Munro et al., 2006; Holden et al., 2012; Mowat et al., 2013).

One of the most important factors regulating the availability and productivity of certain grizzly bear foods is forest disturbance (Nielsen et al., 2004b). In Alberta, natural disturbance regimes that were historically dominated by fire have been disrupted over the past century (Hamer and Herrero, 1987; Johnson et al., 2001; Linke et al., 2013). In place of wildfire, forest harvesting has become the most prevalent source of disturbance within the forested areas of Alberta's grizzly bear range (Nielsen et al., 2008; Festa-Bianchet, 2010; Stewart et al., 2012; White et al., 2014). Forest harvesting can increase local food supply for bears under certain conditions, especially in areas where fire suppression limits the availability of natural forest openings (Nielsen et al., 2004a; Stewart et al., 2012). However, forest harvests can also negatively affect the recovery of some fruiting species, including *Shepherdia canadensis* (Canada buffaloberry; Nielsen et al., 2004b) and *Vaccinium membranaceum* (black huckleberry; Anzinger, 2002),

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which are important late-season food sources for bears (Hamer and Herrero, 1987; Hamer et al., 1991; McLellan and Hovey, 1995; Munro et al., 2006). Silvicultural practices such as scarification can disrupt the roots or rhizomes of these species, thereby limiting their vegetative recovery post-harvest (Anzinger, 2002; Nielsen et al., 2004b). Thus, even with the removal of canopy during forest harvest, which should promote fruit production (Hamer, 1996; Nielsen et al., 2004b), some key bear foods vital for developing body mass prior to hibernation are not available. Because of this, the late-season food supply for bears in these areas is reduced (Nielsen et al., 2004b) and may lead to bears using high human-conflict zones in search of alternate food resources.

To mitigate the effect of forest harvesting, habitat enhancements (wildlife food plots) have been proposed to accelerate the recovery of fruiting species in forest harvests (Nielsen et al., 2004b). Planting fruiting shrubs in forest harvests (or other anthropogenically-created disturbances such as reclaimed mine sites; Cristescu et al., 2012) where there is no canopy cover could generate significant increases in late-season food supply for grizzly bears. This, coupled with access restrictions and silvicultural forest thinning to maintain or enhance fruit production over time, could be used as management tools to improve habitat quality and hasten population recovery (Braid and Nielsen, 2015). However, little is known about whether habitat enhancements represent a feasible option for improving grizzly bear habitat quality. In particular, tests of the effectiveness of planting seedlings of different fruiting shrub species in forest harvests are lacking.

In southwestern Alberta, the confluence of extensive forest harvesting with a diverse array of climatic zones presents a unique opportunity to test across an elevation (climatic) gradient the viability of using habitat enhancements to boost grizzly bear food supply in forest harvests. We conducted short-term planting trials for three important late-season grizzly bear foods – *V. membranaceum*, *S. canadensis*, and *Amelanchier alnifolia* (saskatoon) – to evaluate initial establishment (survival) rates of seedlings. Specifically, our objectives were to: (1) test whether a soil nutrient amendment and/or fencing treatments affected seedling survival; (2) test whether seedling size (vigour) affected survival rates; (3) test whether patterns in seedling survival rates along an elevation (climatic) gradient were consistent with local patterns in occupancy rates (expected niche spaces); and (4) test whether local variations in terrain (solar radiation) affected seedling survival.

## 2. Methods

### 2.1. Study area

We established planting trials across a 5065 km<sup>2</sup> study area in southwestern Alberta (Fig. 1). At higher elevations (alpine and sub-alpine zones), summers are short and cool, and precipitation (particularly snow) is high (Natural Regions Committee, 2006; Government of Alberta, 2010b). At lower elevations and foothills, summers are short and warm with less precipitation across all seasons (Natural Regions Committee, 2006; Government of Alberta, 2010b). At the highest elevations, plant communities are generally herbaceous meadows or open conifer stands, whereas closed conifer, mixed-wood, and grassland communities occur at moderate to low elevations (Natural Regions Committee, 2006). Common conifer species include *Pinus contorta* (lodgepole pine), *Pinus flexilis* (limber pine), *Picea engelmannii* (Engelmann spruce), *Picea glauca* (white spruce), *Abies lasiocarpa* (subalpine fir), and *Pseudotsuga menziesii* (Douglas fir). The most common deciduous species are *Populus tremuloides* (trembling aspen) and *Populus balsamifera* (balsam poplar). The primary source of natural forest disturbance in the region is fire, although aggressive fire suppression and

long-term climatic cycles have diminished the occurrences of fire (Johnson et al., 2001). Timber harvesting is prevalent in the area, replacing fire as the primary source of forest disturbance (Government of Alberta, 2010a; Stewart et al., 2012). In some areas, large amounts of unmerchantable timber lead to substantial logging debris. Regeneration of these sites often necessitates the use of scarification treatments to expose mineral soil (Government of Alberta, 2010b).

### 2.2. Trial species

Trial species included *S. canadensis*, *V. membranaceum*, and *A. alnifolia*, three fruiting shrubs that are important food sources for bears during hyperphagia (late summer to early fall). Fruit from *S. canadensis* and *V. membranaceum* comprise the majority of grizzly bear diets in the southern Canadian Rockies during hyperphagia (Hamer and Herrero, 1987; Hamer et al., 1991; McLellan and Hovey, 1995; Munro et al., 2006), and in some cases *A. alnifolia* also features prominently in the diet of bears (Hamer et al., 1991). *S. canadensis* is a nitrogen-fixing shrub that is able to thrive on nutrient-poor sites (Walkup, 1991). Vegetative reproduction is generally slow (Walkup, 1991). In the southern Canadian Rockies, *S. canadensis* is typically found at low to moderate elevations (Walkup, 1991; Nielsen et al., 2003, 2004b; Roberts et al., 2014), and fruit production is inversely related to canopy cover (Hamer, 1996; Nielsen et al., 2004b). *V. membranaceum* is an understory shrub species that most often reproduces vegetatively via extensive systems of rhizomes. It typically thrives on cool, mesic sites with fruit production peaking in forest openings (Simonin, 2000). *V. membranaceum* most often occurs at moderate to high elevations in the southern Canadian Rockies (Haussler and Coates, 1986; Roberts et al., 2014). Both *S. canadensis* and *V. membranaceum* utilize mycorrhizal symbiosis to help attain essential nutrients (Visser et al., 1991; McCracken, 1999). Finally, *A. alnifolia* is a thicket- or clump-forming species that occurs in a wide variety of habitats, often reproducing vegetatively by sprouting from root crowns and rhizomes (Fryer, 1997; Chai et al., 2013). *A. alnifolia* is limited by moisture availability and will not tolerate prolonged periods of drought (Fryer, 1997). It is shade intolerant and generally grows in forest openings or under moderate levels of canopy cover (Fryer, 1997). In the southern Canadian Rockies, *A. alnifolia* is found from low to high elevations (Roberts et al., 2014), although it is less common at higher elevations where growth is often limited by temperature.

### 2.3. Presence–absence data

Presence–absence data were collected for *S. canadensis*, *V. membranaceum*, and *A. alnifolia* at 322 stratified field plots during the springs and summers of 2012 and 2013. Occupancy rates were calculated for 100-m elevation zones ranging from 1300 m to 2100 m. The frequency of available elevations in the study area was used to weight sampling effort across each 100-m elevation zone. Refer to Braid and Nielsen (2015) for further information on field methods.

### 2.4. Site selection and planting trial design

Experimental sites included 18 forest harvests with a minimum of three replicates in each of four 100-m elevation zones ranging from 1400 m to 1800 m. Only forest harvests with slopes of less than 10° were used for trials to minimize slope–aspect effects. Site selection was also limited to forest harvests that had been planted within the past five years to reduce competition effects between experimental seedlings and canopy species, including conifer seedlings. Site-specific details for planting trials are summarized in Table A.1.

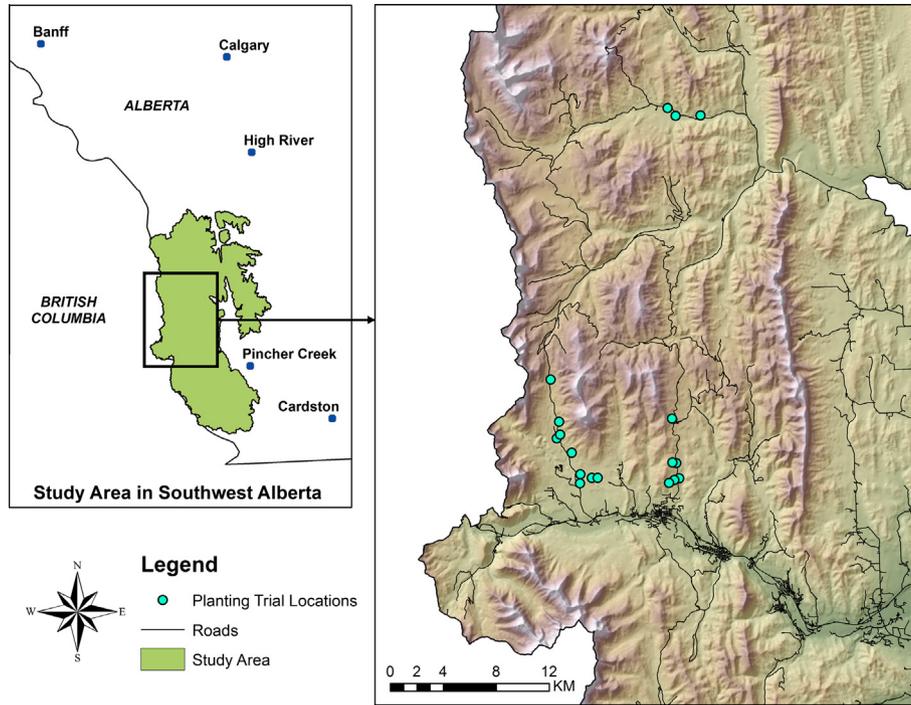


Fig. 1. Planting trial locations in southwestern Alberta.

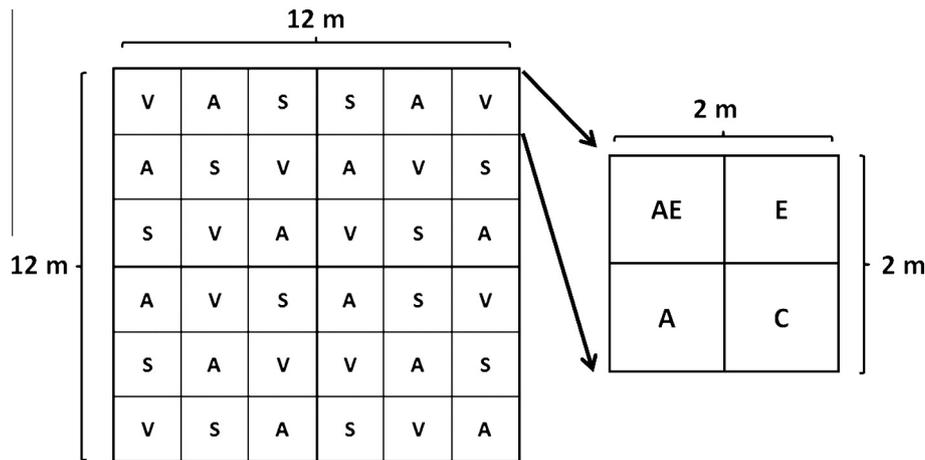


Fig. 2. Planting trials were 144 m<sup>2</sup> plots consisting of 36 randomized species grid squares (V = *Vaccinium membranaceum*, S = *Shepherdia canadensis*, and A = *Alnifolia alnifolia*). Each 4 m<sup>2</sup> species grid (2 m × 2 m) contained four plugs of that species (one for each experimental treatment; AE = amendment and enclosure, E = enclosure, A = amendment, C = control).

Planting trials were designed to incorporate the three trial species (*V. membranaceum*, *S. canadensis*, and *A. alnifolia*) and four experimental treatments. Specifically, treatments included an enclosure (fencing), a soil nutrient amendment, a combined treatment of amendment and enclosure, and a control (no treatment). A total of 864 seedlings were planted for each species (combined total of 2592 seedlings). At each trial site, species were distributed within a 6 × 6 grid (12 m × 12 m, 144 m<sup>2</sup>; Fig. 2). Each grid square (4 m<sup>2</sup>) included four seedlings of that species (one for each of the four experimental treatments) resulting in 12 replicates of each treatment-species combination ( $n = 216$  for each species-treatment combination across all 18 trial sites). The amendment treatment consisted of 10 g of slow-release shrub fertilizer (18-4-

6) applied in separate holes approximately 10 cm deep and 2.5 cm away from each seedling. Newly planted seedlings generally have limited root development and, thus, reduced capacity for water and nutrient uptake (Grossnickle, 2005). For this reason, slow-release fertilizers placed near the root system are generally recommended to help overcome planting stress and improve seedling establishment (Grossnickle, 2005). For the enclosure treatment, cylindrical enclosures measuring approximately 12 in. tall and 5 in. in diameter were constructed from 1-in. hexagonal weave chicken wire. Individual enclosures accommodated the randomized plot layout by removing the need to group seedlings within large enclosures at each site, while still discouraging ungulate browsing.

**Table 1**

Model coefficients and standard errors for first-season, overwinter, second-season, and overall survival (AE = amendment and enclosure, E = enclosure, A = amendment, PDIR = potential direct incident radiation based on a digital elevation model).

Species	Period	Model <sup>a</sup>	Treatments			Covariates			
			AE	E	A	Initial Height	Elevation	Elevation <sup>2</sup> (quadratic)	PDIR
<i>S. canadensis</i>	First	1	−0.36 (0.21) <sup>*</sup>	0.81 (0.21) <sup>***</sup>	−0.92 (0.21) <sup>***</sup>				
		2	−0.36 (0.21) <sup>*</sup>	0.78 (0.21) <sup>***</sup>	−0.94 (0.21) <sup>***</sup>	0.060 (0.037)	5.1 <sup>b</sup> (1.2 <sup>b</sup> ) <sup>***</sup>		12 (3.2) <sup>***</sup>
	Overwinter	1	−0.16 (0.32)	0.77 (0.32) <sup>**</sup>	−0.38 (0.35)				
		2	−0.18 (0.32)	0.78 (0.32) <sup>**</sup>	−0.39 (0.35)	0.016 (0.060)	2.5 <sup>b</sup> (1.9 <sup>b</sup> )		−3.7 (4.4)
	Second	1	0.69 (0.39) <sup>*</sup>	0.22 (0.31)	0.99 (0.46) <sup>**</sup>				
		2	0.65 (0.39) <sup>*</sup>	0.26 (0.32)	0.98 (0.46) <sup>**</sup>	−0.96 <sup>b</sup> (0.061)	4.6 <sup>a</sup> (1.4 <sup>b</sup> ) <sup>***</sup>		6.1 (3.5) <sup>*</sup>
	Overall	1	0.034 (0.26)	0.84 (0.24) <sup>***</sup>	−0.34 (0.28)				
		2	0.022 (0.26)	0.81 (0.24) <sup>***</sup>	−0.36 (0.28)	0.053 (0.043)	6.5 <sup>b</sup> (1.4 <sup>b</sup> ) <sup>***</sup>		9.0 (3.6) <sup>**</sup>
<i>V. membranaceum</i>	First	1	−0.59 (0.22) <sup>***</sup>	0.78 (0.24) <sup>***</sup>	−0.83 (0.22) <sup>***</sup>				
		2	−0.59 (0.22) <sup>***</sup>	0.77 (0.24) <sup>***</sup>	−0.83 (0.22) <sup>***</sup>	0.012 (0.015)	0.094 (0.10)	−0.027 <sup>b</sup> (0.031 <sup>b</sup> )	11 (8.0)
	Overwinter	1	0.055 (0.30)	0.35 (0.28)	−0.25 (0.30)				
		2	0.055 (0.30)	0.40 (0.28)	−0.25 (0.30)	0.035 (0.019) <sup>*</sup>	0.089 (0.054) <sup>†</sup>	−0.026 <sup>b</sup> (0.017 <sup>b</sup> )	−3.1 (4.1)
	Second	1	0.20 (0.34)	0.66 (0.32) <sup>**</sup>	−0.26 (0.35)				
		2	0.17 (0.34)	0.64 (0.32) <sup>**</sup>	−0.27 (0.35)	−2.8 <sup>b</sup> (0.021)	−0.13 (0.085)	0.040 (0.026)	3.8 (6.7)
	Overall	1	−0.21 (0.24)	0.78 (0.23) <sup>***</sup>	−0.72 (0.26) <sup>***</sup>				
		2	−0.21 (0.24)	0.78 (0.23) <sup>***</sup>	−0.73 (0.26) <sup>***</sup>	0.015 (0.015)	6.9 <sup>b</sup> (2.5 <sup>b</sup> ) <sup>***</sup>		8.1 (6.3)
<i>A. alnifolia</i>	First	1	−0.60 (0.25) <sup>**</sup>	0.71 (0.32) <sup>**</sup>	−0.95 (0.25) <sup>***</sup>				
		2	−0.60 (0.26) <sup>**</sup>	0.76 (0.32) <sup>**</sup>	−0.98 (0.25) <sup>***</sup>	0.028 (8.3 <sup>b</sup> ) <sup>***</sup>	−0.026 (0.061)	0.0082 <sup>b</sup> (0.019 <sup>b</sup> )	15 (5.3) <sup>***</sup>
	Overwinter	1	0.37 (0.39)	0.43 (0.38)	−0.39 (0.35)				
		2	0.41 (0.40)	0.52 (0.38)	−0.38 (0.35)	0.032 (0.013) <sup>***</sup>	−0.092 (0.086)	0.029 (0.027)	4.6 (6.7)
	Second	1	0.58 (0.35) <sup>*</sup>	0.71 (0.34) <sup>**</sup>	−0.73 (0.30) <sup>**</sup>				
		2	0.57 (0.35)	0.69 (0.34) <sup>**</sup>	−0.70 (0.30) <sup>**</sup>	−6.6 <sup>b</sup> (0.012)	3.6 <sup>b</sup> (1.5 <sup>b</sup> ) <sup>**</sup>		12 (4.2) <sup>***</sup>
	Overall	1	0.00 (0.21)	0.73 (0.22) <sup>***</sup>	−0.89 (0.21) <sup>***</sup>				
		2	5.4 <sup>b</sup> (0.21)	0.76 (0.23) <sup>***</sup>	−0.90 (0.21) <sup>***</sup>	0.021 (7.1 <sup>b</sup> ) <sup>***</sup>	1.9 <sup>b</sup> (1.4 <sup>b</sup> )		13 (3.8) <sup>***</sup>

<sup>a</sup> Model 1 included only treatment variables; Model 2 included both treatment and non-treatment variables.

<sup>b</sup> Original value multiplied by 1000 for formatting reasons.

<sup>\*</sup> *p*-value < 0.1.

<sup>\*\*</sup> *p*-value < 0.05.

<sup>\*\*\*</sup> *p*-value < 0.01.

### 2.5. Seedling procurement, handling, and planting

Seedlings of *S. canadensis*, *V. membranaceum*, and *A. alnifolia*, were obtained from nearby Cranbrook, British Columbia (approximately 95 km away), which has similar climates and habitats. All stock was established from locally sourced seeds in January 2013 and grown until June 2013. Seedlings were grown in heated greenhouses until they developed a solid root ball, at which point they were moved outside to harden. Shipments were staggered during the planting period (mid- to late-June) to avoid heat or moisture stress prior to planting. Initial analyses revealed that planting date had no effect on survival and was therefore not included in survival models. Mean temperature and total precipitation were 7.5% and 1.2% higher than normal (based on 30-year climate normals) during the summer (June–August) of 2013 and 2014, respectively. Seedlings were planted in June 2013, and first-season survival was measured at the end of the first growing season prior to seedling senescence and snow cover (September, 2013) to allow for identification of live shrubs. Overwinter survival was measured at the start of the second growing season (June, 2014) following snowmelt and leaf out. Finally, second-season survival was measured at the end of the second growing season in late August 2014.

### 2.6. Seedling survival

Seedling survival was assessed separately for each species as a binary response (0 = died; 1 = survived) using mixed effects logistic regression. This was done separately for the first growing season, overwinter, and second growing season periods. Only seedlings that survived a given period were included in analyses for subsequent periods (i.e., only seedlings that survived the first growing season were included in overwinter survival analyses). Overall survival (i.e., dead seedlings were not censored) was also modeled to assess treatment and non-treatment effects across the full trial period (15 months). A random effect (intercept) for trial plot was used to account for replicated observations within a site. Initial analyses revealed that the spatial arrangement of seedlings within each trial plot had no significant effect on survival and was therefore not considered in survival models. Binary variables were coded for each treatment and included in initial models to test for treatment effects on seedling survival. Initial seedling height (representative of initial seedling condition), elevation, and potential direct incident radiation (PDIR; McCune and Keon, 2002) were added to treatment models to test for possible non-treatment effects on survival. Initial seedling height was used to represent initial seedling condition, which may affect survival, whereas elevation was used as a proxy for possible climatic effects. Elevation is a surrogate for a complex set of climatic variables and varies geographically, but is useful for ease of communicating results to managers. Linear and quadratic forms of the elevation covariate were considered for each species, and the most supported form (based on *p*-value from univariate logistic regression) was included in

the full model. PDIR was derived from a digital elevation model and was included to account for possible slope and aspect effects on seedling survival despite trials being installed on sites with slopes of less than 10°.

## 3. Results

### 3.1. Occupancy rates

Overall, occupancy rates for *S. canadensis* decreased with elevation, with a maximum occupancy rate of 0.67 in the lowest elevation zone, and a minimum occupancy rate of 0.17 in the 1900–2000 m elevation zone (Table 2, Fig. 4). Similarly, *A. alnifolia* occupancy rates decreased with elevation, and ranged from absent (e.g. 0.00) in the highest elevation zone to 0.83 in the lowest elevation zone (Table 2, Fig. 4). Finally, occupancy rates for *V. membranaceum* generally increased with elevation, and ranged from absent (e.g. 0.00) in the lowest elevation zone to 0.58 in the 1900–2000 m elevation zone (Table 2, Fig. 4).

### 3.2. Survival rates

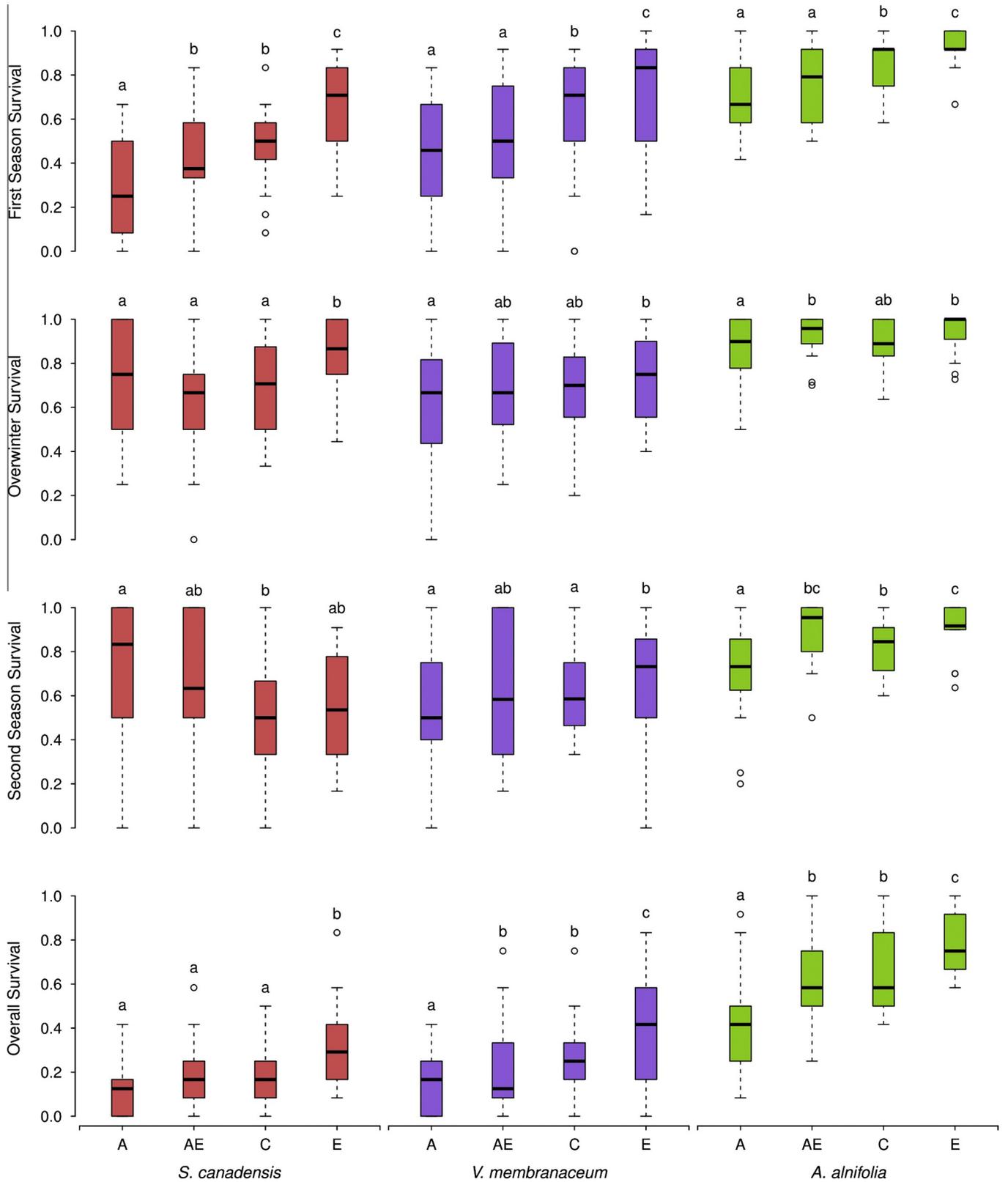
First-season (summer) survival was highest for *A. alnifolia* (80.4%), followed by *V. membranaceum* (57.1%) and *S. canadensis* (45.7%). Treatment effects on first-season survival were consistent across all trials species (Table 1, Fig. 3). Amendment and combined (included both amendment and exclosures) treatments were negatively related to survival, whereas the exclosure treatment increased survival rates. First-season survival of *S. canadensis* was positively related to elevation and PDIR. First-season survival for *V. membranaceum* was not related to any tested treatments. First-season survival of *A. alnifolia* was positively related to initial seedling height and PDIR.

Overwinter survival for seedlings that survived their first summer was higher than first season (summer) survival at 90.5%, 71.4%, and 70.8% for *A. alnifolia*, *S. canadensis*, and *V. membranaceum*, respectively. The exclosure treatment increased overwinter survival rates in *S. canadensis*, but no other treatment effects were supported in overwinter survival models (Table 1, Fig. 3). Non-treatment factors were generally not supported in overwinter survival models with the exception of initial seedling height, which was positively related overwinter survival in *A. alnifolia*.

*A. alnifolia* had the highest second-season (summer) survival rate (85.1%), followed by *V. membranaceum* (63.6%) and *S. canadensis* (61.7%). The exclosure treatment increased second-season survival for *V. membranaceum* and *A. alnifolia* (Table 1, Fig. 3). The amendment treatment had a positive effect on second-season survival of *S. canadensis* and a negative effect on second-season survival of *A. alnifolia*. Second-season survival for *S. canadensis* was positively related to elevation. A positive relationship between PDIR

**Table 2**  
Occupancy rates for trial species and number of field plots in 100-m elevation zones ranging from 1300 m to 2100 m (Braid and Nielsen, 2015). Occupancy rates for each elevation zone are the number field plots occupied by a given trial species divided by the total number of field plots within that elevation zone.

Elevation zone (m)	<i>S. canadensis</i> occupancy rate	<i>V. membranaceum</i> occupancy rate	<i>A. alnifolia</i> occupancy rate	Number of field plots
1300–1400	0.67	0.00	0.83	6
1400–1500	0.48	0.18	0.56	62
1500–1600	0.41	0.06	0.50	70
1600–1700	0.51	0.03	0.40	67
1700–1800	0.41	0.02	0.28	64
1800–1900	0.25	0.36	0.04	28
1900–2000	0.17	0.58	0.17	12
2000–2100	0.25	0.38	0.00	8

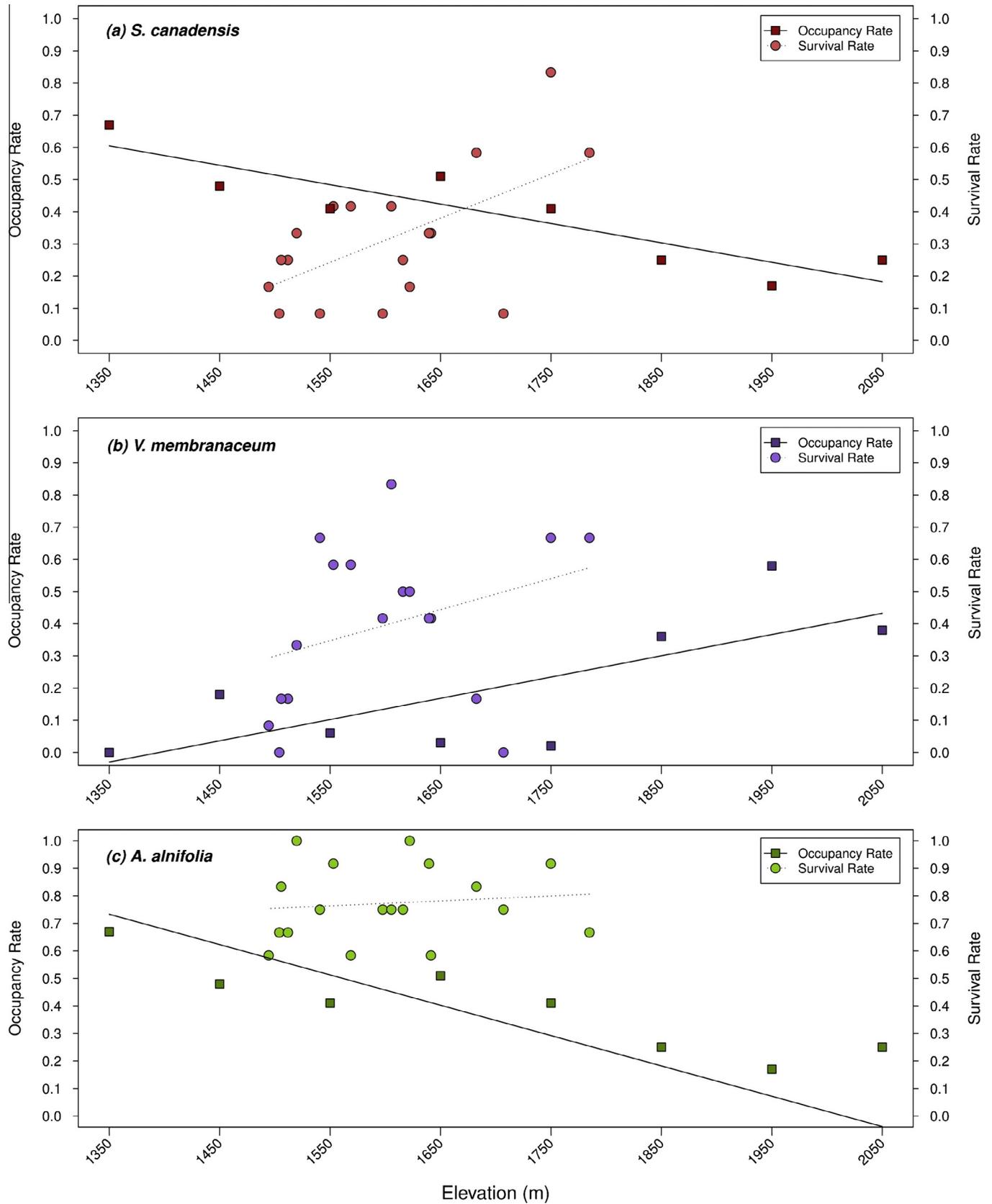


**Fig. 3.** Boxplots of first-season, overwinter, second-season, and overall survival (proportion of seedlings survived) by trial plot for each species (A = amendment; AE = amendment and enclosure; C = control; E = enclosure). Letters indicate significant differences between treatments (while controlling for effects of solar radiation, elevation, and initial seedling height using logistic regression;  $p < 0.05$ ).

and second-season survival was weakly supported for *S. canadensis*, and strongly supported for *A. alnifolia*.

Overall survival was highest for *A. alnifolia* (61.9%), followed by *V. membranaceum* (25.7%) and *S. canadensis* (20.1%). The enclosure

treatment positively affected overall survival for all three trial species, whereas the amendment treatment negatively affected overall survival for *A. alnifolia* and *V. membranaceum* (Table 1, Fig. 3). The combined treatment of enclosure and amendment did not



**Fig. 4.** Occupancy rates and survival rates for (a) *Shepherdia canadensis*, (b) *Vaccinium membranaceum*, and (c) *Amelanchier alnifolia* along an elevation gradient. Occupancy rates were calculated for 100-m elevation zones ranging from 1300 m to 2100 m using presence–absence data from 322 stratified field plots (Braid and Nielsen, 2015). Overall survival rates were calculated for each trial site and plotted against elevation.

affect overall survival for any trial species. Initial seedling height positively affected overall survival for *A. alnifolia*. Overall survival for *S. canadensis* and *V. membranaceum* increased with elevation, whereas no effect of elevation was observed on overall survival of *A. alnifolia*. As with first- and second-season survival, PDIR positively affected overall survival for *S. canadensis* and *A. alnifolia*.

## 4. Discussion

### 4.1. Seedling survival

Survival rates were lowest during the first growing season for all three trial species, and increased for the overwinter and second-season periods. Overall survival was highest for *A. alnifolia* (61.9%), followed by *V. membranaceum* (25.7%) and *S. canadensis* (20.1%). Similar tests of containerized *A. alnifolia* and *S. canadensis* seedling survival have been conducted in reclamation experiments given their natural association with nutrient-deprived, disturbed sites (Walkup, 1991; Fryer, 1997; Shaw et al., 2004). Dreesen (2000) obtained a similar survival rate of 53% for containerized *A. alnifolia* seedlings planted on mine overburden piles, whereas Fedkenheuer et al. (1980) reported survival rates of between 78% and 100% for *A. alnifolia* seedlings planted on amended oil sand tailings. In the same study, survival rates for containerized *S. canadensis* seedlings ranged from 56% to 100%. Similarly, Visser et al. (1991) reported first-year survival rates for *S. canadensis* seedlings planted on amended oil sand tailings of 53–75%, although they noted much lower survival in the second year. The lack of browsing and herbaceous competition may explain the higher survival rates for both species when planted on amended oil sand tailings. Comparable tests of containerized *Vaccinium* spp. seedling survival on disturbed sites are lacking.

### 4.2. Treatment effects

Treatment effects were strongest during the first growing season, indicating that although amendments and enclosures may have played significant roles in determining initial seedling establishment (i.e. first-season survival), they did not influence subsequent seedling survival (Table 1, Fig. 3). Low survival rates and strong treatment effects during the first growing season affected overall survival rates, with patterns in overall survival data paralleling first-season patterns (Fig. 3). The enclosure treatment positively affected overall seedling survival for all trial species, although evidence of browsing was limited (Table 1, Fig. 3). Generally, this suggests that enclosures may have increased survival rates by limiting competition from neighbouring plants and not necessarily by protecting the seedlings from browsing. This is consistent with Straker et al. (2010) who found that individual plant protectors (enclosures) increased survival rates for most deciduous species. Contrary to what was predicted, the amendment treatment negatively affected overall survival for both *V. membranaceum* and *A. alnifolia*, but did not significantly affect overall survival in *S. canadensis* (Table 1, Fig. 3). The addition of soil nutrients may have increased the competitive ability of neighbouring plants. Limited root development and root-soil contact could have reduced the seedlings' ability to uptake nutrients compared to other plants already established in the forest harvest (Grossnickle, 2005). Dreesen (2000) observed a similar negative relationship between soil nutrient amendments and seedling survival rates for containerized *A. alnifolia* seedlings, although they applied fertilizer over five successive growing seasons. Conversely, Densmore and Holmes (1987) found that fertilizer treatments had little to no effect on short-term (first-season) containerized seedling survival.

### 4.3. Non-treatment effects

Initial seedling height did not affect survival rates for *S. canadensis* or *V. membranaceum*. This is consistent with the findings of Straker et al. (2010), who found that stock age and size did not significantly affect long-term seedling survival for containerized shrub seedlings used in coal mine reclamation, and suggested that younger seedlings are generally more cost-effective. Conversely, initial height was positively related to survival for *A. alnifolia* (first-season, overwinter, and overall survival), suggesting that initial seedling condition plays an important role in determining survival rates for *A. alnifolia*, with more developed seedlings having a higher chance of successful establishment.

Elevation was positively related to overall survival for *S. canadensis*, which is unexpected given that *S. canadensis* is typically described as a low to moderate-elevation species in Alberta (Walkup, 1991; Nielsen et al., 2003, 2004b). Observed occupancy rates of *S. canadensis* were consistent with the expected niche space of the species and decreased with elevation (Table 2, Fig. 4). This suggests that other factors (potentially site-specific factors, such as soil characteristics) influenced *S. canadensis* survival more strongly than elevation increasing survival at higher elevations. Overall survival rates increased with elevation for *V. membranaceum*, which is consistent with observed patterns in occupancy rates and the expected niche space for the species (moderate to high elevations; Roberts et al., 2014). Changes in observed occupancy rates of *V. membranaceum* with elevation were consistent with changes in survival rates along the same gradient (Table 2, Fig. 4). Similar to *S. canadensis*, *A. alnifolia* typically occurs at low to moderate elevations in Alberta (Roberts et al., 2014). Observed occupancy rates of *A. alnifolia* corroborated this pattern with decreases in occupancy with elevation (Table 2, Fig. 4). Conversely, overall survival rates of *A. alnifolia* were consistently high across all elevations, contrary to the expected niche space of the species suggesting that the fundamental niche of the species may be much wider than its realized niche, which is shaped by longer-term processes like interspecific competition for resources (Griesemer, 1992; Pulliam, 2000).

Lastly, solar radiation (PDIR) positively affected first-season and overall survival for *S. canadensis* and *A. alnifolia*, suggesting that microsite-related increases in growing degree days may be more important than moisture in limiting survival of these two species. However, given that all trial sites had slopes less than 10°, the range of PDIR values was relatively narrow, and thus relationships between PDIR and survival rates are representative of only a narrow range of possible PDIR values.

### 4.4. Management recommendations

Overall survival rates over two growing seasons were lowest for *S. canadensis* and *V. membranaceum*, at 20% and 26% respectively. This indicates that establishment of these species in forest harvests is feasible, although survival rates may be increased by testing alternative growing and outplanting methods. *A. alnifolia* had the highest overall survival rate (62%), but is also preferred winter browse for ungulates which can limit its long-term productivity (Ferguson, 1983; Kay, 1995; Paschke et al., 2003; Shaw et al., 2004; Straker et al., 2010). Thus, even though *S. canadensis* and *V. membranaceum* may have lower short-term survival rates, they would also have lower browsing pressure and may therefore be more productive than *A. alnifolia* in the long-term.

Enclosures increased survival rates but required a significant monetary investment to construct and install (Straker et al., 2010). For preferred browse species such as *A. alnifolia*, the use of enclosures can help to ensure successful establishment and to protect seedlings until they are sufficiently developed to resist

browsing pressure (Straker et al., 2010). Indeed, protection from browsing pressure is generally recommended for *A. alnifolia* seedlings during the first 3–4 growing seasons because new shoots are highly palatable to ungulates (Paschke et al., 2003; Shaw et al., 2004; Straker et al., 2010). This is especially true for forest grazing leases (which are prevalent in this study area) because young *A. alnifolia* growth is palatable to livestock (Paschke et al., 2003). Conversely, habitat enhancements using less palatable species such as *S. canadensis* or *V. membranaceum* could benefit from simply planting additional seedlings rather than investing in protective measures such as exclosures.

The addition of soil nutrient amendments was expected to bolster seedling survival and growth, but had the opposite effect with decreased survival rates. The use of soil nutrient amendments in wildlife habitat enhancements should be informed by site-specific soil nutrient assessments and should be applied on a case-by-case basis. Nutrient regimes will differ between sites, and nutrient requirements of candidate shrub species will also vary. For example, *S. canadensis* is a nitrogen-fixing species that can thrive on disturbed, nutrient-poor sites (Walkup, 1991). Because of this, it may not require additional nutrients, and may even be negatively affected by fertilizer treatments if they increase herbaceous competition.

Both *S. canadensis* and *A. alnifolia* typically occur at low to moderate elevations in Alberta (Walkup, 1991; Nielsen et al., 2003, 2004b; Roberts et al., 2014), yet the results of these trials indicate the opposite trend for *S. canadensis*, and no effect of elevation was observed on *A. alnifolia* survival. In the case of *S. canadensis*, this suggests that knowledge of its niche space along the elevation gradient alone is not sufficient to identify areas where it will have higher initial establishment. On the other hand, for *A. alnifolia* consistently high survival rates across the elevation gradient suggests that its fundamental niche is much wider than its realized niche, which in turn indicates that it is possible to plant the species outside of its expected niche space and still have successful initial establishment. From a management perspective, knowledge of the relationships between the survival and growth of these species and elevation will be an important component of designing successful wildlife habitat enhancements.

Finally, *A. alnifolia* typically shows adaptations to local conditions (Shaw et al., 2004). It is recommended that seeds used to

grow containerized stock are collected in close proximity to eventual planting locations (Paschke et al., 2003; Shaw et al., 2004). While it is unclear whether this also applies to *S. canadensis* and *V. membranaceum*, it is not unreasonable to assume that most shrub species exhibit local optimality to some extent (Chai et al., 2013), and that seedlings may underperform when planted on sites dissimilar to their original seed sources. The closest native plant nursery with sufficient quantities of planting stock for this study was located in Cranbrook, British Columbia at a distance of approximately 95 km (59 miles). Though they source their seeds locally and the general range of climates between the areas (seed sources and planting locations) is similar, it is possible that this may have reduced survival rates (Hope et al., 1991; Ketchenson et al., 1991; Coupé et al., 1991; Natural Regions Committee, 2006). Transfer of seedlings between similar biogeoclimatic regions is also consistent with Alberta's native plant revegetation guidelines (Native Plant Working Group, 2000). Where possible, managers should strive to obtain planting stock from local sources to help maximize survival rates. In some cases (such as in Alberta), use of locally-sourced planting stock for shrubs is becoming a regulatory requirement to limit maladaptation and to maintain genetic integrity (Chai et al., 2013).

## 5. Conclusions

Habitat enhancements have the potential to increase grizzly bear food supply in disturbed areas, including forest harvests. However, long-term tests are needed to quantify fruit production and the effects of inter-annual climatic variation and interspecific interactions (browsing, competition for resources, etc.), which may influence long-term survival, growth, and fruit production (Griesemer, 1992; Pulliam, 2000). As natural forest openings become less prevalent (Nielsen et al., 2004a; Stewart et al., 2012), anthropogenically-created forest openings, if properly managed, have the potential to provide considerable quantities of late-season food resources (fruit) for grizzly bears. Active management techniques such as planting fruit-producing food items in harvested blocks (Nielsen et al., 2004a) represent one possible step in a mitigation strategy to benefit grizzly bear conservation. Moreover, the use of habitat enhancements must be coupled with access restrictions to avoid the development of attractive sinks (high risk,

**Table A.1**

Site details for planting trials in southwestern Alberta. Universal transverse Mercator (UTM) coordinates are specific to UTM zone 11. Opening numbers are unique identifiers for forest harvests and are a concatenation of the forest harvest's legal land description and a grid cell number (format is MRRTTTSSGG, where M = meridian, RR = range, TTT = township, SS = section, GG = grid cell). Percent cover for trial species was calculated using line intercept data from 50-m line intercept transects conducted within each forest harvest.

Site number	UTM easting	UTM northing	Elevation (m)	Slope (°)	Aspect (°)	Opening number	<i>S. canadensis</i> cover (%)	<i>V. membranaceum</i> cover (%)	<i>A. alnifolia</i> cover (%)
1	0674528	5503421	1465	3	164	5050082330	4.2	0.0	3.0
2	0674507	5504120	1476	0	–	5050082340	0.0	0.0	0.4
3	0681535	5508323	1797	3	344	5040090470	0.8	0.0	0.0
4	0683449	5531222	1494	5	190	5040111450	0.0	0.0	0.0
5	0680975	5531778	1518	2	70	5040111510	0.0	0.0	0.0
6	0681651	5531195	1532	2	184	5040111540	0.0	0.0	0.0
7	0672906	5508090	1680	5	262	5050090340	4.0	0.0	2.0
8	0672152	5511278	1757	6	270	5050091500	0.0	0.0	0.0
9	0672624	5506821	1604	7	260	5050083420	–	–	–
10	0673807	5505501	1583	10	225	5050082800	1.2	0.0	0.0
11	0675822	5503785	1485	2	55	5050082410	1.4	0.0	4.4
12	0682026	5503668	1550	8	130	5040082190	1.6	0.0	2.0
13	0681319	5505259	1708	9	120	5040082850	0.0	0.0	1.2
14	0681537	5503651	1592	6	95	5040082160	0.2	0.0	0.0
15	0681384	5503324	1611	7	220	5040082150	0.0	0.0	0.0
16	0673102	5507111	1633	4	200	5050083460	2.6	0.0	1.4
17	0675332	5503769	1478	4	255	5050082380	0.0	0.0	3.0
18	0681319	5505259	1631	7	85	5040082850	0.0	0.0	0.0

high quality habitats; Nielsen et al., 2006; Cristescu et al., 2012). Use of disruptive post-harvest site preparation methods, such as mechanical scarification, should be avoided where possible and patches of native fruit-bearing shrubs should be allowed to regenerate. Long-term periodic thinning of planted conifers should also be considered. Thinning has the potential to bolster grizzly bear food supply in forest harvests by reducing canopy cover (Nielsen et al., 2004a), and can also increase timber yields by reducing competition between conifer saplings. In the absence of periodic thinning (which may also complicate access restrictions), planting containerized shrub seedlings may be the only viable option for producing significant quantities of fruit in forest harvests before canopy closure limits fruit production. Food resources such as fruit are a critical component of high quality grizzly bear habitat, and forestry practices have the potential to play a fundamental role in increasing the availability of fruit-bearing shrubs.

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## Appendix A

See Table A.1.

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