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Comparison of potential non-timber forest products in intensively managed young stands and mature/old-growth forests in south-central British Columbia

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ABSTRACT

Development of understory vegetation has been influenced by the many densely stocked second-growth forest stands in North America, which have an extended stem exclusion successional stage. Understory composition and structure is important for ecosystem functioning, while also having social and economic value through the harvest of certain herb and shrub species. The potential for co-management of young and mature, managed and unmanaged stands for timber and non-timber forest products (NTFPs) was assessed in two separate replicated experiments. Experiment A examined pole-sized lodgepole pine (*Pinus contorta*) stands that had been pre-commercially thinned (PCT) to target densities of 250, 500, 1000, and 2000 stems/ha. Half of each of these four thinning units was repeatedly fertilized, resulting in eight experimental units. Experiment B examined six different stand types: young plantations, pole-sized lodgepole pine stands either PCT, PCT plus repeated fertilization, or unthinned, mature, and old growth. Fifty-four herb and shrub species were identified as potential NTFPs, with the responses of individual species, as well as mean total herb, shrub, berry-producing and overall total NTFPs being assessed. In Experiment A, mean total abundance (crown volume index) of NTFPs, as well as mean total herb NTFPs were significantly greater in fertilized than in unfertilized stands. Thinning treatments did not significantly affect NTFP volume, however, fertilization treatments produced five significant responses by individual species (*Achillea millefolium*, *Epilobium angustifolium*, *Taraxacum officinale*, *Arctostaphylos uva-ursi*, *Rubus idaeus*). In Experiment B, four of the six species responses that were significant had greater abundance in young, managed stands (young plantation, thinned, or thinned-fertilized) than in the unmanaged stands. Mean total NTFP volume and mean total herb NTFP volume also followed this pattern. *A. uva-ursi*, *E. angustifolium*, *Lonicera involucrata*, *Sorbus sitchensis* and *Thalictrum occidentale* all had significantly higher abundance in young, managed stands than in all other treatments. Results suggest that co-management for timber and NTFPs is possible in this ecosystem, with further research needed to evaluate livelihood values of these crops.

1. Introduction

Non-timber forest products (NTFPs) consist mainly of plants and fungi that may be used for a variety of traditional, commercial, recreational or cultural purposes (Vance et al., 2001). NTFPs have been, and continue to be, harvested throughout North America for traditional uses by local First Nations groups (Marles et al., 2000; Duchesne and Wetzel, 2002) Many traditional cultures the world over have a thorough understanding of the relationship between NTFPs and the ecosystems in which they thrive (Myers, 1988; Gautam and Watanabe, 2002). Understory herbs and shrubs, in particular, have been used for millennia by Canadian First Nations for a variety of uses to support livelihoods, including medicinals, edibles, cultural purposes, and trade (Duchesne and Wetzel, 2002). Current livelihood values of these species, which include cultural, subsistence, recreational, and commercial uses, have led to speculation that the harvest of NTFPs may be a sustainable use of natural resources that could aid in the diversification of forest management (Peterson and Maserud, 2002). However, the NTFP industry is relatively uncontrolled and the unsustainable harvest of some of these crops has been noted in recent years (Turner et al., 2000; Ticktin, 2004; Cocksedge and Titus, 2006).

Certain NTFP plants may be associated with old-growth forests that are often high in biodiversity and canopy differentiation; attributes that are not usually present in second-growth stands (Carey, 1998). Structural features such as snags, variable canopy

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gaps, multiple tree layers as well as development of a complex herb and shrub understory, all contribute to old-growth structure and function (Franklin et al., 2002). Second-growth forests may reach a competitive exclusion stage more rapidly than natural stands due to management activities designed to decrease the time until crop trees dominate the landscape. This limits understory development, abbreviating the herb–shrub dominant stage, and decreasing the diversity of this relatively species poor and homogenous sucessional stage (Klinka et al., 1996; Carey, 1998). Managing second-growth forests for old-growth structural factors may be possible by manipulating overstories to enhance the biological function of these second-growth stands (Klinka et al., 1996; Carey, 1998; Sullivan et al., 2001, 2006).

Forest management regimes designed solely to produce merchantable timber neglect other potential economic returns and services from forested ecosystems as well as values outside the traditional timber market. Non-market values include understory biodiversity (Klinka et al., 1996; Bailey and Tappeiner, 1998; Lindh and Muir, 2004), wildlife habitat (Carey, 1998), and nutrient cycling (Tappeiner and Alm, 1975). The economic value of NTFP extraction may offer periodic income during the otherwise profitless period between timber harvests (Duchesne and Wetzel, 2002; Titus et al., 2006). Conversely, land set aside primarily for NTFP purposes such as areas designed to protect wildlife habitat and ecosystem integrity, may often overlook the conservation potential of managed stands (Carey, 1998). The co-management of forested land for multiple resource use may potentially form a synergy between two apparently disparate objectives, economic growth and land stewardship (Carey, 1998; Duchesne and Wetzel, 2002; Gautam and Watanabe, 2002; Peterson and Maserud, 2002).

Forest stands in the Southern Interior of British Columbia are largely dominated by lodgepole pine (*Pinus contorta*). This species regenerates naturally to high-density stands following large-scale disturbances such as fire or timber harvesting. Competition for light, moisture, and nutrients among trees within densely stocked stands can lead to very slow growth rates and a condition known as repression. Consequently, the silvicultural practices of pre-commercial thinning (PCT) and fertilization increase timber growth of repressed lodgepole pine stands, thereby reducing the rotation length (Yang, 1998; Blevins et al., 2005; Brockley, 2005).

Thinning overstory trees increases understory light levels, and consequently has positive effects on growth of understory vegetation. Increased shrub cover in managed stands has been attributed to PCT (Klinka et al., 1996; Thomas et al., 1999; Harrington et al., 2002), and, while thinning may not change patterns of understory succession, it may extend the period conducive to understory growth (Alaback and Herman, 1988). Commercial thinning maintains overstory canopy gaps longer due to the successional stage at time of thinning (Bailey et al., 1998; Lindh and Muir, 2004; Titus et al., 2006). Understory response to fertilization tends to be more variable and species-specific (Thomas et al., 1999; He and Barclay, 2000; Bennett et al., 2004). Although much work has been done on the effects of thinning and fertilization on timber supply (Bennett et al., 2003; Blevins et al., 2005; Brockley, 2005; Sullivan et al., 2006; Lindgren et al., 2007) and understory biodiversity (Lindh and Muir, 2004; Lindgren et al., 2006), the impacts on potential NTFP harvest have yet to be examined at an operational level.

The values provided by NTFP harvest in managed stands may provide an added incentive for land managers to treat understory regrowth and development as an important component to forest management, while simultaneously managing for timber production. However, research of co-managed systems using silviculture and NTFPs is still in its infancy. As part of a larger project on the effects of incremental silviculture of lodgepole pine stands on non-timber values (Sullivan et al., 2001, 2006; Lindgren et al., 2007), this study examined shrubs and herbs within the understory that could potentially contribute to livelihoods. Thus, this study was designed to test the hypothesis that large-scale PCT and repeated fertilization in pole-sized lodgepole pine stands, up to 10 years after the onset of treatments, would enhance production of NTFPs compared to that in young plantations, mature, and old-growth stands.

2. Methods

2.1. Experimental design

Two experiments (A and B) were conducted. Each of the three replicated study areas used during Experiment A was divided into four treatment units, each receiving a randomly assigned PCT treatment of either 250, 500, 1000, or 2000 stems/ha. One-half of each thinning unit received fertilizer treatments. Assignment of fertilizer treatments was partially dependent on logistics related to the helicopter application method used to deliver the fertilizer and was, therefore, not completely random. Fertilization was applied at a commercial scale for timber production, with the intention of measuring non-timber responses to this treatment.

In Experiment B (mosaic of habitats), three replicates were chosen at the Kelowna (replicate 1, medium sites; replicate 2, wet sites) and Summerland (replicate 3) study areas. Each mosaic consisted of six habitats which represented the most common habitat types in these particular forest management areas: (1) young plantation; (2) young thinned stand; (3) young thinned and fertilized stand; (4) young unthinned stand; (5) mature stand; and (6) old-growth stand. An outline of the experimental design for each of Experiments A and B is given in Table 1.

2.2. Study areas

Experiment A was conducted at three replicated study areas in southern British Columbia (BC) in pole-sized lodgepole pine stands that had relatively uniform tree cover, comparable diameter, height, and density of trees prior to stand treatments. PCT treatments were applied at all study areas in 1993, at which time mean stand age ranged from 12 to 14 years. Beginning in the fall of 1994, fertilization treatments (100–200 kg N/ha plus lesser amounts of P, K, S, B, and Mg) were applied every second year for a total of five applications (further details below). The Summerland study area was located in the Bald Range 25 km west of Summerland in south-central BC (49°40′N; 119°53′W). This area is within the Montane Spruce (MS_{dm}) biogeoclimatic zone (Meidinger and Pojar, 1991) at an elevation range of 1450–1520 m with gently rolling topography and sandy loam soil. The MS has a cool, continental climate with cold winters and moderately short, warm summers. Mean annual temperature is 0.5–4.7 °C and precipitation ranges from 380 to 900 mm.

Clearcut harvesting of lodgepole pine with some single and group seed-tree reserves of Douglas-fir (*Pseudotsuga menziesii*) began in this area in 1978 in response to an outbreak of mountain pine beetle (*Dendroctonus ponderosa*). Depending on the original composition of the harvested stands and the degree of windthrow after harvesting, the number of residual Douglas-fir ranged from none to 1 or 2 trees per ha in our candidate stands. Lodgepole pine regenerated naturally after harvesting and was the dominant tree species in these young stands. Our study area was made up of three harvested units with pre-thinning stand densities ranging from 9980 to 11,150 stems/ha. Minor components of the stands included Douglas-fir, interior hybrid spruce (*Picea glauca* × *Picea*

Table 1
Experimental design for each of Experiments A and B

	Experiment A								
	Stand density and treatment								
	250		500		1000		2000		Unthinned
	T	T + F	T	T + F	T	T + F	T	T + F	
Replicate[a]									
1	A	B	C	D	E	F	G	H	I
2	A	B	C	D	E	F	G	H	I
3	A	B	C	D	E	F	G	H	I

	Experiment B					
	Stand treatment					
	Young plantation	Thinned[c]	Thinned[c] and fertilized	Unthinned	Mature	Old growth
Replicate[b]						
1	Y_1	T_1	TF_1	U_1	M_1	OG_1
2	Y_2	T_2	TF_2	U_2	M_2	OG_2
3	Y_3	T_3	TF_3	U_3	M_3	OG_3

T, Thinned; F, fertilized.
[a] Replicate 1 = Summerland, 2 = Kelowna, 3 = Cariboo study areas.
[b] Replicate 1 = Kelowna (medium sites), 2 = Kelowna (wet sites), 3 = Summerland study areas.
[c] Pre-commercially thinned to 1000 stems/ha.

engelmannii), subalpine fir (*Abies lasiocarpa*), ponderosa pine (*Pinus ponderosa*), willows (*Salix* sp.), Sitka alder (*Alnus sinuata*), and trembling aspen (*Populus tremuloides*).

In 1998 at 5 years after the start of treatments, and at the initiation of this study, mean (±S.E.) diameter at breast height (dbh = 1.3 m) ranged from 5.0 ± 0.2 to 9.5 ± 0.2 cm and mean (±S.E.) stand height ranged from 4.1 ± 0.1 to 5.1 ± 0.1 m, with a mean age of 17–19 years. Area of stands ranged from 4.4 to 11.3 ha.

The Kelowna study area was located 37 km northwest of Kelowna, BC (50°04′N; 119°34′W) in the MS_{dm} biogeoclimatic subzone. Topography of this area is also gently rolling to flat with sandy loam soil at 1220–1240 m elevation. This area was also clearcut harvested in 1979–1980 and regenerated naturally to lodgepole pine with the other coniferous species, including western larch (*Larix occidentalis*), as minor components. One large unit (84.8 ha) with a pre-thinning density of 8686 stems/ha was shaped in a horseshoe with an unharvested riparian buffer zone separating the two arms. This riparian zone had a steep ravine and varied in width from 75 to 300 m. The overall unit was separated into eight treatment stands as per the experimental design. An additional unit (12.6 ha) 0.5 km away was used as the unthinned stand.

In 1998, the mean (±S.E.) dbh ranged from 6.2 ± 0.2 to 10.8 ± 0.2 cm and mean (±S.E.) stand height ranged from 5.3 ± 0.1 to 6.4 ± 0.1 m with a mean stand age of 17–18 years. Area of stands ranged from 9.5 to 12.6 ha.

The Cariboo study area was located in the Alex Fraser Research Forest (University of British Columbia), 75 km northeast of Williams Lake, BC (52°29′N; 121°45′W) in the Sub-Boreal Spruce (SBS_{dm}) biogeoclimatic zone (Meidinger and Pojar, 1991). While this study area was located in a different zone than the two areas to the south, the MS and SBS zones have many similarities, including comparable mean winter temperatures and snow conditions (Meidinger and Pojar, 1991). The general topography is gently rolling to flat at 850–870 m elevation. In mature stands, interior hybrid spruce, subalpine fir and some Douglas-fir are mixed with extensive stands of lodgepole pine, which regenerated after wildfires. This unit covered 80 ha and was clearcut harvested in 1976 followed by some natural regeneration and some planting of lodgepole pine in 1983. Pre-thinning stand density was 3333 stems/ha. Eight treatment stands were located on this unit. Paired stands were contiguous on one side only. A ninth treatment unit acted as the unthinned stand as per the experimental design.

In 1998, the mean (±S.E.) dbh ranged from 8.5 ± 0.2 to 12.7 ± 0.3 cm and mean (±S.E.) stand height ranged from 6.1 ± 0.1 to 7.6 ± 0.2 m, with a mean stand age of 18 years. Area of stands ranged from 1.5 to 4.5 ha. Thinned units were separated by 0.2–0.5 km.

2.3. Stand treatments

In Experiment A, the initial treatment was PCT of young stands of pine at an appropriate time to maximize growth response potential before they experience severe growth repression. Thinning was done at an operational scale at all study areas in the late summer-early fall of 1993.

The fertilization treatments were designed as large-scale applications of previously established "optimum nutrition" fertilization field experiments in Sweden (Tamm et al., 1999) and BC (Kishchuk et al., 2002; Brockley, 2005). Fertilizer was applied at 2-year intervals for 10 years (total of 5 applications), using multi-nutrient fertilizer formulations developed from annual nutrient diagnosis of lodgepole pine foliage samples. The objective was to maintain elevated foliar N levels (~1.3%), with levels of all other nutrients in proportional balance with N (Ingestad, 1987; Linder, 1995). Fertilization treatments were initiated in November 1994 (Summerland and Kelowna) and April 1995 (Cariboo) using a blended fertilizer formulated to provide 100 kg/ha nitrogen (100 N), 100 kg/ha phosphorus (100 P), 100 kg/ha potassium (100 K), 50 kg/ha sulfur (50 S), 25 kg/ha magnesium (25 Mg), and 1.5 kg/ha boron (1.5 B). The blended product (11–25–13–5.5S–2.7Mg–0.17B) was applied aerially (helicopter) at the Summerland and Kelowna study areas and manually at the Cariboo study area (due to the relatively small treatment areas), at a rate of 906 kg/ha.

Treatment stands were re-fertilized in May 1997 with a N + S blended fertilizer (36–0–0–9S). At an application rate of 547 kg/ha, the blend delivered 200 N and 50 S. All study stands were fertilized for a third time in October 1998, two growing seasons after the second application. Targeted application rates were 150 N, 25 S, and 3 B, using a blended product (37–0–0–6.1S–0.7B) applied at 404 kg/ha. Additional applications were done in fall 2000 and spring 2003. In 2000, targeted application rates were 150 N and 50 S, using a blended product (31.1–0–0–11.3S) applied at 439.4 kg/ha. In 2003, targeted application rates were 150 N and 1.5 B, using a blended product (44.6–0–0–0.45B) applied at 336.1 kg/ha. Application methods (i.e., aerial vs. manual) remained constant throughout the study. Additional details of the PCT and fertilization treatments in Experiment A are reported in Lindgren et al. (2007). Pruning of all pole-sized lodgepole pine and Douglas-fir crop trees at each study area, to a height of 3.0 m, in stands less than 2000 stems/ha was conducted in September to December 1998.

In Experiment B, the two young plantations (Y_1 and Y_2) at Kelowna were clearcut harvested in 1995 and were 13.2 and 9.2 ha in area, respectively. These plantations regenerated naturally to lodgepole pine. Previous forest cover was 99–101-year-old lodgepole pine with mean dbh of 19.5–20.0 cm and mean height of 20.0–20.5 m. The pole-sized lodgepole pine stands were PCT (1993) to 1000 stems/ha as per Experiment A (T_1 and T_2), PCT to 1000 stems/ha and fertilized as per Experiment A (TF_1 and TF_2), and the unthinned stands (U_1 and U_2). These latter stands were clearcut harvested in 1979 and 1982, respectively, and regenerated naturally to lodgepole pine with the other coniferous species as minor components.

The mature forest stands (M_1 and M_2) were composed primarily of lodgepole pine with a minor component of Douglas-fir and

interior spruce at 80–120 years of age. Each of these stands was located near the paired young plantation units (Y_1 and Y_2). The old-growth forest stands (OG_1 and OG_2) were in the 140–250 year age class. Stand OG_1 was dominated by Douglas-fir and stand OG_2 by subalpine fir, Douglas-fir, and interior spruce.

At Summerland, the young plantation (Y_3) was clearcut harvested in winter 1995–1996 and was 12.8 ha in area. This site was planted with lodgepole pine in spring 1997. Previous forest cover was 140–250-year-old lodgepole pine. The pole-sized lodgepole pine stands were PCT (1993) to 1000 stems/ha as per Experiment A (T_3), PCT to 1000 stems/ha and fertilized as per Experiment A (TF_3), and unthinned (U_3) were located on a unit clearcut harvested in 1978. Lodgepole pine regenerated naturally after harvesting and was the dominant tree species in these stands.

The mature forest stand (M_3) in this replicate was composed primarily of 80–120-year-old lodgepole pine with a minor component of Douglas-fir and subalpine fir. There were some veteran Douglas-fir (140–250 years old) trees dispersed through the stand. The old-growth forest stand (OG_3) had 120–140-year-old lodgepole pine and Douglas-fir with subalpine fir and spruce as minor components. Douglas-fir also occurred throughout the stand in the veteran age class of >251 years.

2.4. Sampling of vegetation

To quantify understory vegetation, three permanent transects were established. Each 25-m transect had five plots containing three nested plots of different sizes: 5 m × 5 m, 3 m × 3 m, and 1 m × 1 m for sampling trees, shrubs, and herbs, respectively (Stickney, 1980). Three transects were distributed randomly throughout each stand. Each plant was described by a visual estimate of percent ground cover occupied by a given plant within one of six height classes (0–0.25, 0.25–0.5, 0.5–1.0, 1.0–2.0, 2.0–3.0, and 3.0–5.0 m) determined by the tallest point of a given plant. The height and cover data were then used to calculate the volume of a cylindroid, referred to as a crown volume index (m^3/0.01 ha), which describes the space occupied by each species. Crown volume index values were then averaged by species for each plot size and converted to 0.01-ha base to produce a tabular value given for each species and layer (herbs, shrubs, and trees). Sampling was done annually in July–August 1999–2003 during peak flower and/or fruit production, 6–10 years since PCT. The same person sampled in all years. Grasses were not identified to species. Plant species were identified in accordance with Hitchcock and Cronquist (1973), Parish et al. (1996), and MacKinnon et al. (1992).

For Experiment B, stand ages in the 'young plantation' treatments varied from 1 to 3 years at the initiation of sampling. The 'thinned' and 'thinned-fertilized' stands were 14–15 years and the unthinned stands varied from 13 to 20 years at trial initiation. The mature stands were between 80 and 120 years and the old-growth stands were between 120 and 250 years in age.

2.5. NTFP classification

Non-timber forest products include all products, goods and services from the forest not including timber, or any timber-related product such as wood-shavings (Duchesne and Wetzel, 2002). Mushrooms, berries, and landscaping plants, along with intrinsic goods such as biodiversity, and services like tourism and hunting may also be considered NTFPs. The working definition of NTFP for the purposes of this study include only those understory herbs and shrubs that are currently used in the NTFP sector, or could potentially have use in the future. Much of the knowledge surrounding the use of herbs and shrubs can be attributed to traditional use by indigenous groups (Marles et al., 2000), as well as current NTFP harvesters and users. To determine which species were to be included in an analysis of current and potential NTFPs, each herb and shrub species was evaluated using the literature and plant identification guide books (De Gues, 1995; Willard, 1992; Parish et al., 1996; Vance et al., 2001). The species identified as possessing properties beneficial for use as a NTFP were evaluated on their potential to enter a commercial market. For example, although more plants than were analyzed had potential edible berry crops, berries described as only useful as food in the most dire of needs, or were largely unpalatable regardless of post-harvest preparation methods, were not considered a NTFP (Parish et al., 1996). Also, while cultural uses of NTFPs exist for many of the species examined in this study, species were not selected based on that alone. None of the criteria are mutually exclusive, however, with many species having overlapping uses: commercial, cultural or recreational. The next criterion for selection was a minimum of 0.10 m^3/0.01 ha in total volume for each species. Some species may also have been excluded if their total volume was approximately 0.10 m^3/0.01 ha, but they were present only in one site for 1 year. While a volume of 0.10 m^3/0.01 ha may not represent a lucrative commercial product, the choice was made to include, rather then exclude, many species based on abundance. The compiled list (Table 2) of NTFPs species should not be considered a comprehensive list of all NTFPs in south-central BC, as species chosen for analysis were selected from the larger dataset of herbs and shrubs found within the study areas.

2.6. Statistical analyses

The design of Experiment A restricted the randomness of fertilizer treatment allocation (i.e., applied to one-half of each of the thinned stands). Therefore, a split-plot analysis of variance (ANOVA) (Gotelli and Ellison, 2004) was used to compare mean crown volume index of individual species and groups of species according to NTFP or growth type, and mean species richness among stands. The density and fertilizer treatments were assigned as the main- and split-plots, respectively; time was the split–split-plot. The three regional replicates functioned as blocks and were assigned as a random factor.

A repeated measures analysis of variance (RM-ANOVA) was used in Experiment B (Zar, 1999; Gotelli and Ellison, 2004) to detect significant differences in mean crown volume index of individual species and groups of species according to NTFP or growth type, and mean species richness among stands. Mauchley's W statistic tested for sphericity prior to entering data into the RM-ANOVA (Littel, 1989; Kuehl, 1994). If sphericity could not be assumed (data among repeated measures did not show independence), Huynh–Feldt's correction factor was used to adjust the degrees of freedom for analysis (Huynh and Feldt, 1976). Both experiments did not meet the requirements of normality, therefore data were log transformed prior to analysis.

Duncan's multiple range test (DMRT) was used to compare treatment mean values based on ANOVA results.

Mean values (n = 3 replicate stands) for each year, and overall mean values (n = 15; 3 replicate stands × 5 years), standard errors, and 95% confidence intervals were calculated for abundance of total herbs, total shrubs, total herbs and shrubs together, and total berry-producing shrubs. In all analyses, the level of significance was at least $P = 0.05$.

3. Results

3.1. Abundance of total NTFPs

Mean total abundance of the 54 NTFP species (26 herbs and 28 shrubs—approximately 60% of all understory species in all stands)

Table 2
Non-timber forest product (NTFP) species list, including information on use

Species	Common name	Parts Harvested	Use[a]
Herbs			
Achillea millefolium	Yarrow	Stems, leaves, flowers	Medicinal[c,d,e], floral, landscaping[b]
Anaphalis margaritacea	Pearly everlasting	Roots, stems, flowers	Medicinal[c,d,e], floral[b,d]
Antennaria microphylla	Rosy pussytoes	Roots, stems, leaves	Medicinal[e]
Arnica cordifolia	Heart-leaved arnica	Roots, flowers	Medicinal[c,d,e], landscaping[b]
Aster conspicuus	Showy aster	Roots	Medicinal[e]
Aster foliaceus	Leafy aster	Full	Medicinal[e]
Clintonia uniflora	Queen's cup	Full	Landscaping[e], medicinal[e]
Cornus canadensis	Bunchberry	Full, berries	Landscaping[b,e], edible[e], medicinal[c]
Epilobium angustifolium	Fireweed	Stems, leaves, full	Medicinal[c,e], edible[c,e]
Equisetum arvense	Common horsetail	Roots, stems, full	Medicinal[c,d], edible[c,d], functional[e]
Fragaria sp.	Wild strawberry	Leaves, berries	Medicinal[c,e], edible[b,c,e]
Galium triflorum	Sweet-scented bedstraw	Leaves, roots, full	Edible[b], functional[e], medicinal[b]
Geum macrophyllum	Large-leaved avens	Roots	Medicinal[e]
Lilium columbianum	Tiger lily	Flowers	Edible[e]
Mitella nuda	Common miterwort	Leaves, full	Medicinal[e], landscaping[e]
Osmorhiza chilensis	Mountain sweet-cicely	Roots	Medicinal[e], edible[e]
Petasites palmatus	Palmate coltsfoot	Roots, stems, leaves	Medicinal[c,d], functional[e], edible[c,d]
Smilacina racemosa	False Soloman's-seal	Roots, leaves, berries	Medicinal[c,e], edible[c,e]
Streptopus amplexifolius	Clasping twisted stalk	Roots, stems	Medicinal[e], edible[c]
Streptopus roseus	Rosy twisted stalk	Roots	Medicinal[e]
Streptopus streptopoides	Small twisted stalk	Full	Landscaping[e]
Taraxacum officinale	Common dandelion	Roots, leaves, flowers, full	Medicinal[c], edible[c,e]
Thalictrum occidentale	Western meadowrue	Full	Medicinal[e], edible[c]
Tiarella sp.	Foamflower	Leaves	Medicinal[e]
Verbascum thapsus	Great mullein	Leaves	Medicinal[c]
Viola spp.	Violets	Leaves, flowers	Medicinal[c,d], landscaping, edible[c,d,e]
Shrubs			
Acer glabrum	Douglas maple	Wood, bark	Functional[e]
Alnus incana	Mountain alder	Wood, bark	Medicinal[c,e], functional[c,e]
Alnus sinuata	Sitka alder	Wood, bark	Functional[b,e]
Amelanchier alnifolia	Saskatoon	Full, berries	Medicinal[c], landscaping[e], edible[b,c,e]
Arctostaphylos uva-ursi	Kinnikinnick	Stems, leaves, roots, flowers, berries	Medicinal[b,d], floral[d], landscaping[d], functional[b,d], edible[b,c,e]
Chimaphila umbellata	Prince's pine	Leaves, full	Medicinal[b,c,d,e], edible[c], floral[d]
Cornus stolonifera	Red-osier dogwood	Berries, wood, bark	Medicinal[e], edible[c], landscaping[e], functional[b,c]
Juniperus sp.	Juniper	Stems, leaves, berries, wood, bark	Medicinal[b,c,d,e], floral[b,d], edible[b,c,d,e], landscaping[b,d], functional[d].
Ledum glandulosum	Trapper's tea	Leaves	Medicinal[e], edible[e]
Lonicera involucrata	Black twinberry	Stems, leaves, berries	Medicinal[e]
Mahonia aquifolium	Dull Oregon-grape	Full, berries, wood, bark, roots	Floral[b,d], medicinal[b,c,d], landscaping[d], edible[b,c,d,e], functional[d]
Pachistima myrsinites	Falsebox	Stems, leaves	Floral[b,d], landscaping[b,d]
Ribes cereum	Squaw currant	Berries	Edible[c,e]
Ribes lacustre	Black gooseberry	Berries	Edible[c,e], medicinal[e]
Ribes viscosissimum	Sticky currant	Berries	Edible[c]
Rosa acicularis	Wild rose	Berries	Medicinal[c], edible[b,c,e]
Rubus idaeus	Red raspberry	Roots, stems, leaves, berries	Medicinal[c,d,e], edible[b,c,d,e]
Rubus parviflorus	Thimbleberry	Berries, wood, bark	Edible[b,c,e]
Salix spp.	Willow	Wood, bark	Functional[b], edible[c], medicinal[b]
Sambucus racemosa	Red elderberry	Full, berries	Landscaping[b,d], edible (fruit only)[b,c,d,e]
Shepherdia canadensis	Soopolallie	Leaves, berries, wood, bark	Medicinal[e], edible[c,e]
Sorbus sitchensis	Sitka mountain-ash	Berries, wood, bark	Medicinal[b,e], edible[e]
Spiraea betulifolia	Birch-leaved spiraea	Full	Medicinal[e]
Symphoricarpos albus	Common snowberry	Wood, bark	Medicinal[c,e], landscaping[b]
Vaccinium caespitosum	Dwarf blueberry	Berries	Edible[c,e]
Vaccinium membranaceum	Black huckleberry	Berries	Edible[b,c,d,e]
Vaccinium myrtilloides	Velvet-leaved blueberry	Berries	Edible[b,c,e]
Vaccinium scoparium	Grouseberry	Berries	Edible[c,e]

[a] There is still little scientific information on the uses and components of many of the listed species. More research should be done, and uses confirmed, before consuming any species.
[b] deGues.
[c] Willard.
[d] Vance.
[e] Parish.

in Experiment A (Table 2) had a significant, positive relationship with the fertilizer treatment ($F_{1,8} = 8.06$; $P = 0.02$) (Fig. 1a), as well as time ($F_{4,64} = 6.30$; $P < 0.01$) (Fig. 1b). However, stand density had no effect on mean total volume of NTFP herbs and shrubs ($F_{3,6} = 0.34$; $P = 0.80$) (Fig. 1a). Mean total species richness was also not significantly affected by either density ($F_{3,6} = 1.66$; $P = 0.27$) or fertilization ($F_{1,8} = 3.11$; $P = 0.12$) (Table 3), however, there was a significant time effect ($F_{4,64} = 4.71$; $P < 0.01$). Mean total shrub volume was not affected by fertilizer treatment (Table 4; Fig. 2a), but did increase significantly ($F_{4,64} = 6.42$;

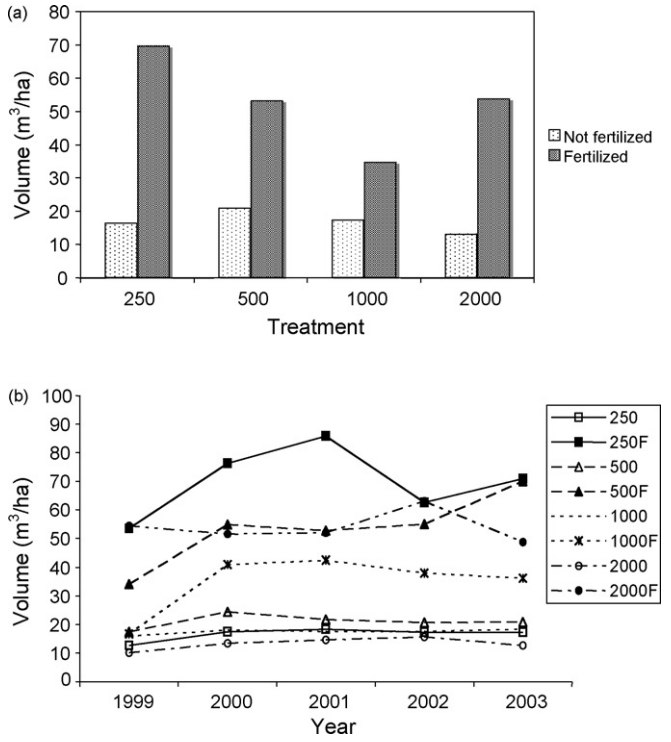

Fig. 1. (a) Mean ($n = 15$) total NTFP herbs and shrubs for each density, with and without fertilization in Experiment A. (b) Mean ($n = 3$) total NTFP herbs and shrubs in all stands 1999–2003, in Experiment A.

$P < 0.01$) by the end of the study (Fig. 2b). Mean herb volume increased in the fertilization treatment ($F_{1,8} = 5.06$; $P = 0.04$) (Fig. 3a). Neither mean total volumes of herbs ($F_{3,6} = 0.22$; $P = 0.88$) nor shrubs ($F_{3,6} = 0.65$; $P = 0.59$) responded significantly to density treatments (Table 4).

Mean total volumes of berry-producing NTFPs were also assessed, indicating a significant change in volume over time ($F_{4,64} = 15.64$; $P < 0.001$) (Fig. 4b). There was no significant density ($F_{3,6} = 0.62$; $P = 0.63$), or fertilization effects ($F_{1,8} = 0.61$; $P = 0.46$) (Fig. 4a). However, a significant time × fertilizer interaction ($F_{4,64} = 3.07$; $P = 0.02$) was evident. This interaction was caused by the effects of fertilization becoming increasingly significant over time, particularly after the year 2000 (Fig. 4b).

In Experiment B, mean total volume of NTFP herbs and shrubs were highest in the intensively managed thinned and fertilized stands (Table 5) (Fig. 5a) ($F_{5,10} = 5.57$; $P = 0.01$). The thinned-fertilized stands had a mean total volume of herb and shrub NTFPs that ranged from 2.3 to 13.7 times greater than the other stands, but was highly variable (Table 5; Fig. 5a). Mean total shrub volumes were similar ($F_{5,10} = 2.02$; $P = 0.16$) among stand types (Fig. 6a), while mean herb volumes were also highest in thinned-fertilized stands ($F_{5,10} = 6.39$; $P < 0.01$) (Fig. 7a). Mean species richness of NTFPs was similar among stands (total $F_{5,10} = 2.61$; $P = 0.09$, herbs $F_{5,10} = 2.74$; $P = 0.08$, shrubs $F_{5,10} = 2.25$; $P = 0.13$).

Mean total NTFP volume, as well as mean total herb and shrub volumes, all had significant time effects in Experiment B (total $F_{4,48} = 7.20$; $P < 0.01$, herbs $F_{4,48} = 6.15$; $P < 0.01$, shrubs $F_{4,48} = 7.71$; $P < 0.01$), which varied across categories and between stand types. Shrub abundance patterns in the various stands increased over time in the young plantation, thinned, and thinned and fertilized stands (Fig. 6b). In general, trends in herb abundance over time peaked in 2000 in almost all stands (except mature), with a general decreasing trend over time in all treatments after

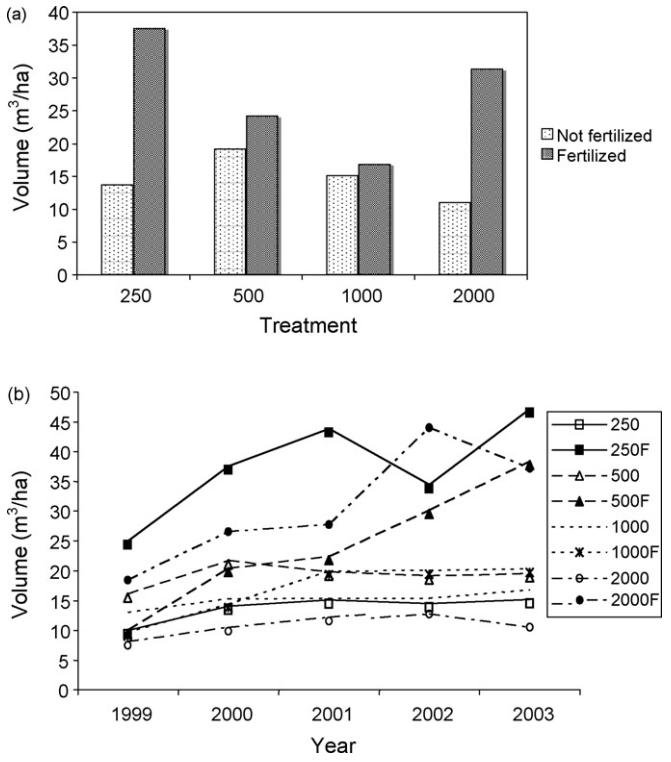

Fig. 2. (a) Mean ($n = 15$) total NTFP shrubs for each density, with and without fertilization in Experiment A. (b) Mean ($n = 3$) total NTFP shrubs in all stands 1999–2003, in Experiment A.

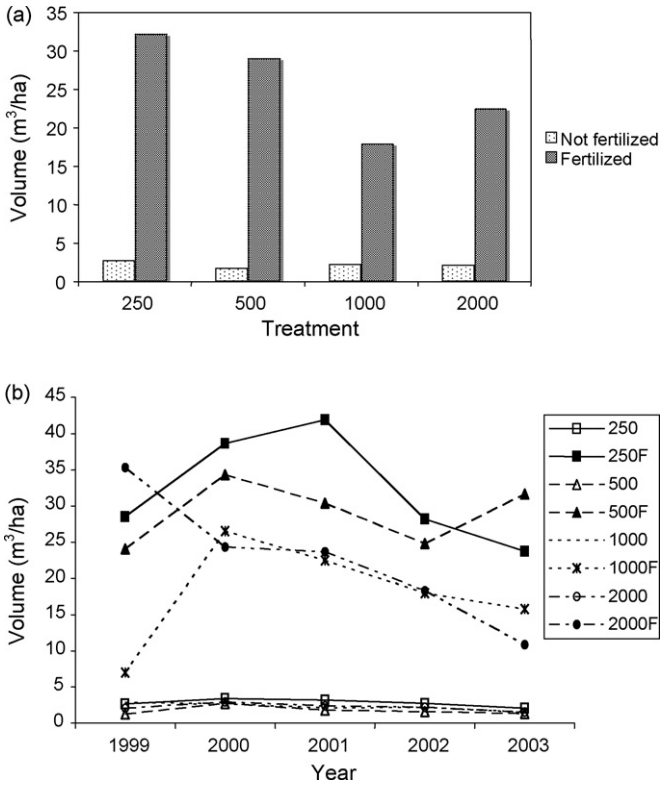

Fig. 3. (a) Mean ($n = 15$) total NTFP herbs for each density, with and without fertilization in Experiment A. (b) Mean ($n = 3$) total NTFP herbs in all stands 1999–2003, in Experiment A.

Table 3
Mean[a] ± S.E. (n = 15; 3 replicate stands × 5 years) crown volume index (m^3/0.01 ha) of NTFP individual species and totals for herbs, shrubs, and berry-producing plants in the eight treatment stands over 5 years in Experiment A

	250	250F	500	500F	1000	1000F	2000	2000F
Herbs								
Achillea millefolium	0.16 ± 0.07	0.25 ± 0.12	0.13 ± 0.03	0.21 ± 0.05	0.07 ± 0.02	0.14 ± 0.04	0.05 ± 0.02	0.2 ± 0.20
Anaphalis margaritacea	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01	0.02 ± 0.01	0.06 ± 0.04	0.01 ± 0.00	0.01 ± 0.00
Antennaria microphylla	0.04 ± 0.02	0.25 ± 0.14	0.10 ± 0.02	0.01 ± 0.01	0.06 ± 0.02	0.09 ± 0.03	0.01 ± 0.00	0.03 ± 0.02
Arnica cordifolia	0.04 ± 0.01	0.00 ± 0.00	0.03 ± 0.01	0.01 ± 0.00	0.06 ± 0.01	0.06 ± 0.05	0.03 ± 0.01	0.05 ± 0.02
Aster conspicuus	0.02 ± 0.01	0.10 ± 0.04	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Aster foliaceus	0.05 ± 0.02	0.02 ± 0.02	0.00 ± 0.00	0.13 ± 0.07	0.02 ± 0.01	0.00 ± 0.00	0.00 ± 0.00	0.15 ± 0.10
Clintonia uniflora	0.01 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Cornus canadensis	0.08 ± 0.02	0.01 ± 0.01	0.10 ± 0.03	0.00 ± 0.00	0.04 ± 0.01	0.00 ± 0.00	0.05 ± 0.02	0.00 ± 0.00
Epilobium angustifolium	0.79 ± 0.14	30.76 ± 6.53	0.61 ± 0.16	28.04 ± 6.76	1.07 ± 0.25	16.57 ± 4.63	1.50 ± 0.30	21.40 ± 5.58
Equisetum arvense	0.00 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Fragaria sp.	1.42 ± 0.22	0.46 ± 0.08	0.59 ± 0.08	0.16 ± 0.02	0.76 ± 0.13	0.53 ± 0.10	0.36 ± 0.07	0.39 ± 0.07
Galium triflorum	0.00 ± 0.00	0.11 ± 0.06	0.00 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01	0.00 ± 0.00
Geum macrophyllum	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.03 ± 0.02	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Lilium columbianum	0.02 ± 0.01	0.02 ± 0.01	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.02 ± 0.01	0.01 ± 0.01	0.00 ± 0.00
Mitella nuda	0.01 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01	0.00 ± 0.00	0.00 ± 0.00
Osmorhiza chilensis	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.01 ± 0.01	0.01 ± 0.00	0.11 ± 0.07	0.00 ± 0.00	0.02 ± 0.01
Petasites palmatus	0.07 ± 0.02	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.02 ± 0.01	0.01 ± 0.00	0.00 ± 0.00
Smilacina racemosa	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Streptopus amplexifolius	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Streptopus roseus	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Streptopus streptopoides	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Taraxacum officinale	0.06 ± 0.01	0.19 ± 0.04	0.09 ± 0.02	0.38 ± 0.07	0.09 ± 0.01	0.31 ± 0.05	0.07 ± 0.02	0.22 ± 0.04
Thalictrum occidentale	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Tiarella spp.	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Verbascum thapsus	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.05 ± 0.02	0.00 ± 0.00	0.01 ± 0.01	0.00 ± 0.00	0.00 ± 0.00
Viola spp.	0.02 ± 0.01	0.01 ± 0.00	0.04 ± 0.01	0.02 ± 0.01	0.06 ± 0.02	0.03 ± 0.01	0.28 ± 0.03	0.04 ± 0.01
Shrubs								
Acer glabrum	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.29 ± 1.29	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Alnus sinuata	5.12 ± 1.87	5.68 ± 2.19	5.33 ± 2.55	1.13 ± 0.63	4.97 ± 2.29	1.49 ± 0.52	0.00 ± 0.00	0.03 ± 0.03
Amelanchier alnifolia	1.38 ± 0.32	2.57 ± 0.63	1.14 ± 0.27	1.31 ± 0.32	0.81 ± 0.29	2.49 ± 0.55	0.36 ± 0.09	2.53 ± 0.86
Arctostaphylos uva-ursi	1.95 ± 0.26	0.62 ± 0.10	1.36 ± 0.21	0.58 ± 0.13	0.86 ± 0.12	0.06 ± 0.01	0.99 ± 0.09	0.11 ± 0.02
Chimaphila umbellata	0.03 ± 0.01	0.00 ± 0.00	0.03 ± 0.01	0.00 ± 0.00	0.05 ± 0.01	0.01 ± 0.00	0.06 ± 0.01	0.00 ± 0.00
Cornus stolonifera	0.00 ± 0.00	0.05 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Juniperus communis	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.00
Ledum glandulosum	0.01 ± 0.01	0.00 ± 0.00	0.35 ± 0.15	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Lonicera involucrata	0.24 ± 0.13	0.29 ± 0.07	0.02 ± 0.01	0.96 ± 0.42	0.07 ± 0.02	0.12 ± 0.04	0.06 ± 0.02	0.12 ± 0.04
Mahonia aquifolium	0.05 ± 0.02	0.03 ± 0.01	0.16 ± 0.04	0.11 ± 0.04	0.02 ± 0.01	0.02 ± 0.01	0.01 ± 0.00	0.13 ± 0.04
Pachistima myrsinites	0.39 ± 0.07	0.43 ± 0.08	0.61 ± 0.13	0.52 ± 0.09	0.58 ± 0.15	0.67 ± 0.14	0.79 ± 0.11	1.11 ± 0.16
Ribes cereum	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.08 ± 0.04	0.00 ± 0.00	0.00 ± 0.00
Ribes lacustre	0.14 ± 0.06	0.10 ± 0.04	0.11 ± 0.03	0.08 ± 0.03	0.13 ± 0.06	0.26 ± 0.07	0.01 ± 0.00	0.12 ± 0.04
Ribes viscosissimum	0.00 ± 0.00	0.00 ± 0.00	0.02 ± 0.01	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Rosa acicularis	1.09 ± 0.23	13.49 ± 3.47	2.51 ± 0.60	14.57 ± 3.81	2.44 ± 0.58	8.32 ± 1.97	4.22 ± 1.03	20.31 ± 5.02
Rubus idaeus	0.04 ± 0.02	0.42 ± 0.10	0.08 ± 0.03	0.27 ± 0.11	0.01 ± 0.01	0.54 ± 0.18	0.06 ± 0.02	0.41 ± 0.13
Rubus parviflorus	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.10 ± 0.05	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Salix spp.	1.26 ± 0.40	11.84 ± 4.84	0.43 ± 0.13	3.55 ± 1.35	0.51 ± 0.15	1.28 ± 0.42	0.87 ± 0.22	5.25 ± 2.20
Sambucus racemosa	0.03 ± 0.02	0.10 ± 0.06	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Shepherdia canadensis	0.42 ± 0.12	0.90 ± 0.24	5.52 ± 1.65	0.12 ± 0.06	0.85 ± 0.38	0.30 ± 0.12	1.55 ± 0.52	0.15 ± 0.06
Sorbus sitchensis	0.01 ± 0.01	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Spiraea betulifolia	0.51 ± 0.06	0.40 ± 0.06	0.43 ± 0.07	0.51 ± 0.09	0.61 ± 0.11	0.76 ± 0.21	0.75 ± 0.15	0.34 ± 0.06
Symphoricarpos albus	0.00 ± 0.00	0.27 ± 0.09	0.07 ± 0.04	0.13 ± 0.06	0.01 ± 0.01	0.21 ± 0.10	0.03 ± 0.01	0.00 ± 0.00
Vaccinium caespitosum	0.62 ± 0.14	0.21 ± 0.07	0.51 ± 0.14	0.06 ± 0.03	0.79 ± 0.29	0.05 ± 0.02	1.00 ± 0.26	0.05 ± 0.02
Vaccinium membranaceum	0.07 ± 0.03	0.00 ± 0.00	0.10 ± 0.04	0.00 ± 0.00	0.03 ± 0.01	0.01 ± 0.01	0.05 ± 0.02	0.03 ± 0.01
Vaccinium myrtilloides	0.08 ± 0.04	0.01 ± 0.01	0.04 ± 0.02	0.00 ± 0.00	0.30 ± 0.10	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Vaccinium scoparium	0.34 ± 0.09	0.20 ± 0.06	0.45 ± 0.09	0.35 ± 0.08	0.80 ± 0.19	0.20 ± 0.05	0.28 ± 0.09	0.73 ± 0.16
Total herbs	2.80 ± 1.42	32.21 ± 33.85	1.76 ± 0.75	29.06 ± 41.11	2.28 ± 0.80	17.96 ± 26.36	2.22 ± 1.51	22.51 ± 33.84
Total shrubs	13.79 ± 5.61	37.60 ± 17.64	19.28 ± 12.87	24.28 ± 29.69	15.22 ± 7.78	16.91 ± 16.56	11.09 ± 11.11	31.43 ± 34.10
Total herbs + shrubs	16.59 ± 6.73	69.81 ± 35.08	21.04 ± 13.21	53.34 ± 42.06	17.49 ± 7.53	34.87 ± 25.75	13.31 ± 11.12	53.95 ± 41.29
Total berry-producing species	7.97 ± 4.05	19.46 ± 25.82	12.73 ± 14.33	18.59 ± 25.55	8.01 ± 7.56	13.01 ± 16.08	9.01 ± 10.87	25.10 ± 36.87

[a] Rounded off to 2 decimal places.

2000 (Fig. 7b). The mature and old-growth stands had minor increases in volume over time. The only decreasing trend in mean NTFP shrub volume occurred in the unthinned stands.

The mean total volume of berry-producing herbs and shrubs in Experiment B was similar among stands ($F_{5,10}$ = 1.69; P = 0.22) (Table 5; Fig. 8a). However, this group of species did demonstrate a significant time effect ($F_{4,48}$ = 5.88; $P < 0.01$) (Fig. 8b). As many of the berry-producing plants were shrub species, the trends over time followed fairly closely the trends seen in mean total shrub volume (Fig. 6b). Highest rates of increase in Experiment B were in the thinned and young plantation stands with slower rates of increase in mature and old-growth stands. There was no overall change in volume over time in the thinned and fertilized stands and a slight decrease with time in the unthinned stands.

Table 4
Results of split-plot ANOVAs of individual and total NTFP species in Experiment A

	Density		Fertilizer		Density × fertilizer		Time		Density × time		Fertilizer × time	
	$F_{3,6}$	P	$F_{1,8}$	P	$F_{3,8}$	P	$F_{4,64}$	P	$F_{12,64}$	P	$F_{4,64}$	P
Herbs												
Achillea millefolium	0.08	0.97	**8.00**	**0.02**	0.43	0.74	**4.00**	**0.01**	1.25	0.27	2.35	0.06
Antennaria microphylla	1.31	0.35	0.20	0.67	1.35	0.33	**2.85**	**0.03**	1.15	0.34	0.84	0.51
Arnica cordifolia	1.85	0.24	0.65	0.45	0.23	0.87	**4.38**	**<0.01**	1.14	0.35	2.28	0.07
Aster conspicuous	3.70	0.08	0.67	0.44	1.21	0.37	0.27	0.90	0.31	0.99	0.89	0.48
Clintonia uniflora	0.89	0.50	3.33	0.11	0.57	0.65	2.07	0.10	0.64	0.80	2.07	0.10
Cornus canadensis	1.42	0.33	3.05	0.12	0.09	0.96	**3.13**	**0.02**	0.44	0.94	2.20	0.08
Epilobium angustifolium	0.86	0.51	**5.10**	**0.05**	0.27	0.85	3.87	0.07	0.82	0.63	0.40	0.81
Fragaria sp.	4.17	0.07	1.98	0.20	0.41	0.75	**5.42**	**<0.01**	1.23	0.28	0.67	0.62
Smilacina racemosa	2.28	0.18	3.16	0.11	1.80	0.23	**3.16**	**0.02**	1.80	0.07	**3.16**	**0.02**
Streptopus streptopoides	1.00	0.46	1.67	0.23	0.78	0.54	1.60	0.19	0.69	0.76	2.38	0.06
Taraxacum officinale	1.66	0.27	**11.75**	**0.01**	0.27	0.85	**3.30**	**0.02**	0.80	0.65	1.89	0.12
Shrubs												
Alnus sinuata	1.30	0.36	1.14	0.32	0.24	0.86	**3.17**	**0.02**	1.36	0.21	0.87	0.49
Amelanchier alnifolia	0.70	0.59	2.76	0.14	0.38	0.77	**4.30**	**<0.01**	0.26	0.99	1.28	0.29
Arctostaphylos uva-ursi	0.80	0.54	**59.96**	**<0.001**	0.40	0.76	**6.67**	**<0.001**	0.86	0.59	**3.03**	**0.02**
Chimaphila umbellata	1.14	0.41	4.67	0.06	0.15	0.93	**3.08**	**0.02**	0.32	0.98	**3.20**	**0.02**
Ribes lacustre	0.43	0.74	1.20	0.31	0.84	0.51	**2.83**	**0.03**	1.25	0.27	0.83	0.51
Rosa acicularis	0.77	0.55	3.84	0.09	0.06	0.98	**4.78**	**<0.01**	0.38	0.97	1.61	0.18
Rubus idaeus	0.11	0.95	**19.23**	**<0.01**	0.75	0.55	**9.63**	**<0.001**	1.11	0.37	**5.38**	**<0.01**
Spiraea betulifolia	0.14	0.93	0.97	0.35	0.96	0.46	**8.62**	**<0.001**	0.80	0.65	0.49	0.74
Symphoricarpos albus	1.04	0.44	1.68	0.23	0.65	0.61	**2.79**	**0.03**	0.53	0.89	1.14	0.35
Vaccinium caespitosum	0.52	0.68	3.41	0.10	0.07	0.97	**2.93**	**0.03**	0.32	0.98	**2.72**	**0.04**
Vaccinium membranaceum	0.35	0.79	2.41	0.16	0.41	0.75	**3.81**	**0.01**	1.17	0.32	2.35	0.06
Vaccinium myrtilloides	1.00	0.46	1.96	0.20	0.68	0.59	0.57	0.69	0.90	0.55	2.20	0.08
Vaccinium scoparium	0.33	0.81	0.21	0.66	1.14	0.39	1.94	0.12	**2.49**	**0.01**	2.28	0.07
Total herbs	0.22	0.88	**5.06**	**0.04**	0.09	0.97	**12.13**	**<0.001**	1.72	0.15	0.45	0.77
Total shrubs	0.65	0.59	1.94	0.21	1.26	0.36	**6.42**	**<0.01**	1.73	0.15	0.92	0.48
Total herbs + shrubs	0.34	0.80	**8.06**	**0.02**	0.51	0.68	**6.30**	**<0.01**	**2.48**	**0.05**	0.54	0.71
Total berry-producing species	0.62	0.63	0.61	0.46	0.16	0.92	**15.64**	**<0.001**	0.81	0.64	**3.07**	**0.02**
Species richness												
Herbs	0.57	0.65	3.80	0.09	0.06	0.98	**7.58**	**<0.001**	0.99	0.47	0.26	0.90
Shrubs	0.42	0.74	2.19	0.18	0.67	0.60	**20.65**	**<0.001**	0.71	0.74	2.41	0.06
Total herbs + shrubs	0.58	0.65	**9.49**	**0.02**	0.33	0.81	**10.42**	**<0.001**	0.76	0.69	1.08	0.37
Total berry-producing species	2.97	0.12	0.56	0.65	1.52	0.25	**2.61**	**0.04**	0.59	0.84	1.29	0.28

Significant results are in bold.

3.2. Individual NTFP species

Three herb species responded significantly to either density or fertilization treatments in Experiment A. Mean abundance of yarrow (*Achillea millefolium*) responded positively to fertilizer application ($F_{1,8} = 8.00$; $P = 0.02$) (Table 4). A significant time effect ($F_{4,64} = 4.00$; $P = 0.01$) was also evident, however, there was not a significant fertilization × time effect ($F_{4,64} = 2.35$, $P = 0.06$). Fireweed (*Epilobium angustifolium*) also had significantly ($F_{1,8} = 5.15$; $P = 0.05$) higher volumes in fertilized stands than in the other treatments, but with no significant time effect ($F_{4,64} = 3.87$; $P = 0.07$) (Table 4). Mean abundance of common dandelion (*Taraxacum officinale*) was significantly ($F_{1,8} = 11.75$; $P = 0.01$) different among stands with respect to fertilization, yielding higher volumes in fertilized stands (Table 3). A significant time effect ($F_{4,64} = 3.30$; $P = 0.02$) indicated a slight decline in this species in fertilized treatments over time.

Fireweed reached a very high mean abundance in fertilized (24.19 m^3/0.01 ha) vs. unfertilized (0.99 m^3/0.01 ha) stands in Experiment A (Table 3). However, mean abundance of fireweed did not differ between density treatments ($F_{3,6} = 0.86$; $P = 0.51$). Fireweed had a significant ($F_{5,10} = 3.92$; $P = 0.03$) treatment effect in Experiment B, with highest volumes observed in the thinned-fertilized stands (Table 5). There was also a significant ($F_{4,48} = 4.51$; $P < 0.01$) fireweed time effect in this experiment.

Experiment B yielded only a single herb species, western meadowrue (*Thalictrum occidentale*) with a significant ($F_{5,10} = 3.73$; $P = 0.04$) difference in abundance among treatment stands (Table 5). This herb was recorded in the unthinned stands only, and was significantly different from all other stands (DMRT; $P = 0.05$). This species did not show a significant time effect ($F_{4,48} = 0.58$; $P = 0.57$).

Several individual shrub species demonstrated significant treatment responses in both Experiments A and B. In Experiment A, mean abundance of kinnikinnick (*Arctostaphylos uva-ursi*) was significantly different among treatment stands with respect to fertilization ($F_{1,8} = 59.96$; $P < 0.001$), but not density ($F_{3,6} = 0.80$; $P = 0.54$). Mean abundance of this species in the non-fertilized (1.29 m^3/0.01 ha) was 3.8 times higher than that in the fertilized (0.34 m^3/0.01 ha) stands (Table 3). Kinnikinnick also showed a significant time effect ($F_{4,64} = 6.67$; $P < 0.001$) and time × fertilizer interaction ($F_{4,64} = 3.03$; $P = 0.02$), likely owing to a decline in abundance in the fertilized stands. This pattern was further elucidated in Experiment B, where kinnikinnick had significantly ($F_{5,10} = 10.09$; $P < 0.01$) greater mean volume in the thinned stands (1.03 m^3/0.01 ha) compared to all other stands (DMRT; $P = 0.05$) (Table 5). Red raspberry (*Rubus idaeus*) also showed a positive response to fertilization ($F_{1,8} = 19.23$; $P < 0.01$) in Experiment A, with a significant time effect ($F_{4,64} = 9.63$; $P < 0.01$) and time - × fertilizer interaction ($F_{4,64} = 5.38$; $P < 0.01$). This interaction may

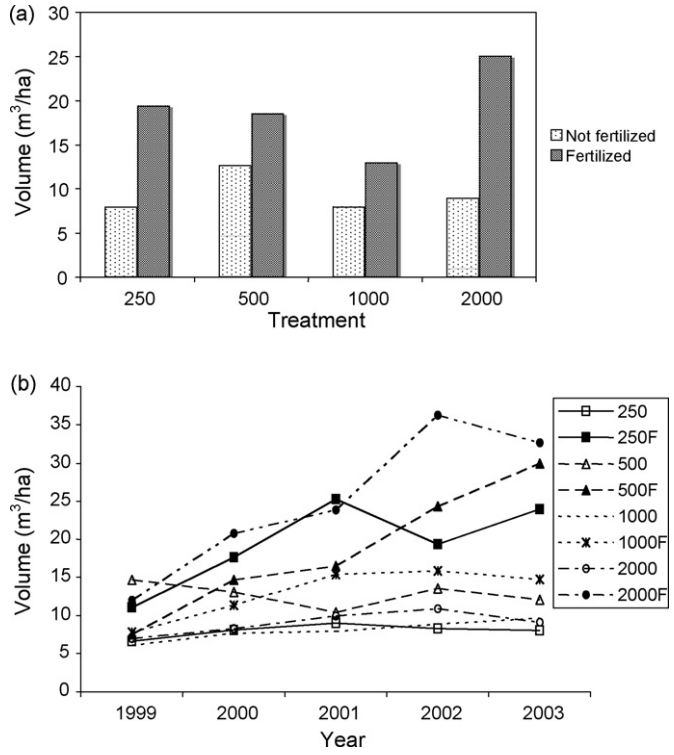

Fig. 4. (a) Mean ($n = 15$) total NTFP berry-producing plants for each density, with and without fertilization in Experiment A. (b) Mean ($n = 3$) total NTFP berry-producing shrubs in all stands 1999–2003, in Experiment A.

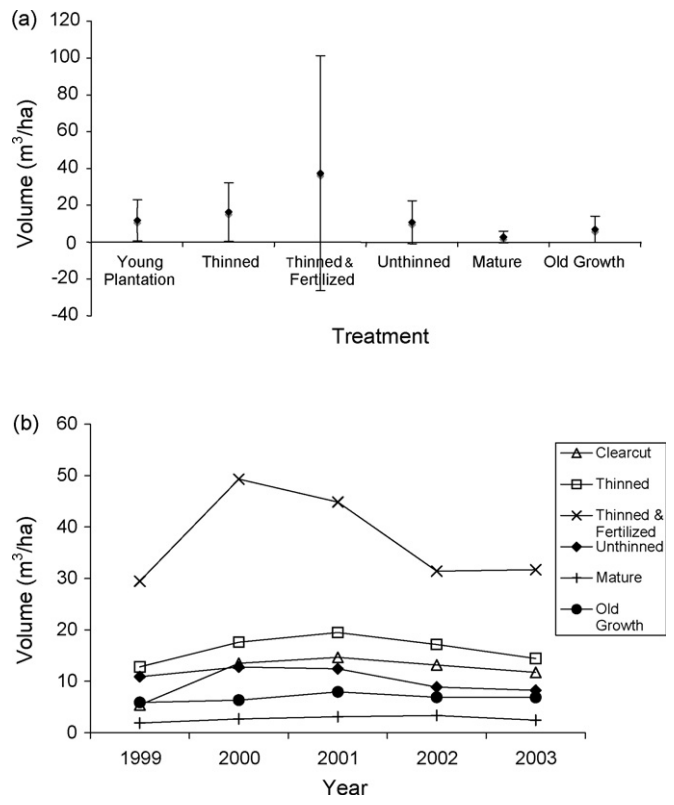

Fig. 5. (a) Mean ($n = 15$) ±95% CI total NTFP herbs and shrubs in the six treatment stands. (b) Mean ($n = 3$) total NTFP herbs and shrubs in all stands 1999–2003, in Experiment B.

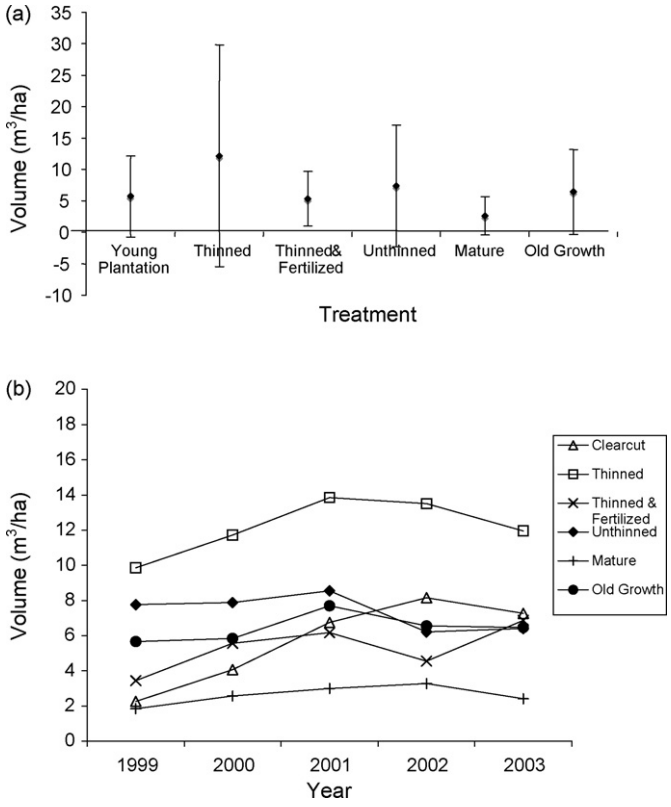

Fig. 6. (a) Mean ($n = 15$) ±95% CI total NTFP shrubs in the six treatment stands. (b) Mean ($n = 3$) total NTFP shrubs in all stands 1999–2003, in Experiment B.

have been caused by an increase in volume over time in fertilized, but not unfertilized stands. Grouseberry (*Vaccinium scoparium*) had a significant time × density interaction ($F_{12,64} = 2.49$; $P = 0.01$). This interaction can be explained by grouseberry decreasing in fertilized stands over time compared to non-fertilized stands. Prince's pine (*Chimaphila umbellata*) approached significance ($F_{1,8} = 4.67$; $P = 0.06$) in terms of a response to fertilization, with a significant time ($F_{4,64} = 3.08$; $P = 0.02$) and time × fertilizer interaction ($F_{4,64} = 3.20$; $P = 0.02$). This was caused by an increase in volume over time, which was more pronounced in the unfertilized, but not fertilized stands.

In Experiment B, black twinberry (*Lonicera involucrata*) had the highest ($F_{5,10} = 3.73$; $P = 0.03$) volumes in thinned stands (0.78 m^3/0.01 ha) compared with all other treatments (DMRT; $P = 0.05$), while wild rose (*Rosa acicularis*) had highest volume in unthinned stands compared to all others ($F_{5,10} = 3.34$; $P = 0.05$) (DMRT; $P = 0.05$) (Table 5). Sitka mountain ash (*Sorbus sitchensis*) was present (<0.01 m^3/0.01 ha) only within the 'young plantation' stands.

4. Discussion

4.1. Effects of time

Sampling for this study took place over a relatively short period (5 years). Studies noting the time-sensitive nature of understory response to overstory cover indicate that the NTFP patterns observed in this study may not continue into the future (He and Barclay, 2000). Increased light availability due to stand thinning has been shown to enhance the growth of understory vegetation (Alaback and Herman, 1988; Thomas et al., 1999; Lindh and Muir, 2004; Lindgren et al., 2006). However, this response may decline over time due to canopy closure, resulting in relatively short-lived treatment effects (He and Barclay, 2000). Conversely, many NTFP

Table 5
Mean[a] ± S.E. (n = 15; 3 replicate stands × 5 years) crown volume index (m^3/0.01 ha) of NTFPs in the six treatment stands over 5 years in Experiment B

	Young plantation	Thinned	Thinned and fertilized	Unthinned	Mature	Old growth
Herbs						
Achillea millefolium	0.00 ± 0.00	0.03 ± 0.01	0.15 ± 0.04	0.06 ± 0.02	0.00 ± 0.00	0.00 ± 0.00
Anaphalis margaritacea	0.03 ± 0.01	0.03 ± 0.01	0.48 ± 0.21	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Antennaria microphylla	0.00 ± 0.00	0.06 ± 0.02	0.09 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	0.03 ± 0.03
Arnica cordifolia	0.02 ± 0.01	0.04 ± 0.01	0.08 ± 0.05	0.10 ± 0.03	0.00 ± 0.00	0.24 ± 0.05
Aster conspicuus	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.07 ± 0.03	0.00 ± 0.00	0.00 ± 0.00
Aster foliaceus	0.00 ± 0.00	0.10 ± 0.05	0.05 ± 0.04	0.01 ± 0.01	0.00 ± 0.00	0.00 ± 0.00
Clintonia uniflora	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.03 ± 0.01	0.01 ± 0.01	0.00 ± 0.00
Cornus canadensis	0.05 ± 0.02	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.03 ± 0.01	0.00 ± 0.00
Epilobium angustifolium	5.70 ± 0.75	3.39 ± 0.60	30.37 ± 4.91	2.72 ± 0.46	0.00 ± 0.00	0.00 ± 0.00
Equisetum arvense	0.16 ± 0.08	0.03 ± 0.01	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Fragaria spp.	0.00 ± 0.00	0.37 ± 0.09	0.48 ± 0.10	0.14 ± 0.02	0.00 ± 0.00	0.04 ± 0.01
Galium triflorum	0.00 ± 0.00	0.03 ± 0.02	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Geum macrophyllum	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01
Lilium columbianum	0.01 ± 0.01	0.00 ± 0.00	0.02 ± 0.01	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Mitella nuda	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Osmorhiza chilensis	0.01 ± 0.00	0.02 ± 0.00	0.13 ± 0.08	0.00 ± 0.00	0.01 ± 0.01	0.01 ± 0.00
Petasites palmatus	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Smilacina racemosa	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.02 ± 0.01	0.00 ± 0.00	0.02 ± 0.01
Streptopus amplexifolius	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Streptopus roseus	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.02 ± 0.01	0.01 ± 0.01	0.00 ± 0.00
Streptopus streptopoides	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Taraxacum officinale	0.01 ± 0.00	0.04 ± 0.01	0.13 ± 0.03	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Thalictrum occidentale	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.07 ± 0.02	0.00 ± 0.00	0.00 ± 0.00
Tiarella spp.	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01	0.00 ± 0.00	0.03 ± 0.01	0.00 ± 0.00
Verbascum thapsus	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Viola spp.	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.03 ± 0.01	0.01 ± 0.00	0.00 ± 0.00
Shrubs						
Acer glabrum	0.00 ± 0.00	1.29 ± 1.29	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Alnus incana	2.38 ± 0.87	3.82 ± 2.03	1.29 ± 0.51	0.08 ± 0.07	0.68 ± 0.36	0.04 ± 0.04
Alnus sinuata	0.15 ± 0.10	1.16 ± 1.15	0.17 ± 0.14	0.29 ± 0.23	0.14 ± 0.14	0.00 ± 0.00
Amelanchier alnifolia	0.01 ± 0.01	0.00 ± 0.00	0.29 ± 0.17	0.77 ± 0.22	0.00 ± 0.00	0.12 ± 0.06
Arctostaphylos uva-ursi	0.10 ± 0.05	1.03 ± 0.14	0.11 ± 0.01	0.43 ± 0.12	0.00 ± 0.00	0.13 ± 0.03
Chimaphila umbellata	0.09 ± 0.01	0.06 ± 0.01	0.01 ± 0.00	0.03 ± 0.01	0.30 ± 0.07	0.34 ± 0.07
Cornus stolonifera	0.15 ± 0.07	0.00 ± 0.00	0.00 ± 0.00	0.03 ± 0.01	0.00 ± 0.00	0.00 ± 0.00
Juniperus sp.	0.01 ± 0.01	0.00 ± 0.00	0.00 ± 0.00	0.13 ± 0.06	0.00 ± 0.00	1.10 ± 0.50
Ledum glandulosum	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Lonicera involucrata	0.01 ± 0.01	0.78 ± 0.33	0.01 ± 0.01	0.02 ± 0.01	0.00 ± 0.00	0.00 ± 0.00
Mahonia aquifolium	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.03 ± 0.01	0.01 ± 0.00	0.05 ± 0.01
Paxistima myrsinites	0.40 ± 0.05	0.88 ± 0.15	0.97 ± 0.14	1.57 ± 0.15	1.03 ± 0.16	0.89 ± 0.15
Ribes cereum	0.00 ± 0.00	0.00 ± 0.00	0.08 ± 0.04	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Ribes lacustre	0.06 ± 0.01	0.14 ± 0.06	0.30 ± 0.07	0.10 ± 0.04	0.04 ± 0.02	0.00 ± 0.00
Ribes viscosissimum	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.04 ± 0.02
Rosa acicularis	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01	1.18 ± 0.24	0.00 ± 0.00	0.15 ± 0.07
Rubus idaeus	0.24 ± 0.04	0.00 ± 0.00	0.44 ± 0.17	0.00 ± 0.00	0.00 ± 0.00	0.22 ± 0.12
Rubus parviflorus	0.02 ± 0.01	0.00 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Salix spp.	0.55 ± 0.21	1.59 ± 0.62	0.44 ± 0.12	0.62 ± 0.21	0.01 ± 0.01	0.29 ± 0.11
Sambucus racemosa	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Shepherdia canadensis	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.33 ± 0.16
Sorbus sitchensis	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Spiraea betulifolia	0.64 ± 0.11	0.55 ± 0.12	0.92 ± 0.21	1.33 ± 0.17	0.22 ± 0.06	0.56 ± 0.10
Symphoricarpos albus	0.00 ± 0.00	0.02 ± 0.01	0.03 ± 0.02	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Vaccinium caespitosum	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Vaccinium membranaceum	0.02 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.09 ± 0.02	0.07 ± 0.02	1.06 ± 0.31
Vaccinium scoparium	0.83 ± 0.16	0.84 ± 0.18	0.21 ± 0.05	0.66 ± 0.14	0.12 ± 0.02	1.10 ± 0.31
Total herbs	6.01 ± 4.48	4.14 ± 2.90	32.03 ± 29.72	3.31 ± 2.55	0.11 ± 0.17	0.36 ± 0.42
Total shrubs	5.70 ± 3.02	12.18 ± 8.23	5.31 ± 2.02	7.36 ± 4.53	2.61 ± 1.41	6.44 ± 3.15
Total herbs + shrubs	11.71 ± 5.19	16.32 ± 7.42	37.34 ± 29.75	10.67 ± 5.45	2.72 ± 1.43	6.80 ± 3.33
Total berries	1.54 ± 0.95	3.19 ± 1.81	1.97 ± 1.47	3.60 ± 1.88	0.26 ± 0.20	4.38 ± 3.28

[a] Rounded off to 2 decimal places.

species in this study demonstrated increased growth with time, indicating that understory NTFP production may not be fully expressed even 10 years after the onset of treatments. Regardless, the positive response of several NTFPs to thinning and fertilization within young stands, in both Experiments A and B, indicated the potential of such stands for the development of NTFPs.

In addition, because our study took place over 5 years, differences in weather conditions from 1 year to the next (e.g., precipitation, growing degree-days, etc.), as well as differences in rates of overstory structural development, may also have influenced understory response. For example, in both Experiments A and B, mean total abundance of NTFP herb species peaked in volumes during 2000 in almost all stands (Figs. 3b and 7b). This was at least partly due to environmental conditions such as below average precipitation during the period of 2001–2003. Dry summers during the final 3 years of the study would have created the appearance of a peak in 2000 that was observed simultaneously in nearly all stands, regardless of treatment.

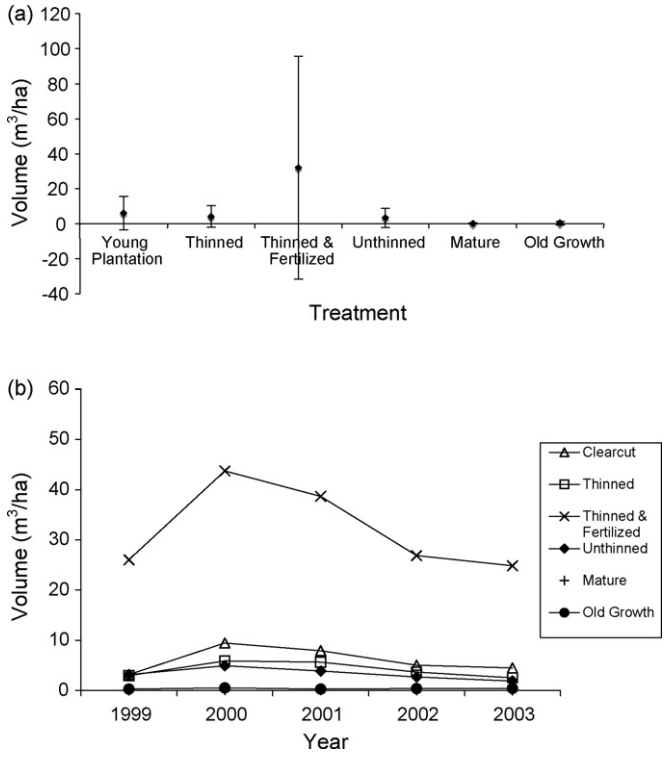

Fig. 7. (a) Mean ($n = 15$) ±95% CI total NTFP herbs in the six treatment stands. (b) Mean ($n = 3$) total NTFP herbs in all stands 1999–2003, in Experiment B.

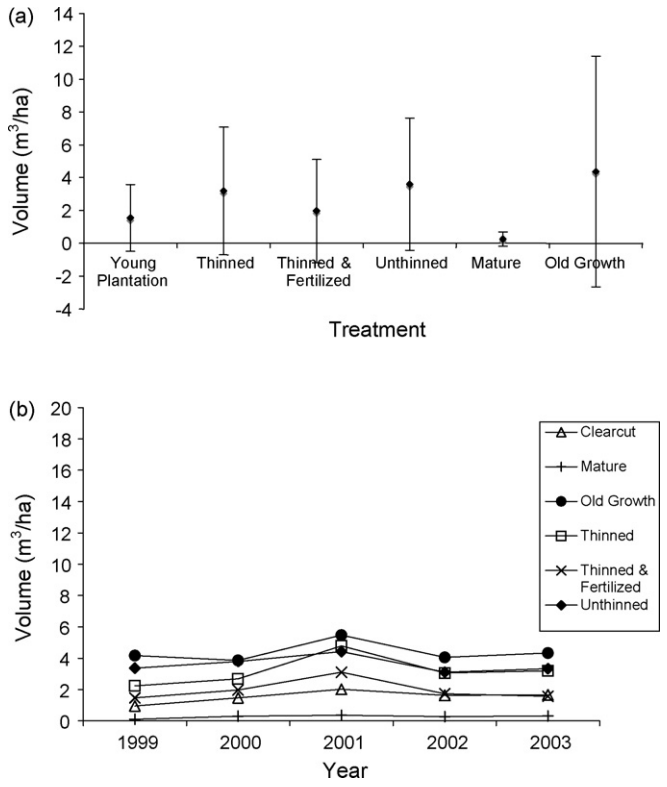

Fig. 8. (a) Mean ($n = 15$) ±95% CI total NTFP berry-producing shrubs in the six treatment stands. (b) Mean ($n = 3$) total NTFP berry-producing shrubs in all stands 1999–2003, in Experiment B.

Mean volumes of NTFP shrubs in Experiment B did not respond uniformly over time. Overall, mean shrub volumes increased with time in young plantation, thinned, and thinned-fertilized stands, which indicated that these open stands may have promoted increased shrub growth rates relative to more densely stocked and older stands (Alaback and Herman, 1988; Thomas et al., 1999; Lindh and Muir, 2004; Lindgren et al., 2006). The unthinned was the only stand type with decreased NTFP shrub volume; likely due to decreased light and resource availability within the understory of these dense stands (Klinka et al., 1996).

4.2. Effects of thinning

PCT treatments in Experiments A and B did not result in changes to overall NTFP abundance. This may be a result of different understory responses to PCT in comparison to commercial thinning treatments, due to increased rate of canopy closure post-treatment (Thomas et al., 1999; Lindh and Muir, 2004; Kerns et al., 2004), as well as the larger amount of debris from stems and branches remaining on site after PCT (Thomas et al., 1999). Varied understory responses to thinning in our study could be attributed to different life-history and growth strategies of selected NFTP species (Bailey and Tappeiner, 1998; Thomas et al., 1999). Early seral understory species tend to remain in thinned stands longer than usual due to gap dynamics during the open canopy phase (Alaback and Herman, 1988; Lindh and Muir, 2004). Thomas et al. (1999), however, found little correlation between understory functional type (i.e., successional status, growth, reproduction) and stand type.

Further, the multitude of studies reporting the varied understory response to thinning indicated the species-specific nature of this response (Thomas et al., 1999; He and Barclay, 2000; Sullivan et al., 2001; Kerns et al., 2004; Lindh and Muir, 2004; Lindgren et al., 2006). The low number of significant responses to PCT by individual NTFP species during this study could, therefore, have been due to the individual species selected for analysis within the understory communities. The few species that did provide significant results indicated a potential benefit to PCT for NTFP production. For example, in Experiment B, *A. uva-ursi* and *L. involucrata* both responded positively to thinning, and are common in open canopy stands (Parish et al., 1996).

Intensity of PCT in Experiment A also did not result in a significant NTFP response. Mean total NTFP abundance, as well as mean total herb and total shrub volumes appeared to be highest in lowest density stands (250 stems/ha), decreasing in 500 and 1000 stems/ha, and increasing in 2000 stems/ha stands. This was not a significant treatment response, however, and was only the trend in fertilized treatments. However, high understory herb and shrub cover following thinning has been observed in previous studies (Alaback and Herman, 1988; Lindgren et al., 2006).

As increased berry production is often correlated with increased light availability (Harrington et al., 2002; Kerns et al., 2004), it can be expected that the unthinned stands in Experiment B (>3000 stems/ha), and high-density stands (2000 stems/ha) in Experiment A, although yielding a high volume of berry-producing plants, may not result in larger amounts of berries. Berry-producing plants observed in the thinned stands (1000 stems/ha or less), may have a greater potential for increased berry production (Wender et al., 2004). Unfortunately, inferences regarding berry production remain speculative, as berries were not directly sampled during this study.

As understory vegetation often indicates micro-site conditions, it is evident that other factors are present in each treatment stand. For example, microclimate (Alaback and Herman, 1988), as well as site history and vegetation present prior to treatment (Klinka et al.,

1996), may have been responsible for determining post-thinning understory composition. The lack of a significant NTFP understory response to PCT may have been due to these, as well as other confounding, factors that influence growth (Egler, 1954; Klinka et al., 1996).

4.3. Effects of fertilization

Fertilization treatments successfully increased the total volume of NTFP species in Experiment A. While the fertilization effect was significant and density of stands was not, inspection of the data indicated that heavily thinned stands (250, 500 stems/ha) and high-density (2000 stems/ha) stands produced the highest mean volumes of NTFPs when coupled with fertilization. This similarity was not evident in non-fertilized stands, with marginally lowest mean volumes in the high-density (2000 stems/ha) stands. Similar production of NTFPs within the fertilized 2000 stems/ha stands as within the heavily thinned 250 and 500 stems/ha stands, suggested that understory vegetation can be enhanced by fertilization despite a non-conducive overstory environment. Long-term data collection is needed to follow the succession of these young stands through to mature forest.

4.4. Difference between young, managed stands and old, unmanaged stands

Four shrub species in Experiment B responded significantly with highest volumes in young managed stands: *A. uva-ursi* and *L. involucrata* in the thinned, *S. sitchensis* in the regenerating young plantation, and *R. acicularis* in young, unthinned stands. This pattern was supported by significantly higher mean total NTFP and mean total herb NTFP volumes in the young managed stands than in the mature and old-growth stands.

E. angustifolium, as discussed above, also demonstrated a difference between young managed stands and old unmanaged stands in Experiment B. The mature and old-growth stands produced negligible amounts of fireweed, whereas all young, managed stands produced relatively large amounts of *Epilobium*.

Experiment A also suggested benefits to co-management by testing the response of understory vegetation to a range of management intensities. NTFPs responded to fertilization with a significant increase in total abundance compared to unmanaged stands (high density, no fertilizer). This difference was most pronounced in low density, fertilized stands, however, the application of fertilizer to higher density stands also increased NTFP abundance compared to those without fertilizer. This provided empirical data to support the benefits of silvilcultural management in enhancing abundance of understory vascular plants.

While our study focused primarily on vegetative cover in a diversity of young, old, managed and unmanaged stands, many NTFP species are harvested from parts of the plant that were not directly measured during this study. Berry production, as mentioned above, was not measured nor was flowering, or quality of vegetation. These are all significant for NTFP trade (Duchesne and Wetzel, 2002; Cocksedge and Titus, 2006). Our study was also species-specific, and did not evaluate the difference among understory communities in each stand type.

Our hypothesis that large-scale stand thinning (PCT) and repeated fertilization in pole-sized lodgepole pine stands, up to 10 years after the onset of treatments, would enhance production of NTFPs compared to that in mature and old-growth stands is largely supported. The role of old-growth forest stands for NTFP extraction should not be overlooked given the association of many of the NTFP species with older forests. This study, nonetheless, indicated the potential benefit of incorporating non-timber values into young stand development through overstory manipulation.

5. Conclusions

Although trends between overstory structure and NTFP production were evident, theoretical determination of understory NTFP species distribution at a large-scale may be unsuccessful in predicting small-scale trends, as these relationships are closely linked to site-specific micro-habitat conditions (Egler, 1954; Klinka et al., 1996; Kerns et al., 2004). Ultimately, the development of co-management strategies linking timber management and NTFP harvest may yield a realistic model for the 'systems approach' to ecosystem management. This approach would incorporate multiple forest values such as timber production, equitable use of forest resources including traditional uses, sustainability, and conservation of biodiversity (Carey, 1998). The high volume of NTFP species in young managed stands, especially with the application of fertilizer, indicates the importance and potential benefit of using these stand types for non-timber resource extraction. Land will continue to be used for timber extraction, resulting in young forest stands. The incorporation of non-timber values through NTFP extraction may provide at least one avenue for diversifying land-use practices from this managed land, while also providing periodic income to landowners or tenure-holders.

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