Ecology of the 2004 morel harvest in the Rocky Mountain Forest District of British Columbia

Richard S. Winder and Michael E. Keefer

Abstract: In the Rocky Mountain Forest District of British Columbia, a dramatic series of fires occurred during 2003, setting the stage for an abundant morel crop in the following year. During 2004, the abundance of post-fire morels (*Morchella* spp.) was measured and the plant community associated with morel production was characterized. Morel production averaged 6473 ± 2721 morels·ha^{-1} in five burnt forests that were surveyed. Production ranged from 1702·ha^{-1} at Plumbob Mountain to a significantly higher 16827·ha^{-1} in the Kootenay National Park, where the highest level of duff consumption (71%) was also observed. Several plant species had high importance in morel habitat, and were also associated with above-average morel abundance: *Chamerion angustifolium* (L.) Holub, *Arnica cordifolia* Hook., *Erythronium grandiflorum* Pursh, *Spiraea betulifolia* Pallas subsp. *lucida* (Dougl. ex Greene) Taylor and MacBryde, *Menziesia ferruginea* Sm., *Rosa acicularis* Lindl. subsp. *sayi* (Schwein.) W.H. Lewis, *Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm., *Abies lasiocarpa* (Hook.) Nutt., and *Picea glauca* (Moench) Voss × *engelmannii* (Torr. & Gray ex Hook.) Brayshaw. Compositae and *Vaccinium* spp. were important species when considered as groups. Grass species, including *Calamagrostis rubescens* Buckl., were more proximate to morel-free plots. The characteristics of morel habitats observed in this study may be useful in future management of the resource, through conservation of habitat, management of prescribed burning, and postponement of salvage logging in potentially highly productive areas.

Key words: *Morchella*, indicators, fire, mushroom.

Résumé : Le District forestier des montagnes Rocheuses, en Colombie canadienne, a connu en 2003 de spectaculaires incendies de forêt, préparant les sites pour une abondante récolte de morilles l'année suivante. En 2004, les auteurs ont mesuré l'abondance de morilles (*Morchella* spp.) post incendie et ont caractérisé la communauté végétale associée. La production moyenne de morilles a atteint 6473 ± 2721 morilles·ha^{-1} dans les cinq forêts brûlées observées. La production allait de 1702·ha^{-1} in Plumbob Mountain à une quantité significativement plus élevée de 16827·ha^{-1} dans le Parc national de Kootnay, où la litière a le plus fortement brûlé (71 %). On a observé plusieurs espèces de plantes d'importance dans l'habitat des morilles également associées avec une abondance au-dessus de la moyenne des sporophores: *Chamerion angustifolium* (L.) Holub, *Arnica cordifolia* Hook., *Erythronium grandiflorum* Pursh, *Spirea betulifolia* Pallas subsp. *lucida* (Dougl. ex Greene) Taylor and MacBryde, *Menziesia ferruginea* Sm., *Rosa acicularis* Lindl. subsp. *sayi* (Schwein.) W.H. Lewis, *Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm., *Abies lasiocarpa* (Hook.) Nutt., and *Picea glauca* (Moench) Voss ×*engelmannii* (Torr. & Gray ex Hook.) Brayshaw. Les composées et les *Vaccinium* spp. occupent une place importante comme groupes. Les graminées, incluant le *Calamagrostis rubescens*, se retrouvent plutôt à proximité des parcelles sans morille. Les caractéristiques des habitats de la morille, observées dans cette étude, pourraient être utiles pour l'aménagement de la ressource, en assurant la conservation de l'habitat, l'utilisation du brûlage contrôlé, et la remise à plus tard de la récolte sur les surfaces à fort potentiel de production.

Mots-clés : *Morchella*, indicateurs, feu, champignon.

[Traduit par la Rédaction]

Introduction

After a large forest fire, the emergence of phoenicoid mushrooms signals the renewal of forest life, as well as the almost certain arrival of morel pickers. Cooked morels (*Morchella* spp.) are a highly-prized delicacy (Pegler 2003) and figure prominently in gourmet recipes featuring wild mushrooms. Their popularity has fostered a burgeoning trade in North America in fresh and dried morels for both domestic consumption and the export market. In British Columbia (B.C.), the prominence of morels as a nontimber forest resource (NTFR) rivals that of pine mushrooms and chanterelles (de Geus 1993, 1995; Wills and Lipsey 1999).

Wildfires provide the most productive habitat for morel harvests (Amaranthus and Pilz 1994), and larger fires provide a larger opportunity for potential profits for commercial morel harvesters. This was certainly the case in 2003, when over 250000 ha of forest burned in B.C. during an unusually intense fire season (Filmon 2004). In a departure from past

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Fig. 1. Black morels fruiting after the Middle Fork White River fire of 2003. Small cup fungi (Geopyxis sp.) are visible to the left of the morels.

fire seasons, fires occurring during July of that year exhib- ited unpredictable ‘‘extreme behaviour,’’ with 334 residences being consumed and over 45000 people evacuated (Filmon 2004). A substantial part of these fires occurred in the Rocky Mountain Forest District. Despite this unfortunate devastation, a new window of opportunity opened for morel harvests in 2004.

The productivity of Morchella spp. in burned natural areas has been documented throughout North America (Duchesne and Weber 1993; Kenney 1996; Obst and Brown 2000; Pilz et al. 2004, 2007; McFarlane et al. 2005; Wurtz et al. 2005). Morel ascocarps usually form during the first spring following a wildfire (Fig. 1). They are well adapted for post-fire environments; the ascocarps often resemble dull-coloured cinders, rendering them difficult to discover even in productive habitats (Weber 1988). Several attributes of wildfires are thought to combine to trigger the formation of morel ascocarps. One is mortality or severe stress in trees and other plants associated with the underground sclerotia and mycelium, which can be a factor even in the absence of wildfires. Dutch elm disease (Ophiostoma ulmi (Buisman) Nannfeldt) triggers ascocarp formation when it kills Ulmus

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americana L. (American elm) (Weber 1988), and the moun- tain pine beetle (Dendroctonus ponderosae Hopkins) trig- gers ascocarp formation when it attacks and kills conifers (Pilz et al. 2004). Although they can be saprobic, morels are also known to associate with various plant roots (Roze 1883; Buscot and Roux 1987; Buscot and Kottke 1990; Buscot 1992, 1993; Dahlstrom et al. 2000). Whether these associations are beneficial, neutral, or parasitic, their disrup- tion by fire would likely trigger ascocarp formation. Fires also change soil characteristics, producing an alkaline ‘‘pulse’’ of calcium, manganese, and sterilized cellulosic substrates (Cilimburg and Short 2005). These same edaphic factors also tend to stimulate the growth of morel mycelia in nonfire situations (Winder 2006).

The numerous fires occurring in the Rocky Mountain For- est District during 2003 provided a unique opportunity to study the landscape-level ecology of morels. The objective of this study was to characterize the productivity and habitat of the black morel group (Morchella elata Fries, and related spe- cies sensu Arora 1986) in five burnt forest sites in the Rocky Mountain Forest District, using extensive (landscape-level) survey methods. In the burn sites, the parameters surveyed in-

Table 1. The location and characteristics of British Columbia forest sites surveyed for morel production in 2004.

Approximate

No. of Name of burn site Approximate location

altitude (m a.s.l.) BECa zone Site seriesb

plots Lamb Creek 49820’N, 115854’W 1150–1400 ICHmw2 3,4 6 IDFdm2/ICHmw2 1,4/3,4 8 ESSFdk 1,4 2 Plumbob Mountain 49815’N, 115822’W 1000–1200 MSdk 4 9 IDFdm2 1 4 Middle Fork White River 50825’N, 115811’W 1500–1600 ESSFdk1 1,4 13 Mission Creek 4983’N, 116817’W 1250–1500 ESSFwm 1,4 6 Kootenay National Park 50848’N, 115845’W 1400–1600 ESSFdk1 1,4 16 MSdk 1,5–7 7

aBiogeoclimatic zones according to maps provided by the B.C. Ministry of Forests. ICHdm, Interior cedar – hemlock (dry mild); IDFdm2, Interior Douglas-fir (dry mild, Kootenay variant); ESSFdk1, Engelmann spruce – subalpine fir (dry cool, Kootenay variant); ICHdw1, Interior cedar – hemlock (dry warm, West Kootenay variant).

bSite series level classification is a subdivision of the biogeoclimatic mapping system that is based on site and soil conditions and the vegetation community, as listed in: British Columbia Ministry of Forests and Range. 2008. Biogeoclimatic Ecosystem Classification, available from www.for.gov.bc.ca/hre/becweb/ system/how/site.html [accessed 2 March 2008].

Table 2. Productivity of morels and cup fungi in burnt forests of the Rocky Mountain Forest District in 2004.

Location

© 2008 NRC Canada Plots

MorelsÁplot–1a

Plots with

Estimatedb

Duff

Grey vs. black

Plots with (no.)

(no.)

morels (%)

morelsÁha–1 (no.)

consumed (%)

morels (%)

Geopyxis spp. (%) Lamb Creek 26 9.1a 61.5 1132 40 0.0 11 Plumbob Mountain 18 4.3a 72.2 618 52 0.0 61 Middle Fork White River 20 17.3a 65.0 2237 68 0.0 20 Mission Creek 10 8.4a 60.0 1003 56 0.0 20 Kootenay Nat. Park 24 42.3b 95.8 8062 71 6.6 50 Mean±SE 16.3±6.8 71.1±5.8 2610±1389 62±4 1.3±1.3 32±10

aMeans followed by the same letter are not significantly different according to Tukey’s HSD test performed on transformed [log(x + 1)] data. bThe estimate was calculated as: (morels/plot) x (%plots with morels/100) x (10 000 m2/50.3 m2).

cluded the main factors thought to affect morel fruiting in

Middle Fork White River burn sites; at each

location, a burn sites: plant and fungal communities, fire intensity, and

single plot had to be excluded from the study

because it the amount of ash deposition or duff consumption.

was disturbed by logging. For the two burn sites, this would translate to a total of 4% of plots excluded owing

Materials and methods

to disturbance from the logging activity. The number of plots measured at each site is given in Table 2. The abun-

Morel productivity

dance of morels in each plot was assessed by counting the Morel abundance was measured in burnt forests at five sites in the Rocky Mountain Forest District during May 2004. The sites were chosen based on the availability of road or helicopter access, and on the occurrence of a large (>100 ha) wildfire in the preceding year. The burn sites were located at Lamb Creek, Plumbob Mountain, Middle Fork White River, Mission Creek, and the Tokumm–Verrendrye area of Kootenay National Park (Table 1). Aside from the burn site at Kootenay National Park, all burn sites occurred in forests with complex mosaics of dif- ferent stand ages, pre- and post-wildfire logging, and other silvicultural activities. At Kootenay National Park, the burn site appeared to occur in an even-aged (ca. 100–140 years old) stand. For each burn site, a number of circular (8 m diam.) plots were established using a GPS unit to locate random predetermined points within 100 m of road access. The number of plots established depended on the difficulty of terrain and the time available for the survey. Where suf- ficient time was available, additional plots were selected

number of morel ascocarps and cut morel stipes within the plot, and the mean abundance at each burn site was com- pared using Tukey's HSD test. Intact morel ascocarps were classified as either black or grey according to the descrip- tions of Pilz et al. (2004) and McFarlane et al. (2005). In North America, grey morels require taxonomic clarifica- tion. They are sometimes named Morchella atrotomentosa (Moser) Bride, but this is reported to be an illegitimate name in North America, and the synonym Mor- chella esculenta var. atrotomentosa Moser is not yet val- idly published (Pilz et al. 2007). Cut stipes were classified as grey if they possessed short dark hairs; otherwise they were classified as black. Within each plot, the presence or absence of ascomycete cup fungi (primarily Geopyxis spp.) was also recorded, and the mean incidence for each burn site was calculated to produce an overall mean and standard error. The burnt forests at Lamb Creek and Middle Fork White River were revisited in May 2005; no morels were found, therefore no further measurements were recorded. by starting at the last measured plot and walking in a ran- dom direction for 5 min, and establishing a new plot

Plant associates centre using a randomly tossed

plot marker. Large areas

The morel-producing plots described above

were also of salvage-logging were observed at the Lamb Creek and

used to quantify the plant communities associated with morel production. The quantification method was modified

plants (e.g., Calamagrostis rubescens Buckl.)

could prolifer- from techniques that use land survey data (witness trees) to

ate in portions of the plot without occurring near

fruiting reconstruct the characteristics of historical plant commun-

bodies, we elected to use distance to the center of

the plot ities (Abrams and McCay 1996). In each plot, the two herb,

as a better indication of plant abundance. An

importance shrub, and tree species closest to the plot centre were identi-

value ranging from 0–300 was calculated on a

per-species fied, and their distance to the plot centre was also measured.

basis to assess the degree of association with

morel habitat. The limited number of species observed allowed time for

The importance calculations were performed

separately for more extensive sampling. Because patches of some prolific

herbs, shrubs, and trees, as shown in eqs. 1–5:

1⁄21 Relative frequency 1⁄4 1⁄2ðtotal incidence of individual plant species=total plotsÞ

=ðÆ incidence of herb; shrub; or tree speciesÞ Â 100

1⁄22 Proximity 1⁄4 1 = ðdistance ðcmÞ from plot centre þ 1Þ

compared using t-tests. The t values were computed using the model appropriate for unequal samples and no assump-

1⁄23 Relative proximity 1⁄4 1⁄2ðmean proximity of speciesÞ =

ðÆ proximity all species in groupÞ Â 100

tion of homogeneity of variance.

The plant communities in morel-producing and morel-free plots were also compared by ranking the species at each burn site according to their importance values, and 1⁄24 Relative morel abundance 1⁄4 1⁄2meanðmorels=plotÞ =

1⁄2Æðmorels=plotÞ Â 100

comparing that ranking with expected ranks for species oc- curring in the appropriate biogeoclimatic zone. The expected ranks were calculated using the mid-range cover values for

1⁄25 Importance 1⁄4 Relative frequency þ

the appropriate biogeoclimatic zones and site series provided by British Columbia Ministry of Forests (1992).

Relative proximity þ Relative morel abundance

This importance value was designed to provide a composite measure (0–300) of plant distribution across the landscape (frequency), plant abundance, and degree of as- sociation with morels. In this method, proximity was ex- pected to increasingly reflect plant abundance as frequency of occurrence increased. A reciprocal was used to empha- size the importance of plants occurring well within the plots, because more abundant plants were expected to ap- pear with greater frequency near plot centres. When calcu- lating proximity, 1 cm was added to the distance in the denominator of the reciprocal, because some plants grew at zero distance from the plot centre. Separate analyses of variance were conducted for herbs, shrubs, and trees, using species and burn site as categorical predictors, and a one-

Burn site characteristics

In each plot, the consumption of the soil duff layer was visually estimated. The presumed amount of initial duff was evaluated by excavating the duff in nearby unburned or lightly burned areas, and comparing the depth of the duff with the depth of duff that could be excavated in the plots. Where mineral soil was exposed, duff consumption was rated as 100%. A simple regression of morel production vs. duff consumption was not attempted because normal trans- formation techniques could not reduce heterogeneity of var- iance below significant levels in Levene's test. To illustrate the interaction between duff consumption, plant importance, and burn site location, new importance values were calcu- lated on a per-plot basis, as shown in eqs. 6–9:

tailed probability was used to calculate a least significant difference to compare mean importance values with zero.

1⁄26 Because travel between burn sites limited the time avail-

Relative frequency 1⁄4 1⁄2ðfrequency of species=plotÞ =

ðÆ frequency all species=plotÞ Â 100

able for plot measurements, it was not possible to measure morel-free plots at all sites. However, at Lamb Creek, there

1⁄27 Distance from plot periphery ðDPPÞ 1⁄4

Plot radius was sufficient time to record the presence of plants in 10

À distance

from plot centre morel-free plots. Importance values for plants in these plots were calculated without including the term for morel abun- dance, providing a scale of 0–200. A one-tailed probability 1⁄28 was used to calculate a least significant difference to com-

Relative DPP 1⁄4 1⁄2ðDPP for speciesÞ =

ðÆ

DPPÞ Â 100 pare mean importance values with zero, but these impor- tance values could not be directly compared with

1⁄29 Importance 1⁄4 Relative frequency þ

Relative DPP importance values for morel-associated plants, because they contained different terms. Instead, the mean proximities of

In this instance, relative DPP was used instead of proxim- plant species in both types of plots were subjected to

ity to reduce plot-level bias in the per-plot calculations. The ANOVA, using the presence of morels as a main effect.

importance values were calculated separately for each of the Transformation of the data did not reduce heterogeneity of

two herb, shrub, and tree species in each plot, providing a variance below significant levels, so the mean proximities

0–200 scale for each species. The species values were to- for plants in morel-producing versus morel-free plots were

talled to provide a 0–1200 scale for each plot.

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Statistical methods

Computer software was used to perform analyses of var- iance, covariance, and associated statistical tests (Statistica 6.1, Statsoft, Tulsa, Okla.), as well as t-tests and regression analyses (SPSS, Chicago, Ill.). Bartlett's test was used to evaluate homogeneity of variance for analyses of variance of morel abundance and plant importance; Levene's test was used to test heterogeneity of variance for t-tests of plant proximity and analysis of covariance of duff removal vs. plant importance. Count, percentage, and importance data with using

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ffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffi x þ 1 heterogeneity of variance = 2 prior to further analysis.

was transformed

Results

Morel productivity

The burn sites we studied produced an average of about 2600 morelsÁha–1 in May 2004. Production in the Kootenay National Park was significantly greater (*8000Áha–1) than production in the other burn sites; the highest proportion (96%) of plots producing morels was also found at Koote- nay National Park. Nearly all of the morels found were black morels; a little over 1% were grey morels. Where they co-occurred, the mean minimal distance (±SE) between black morels and grey morels in the plots was 66 ± 13 cm. Cup fungi, including Geopyxis spp., occurred in about one- third of the plots (Table 2). Total morel production averaged 21.1Áplot–1 in the presence of cup fungi, and 24.1Áplot–1 in the absence of cup fungi; a t-test indicated no significant difference in the transformed means (t = –0.32, df 64, P = 0.750). Incidence of cup fungi in each burn site was 38% in morel-free plots, and 33% in morel-producing plots; a t-test indicated no significant difference in the transformed means (t = 0.15, df 6, P = –0.884). No morels were observed in May of 2005 in the burnt forests in Lamb Creek or Middle Fork White River.

Plant associates

Bartlett's test indicated that transformation of the impor- tance values was successful in reducing heterogeneity of variance in the importance values of associated flora. Analy- ses of variance produced significant F-values for the effects of plants, but there were no significant effects of burn site location. The effect of burn location on the importance of herbs was nearly significant (P

transformed

= 0.07) (Table 3). Herbaceous plants occurring in the morel plots (Table 4) were heterogeneously distributed. Herbs having importance values significantly greater than zero and an association with above-average morel productivity included Chamerion angustifolium (L.) Holub (fireweed), Arnica cordifolia Hook., (heart-leaved Arnica), and Erythronium grandiflorum Pursh. (yellow glacier lily). Chamerion angustifolium also occurred in a few morel-free plots but there was no signifi- cant difference in proximity. A group of unidentified Aster spp. and Erigeron spp., all members of the Compositae, had lower importance, but the group was associated with above- average morel productivity. The same was true for Petasites frigidus var. palmatus (Ait.) Cronq. (palmate coltsfoot), an- other member of the Compositae (Table 4).

Among the shrubs in morel plots (Table 5), Spiraea betu- lifolia Pallas subsp. lucida (Dougl. ex Greene) Taylor &

Table 4. The relative importance of herbaceous plants associated with morels occurring in five burned areas in the Rocky Mountain Forest District in May 2004.

Importance values for each sitea

Speciesa

Overall value Calamagrostis rubescens Buckl. 58.8 203.4 52.2 0.0 19.8 60.8 66.9d Chamerion angustifolium (L.) Holub 168.6 0.0 0.0 62.2 94.7 136.3c 65.1d Arnica cordifolia Hook. 72.1 0.0 112.6 0.0 112.6 267.7c 59.1d Erythronium grandiflorum Pursh 0.0 0.0 87.4 0.0 27.9 212.0c 23.1d Viola spp. 0.0 0.0 0.0 92.6 0.0 49.0 18.5 Calamagrostis canadensis (Michx.) Beauv. 0.0 0.0 92.4 0.0 0.0 39.0 18.5 Compositae sppe 0.0 0.0 32.0 0.0 51.1 170.5c 16.6 Elymus repens (L.) Gould 0.0 66.8 0.0 0.0 0.0 7.0 13.3 Hieracium albiflorum Hook. 0.0 60.3 0.0 0.0 0.0 2.0 12.1 Thalictrum occidentale Gray 0.0 0.0 15.6 36.1 6.4 21.7 11.6 Mitella breweri Gray 0.0 0.0 0.0 53.1 0.0 25.0 10.6 Carex spp. 0.0 42.3 0.0 0.0 9.4 17.5 10.4 Poa compressa L. 0.0 46.2 0.0 0.0 0.0 4.0 9.3 Festuca idahoensis Elmer 0.0 45.3 0.0 0.0 0.0 4.0 9.1 Senecio triangularis Hook. 0.0 0.0 0.0 44.0 0.0 27.0 8.8 Valeriana sitchensis Bong. 0.0 0.0 0.0 43.1 0.0 27.0 8.6 Clintonia unifloraf 41.7 0.0 0.0 0.0 0.0 30.0 8.1 Taraxacum officinale G.H. Weber ex Wiggers 0.0 39.8 0.0 0.0 0.0 7.0 8.0 Osmorhiza berteroi DC. 0.0 39.7 0.0 0.0 0.0 15.0 7.9 Fragaria virginiana Duchesne 23.7 0.0 0.0 0.0 18.9 44.5 7.8 Equisetum arvense L. 17.9 0.0 0.0 0.0 12.9 35.0 6.7 Calochortus apiculatus Baker 0.0 32.0 0.0 0.0 0.0 11.0 6.4 Xerophyllum tenax (Pursh) Nutt. 15.5 0.0 0.0 16.7 0.0 7.5 6.4 Lupinus sericeus Pursh 0.0 31.8 0.0 0.0 0.0 14.0 6.4 Petasites frigidus (L.) Fries var. palmatusg 0.0 0.0 0.0 0.0 21.6 142.0c 4.3 Trifolium spp. 0.0 18.4 0.0 0.0 0.0 4.0 3.7 Poa pratensis L. 0.0 18.8 0.0 0.0 0.0 4.0 3.4 Saxifragaceae 0.0 0.0 0.0 16.7 0.0 3.0 3.3 Pyrola picta Sm. 15.1 0.0 0.0 0.0 0.0 5.0 3.0

aTaxonomy and authorities are according to the E-Flora B.C.: Electronic atlas of the plants of British Columbia, accessed from eflora.bc.ca on 7 February 2007, and also the United States Dept. of Agriculture Natural Resources Conservation Service Plants Database, accessed from plants.usda.gov/index.html on 7 February 2007.

bThe mean number of morels corresponding to plots having the plant species in the far left column. cMeans in bold in this column exceed the mean productivity of morels on a per species basis (48.0 ± 25.6, mean ± SE). dMeans in bold in this column are significantly greater than zero, using the LSD from Table 3 on transformed data. Data were transformed using the square root of the importance value +0.5. eAster spp. and Erigeron spp. difficult to identify in the seedling stage. fClintonia uniflora (Menzies ex J.A. & J.H. Schultes) Kunth. gPetasites frigidus var. palmatus (Ait.) Cronq.

Lamb Creek

Plumbob Mt.

Middle Fork White R.

Mission Creek

Kootenay National Park

Morels per speciesb

Table 5. The relative importance of shrubs associated with morels occurring in five burned areas in the Rocky Mountain forest district in May 2004.

Species[a]	Lamb Creek	Plumbob Mt.	Middle Fork White R.	Mission Creek	Kootenay National Park	Morels per species[b]	Overall value
Spiraea betulifolia Pallas subsp. *lucida*[c]	104.3	37.2	21.0	0.0	77.0	161.3[d]	64.7[e]
Menziesia ferruginea Sm.	81.5	72.8	69.4	45.2	35.4	101.7[d]	32.4[e]
Rosa acicularis Lindl. subsp. *sayi*[f]	0.0	0.0	0.0	0.0	28.3	63.3[d]	32.3[e]
Vaccinium membranaceum Dougl. ex Hook.	26.7	0.0	0.0	93.5	9.6	31.3	26.0[e]
Rubus parviflorus Nutt.	15.8	0.0	0.0	89.1	0.0	30.0	21.0[e]
Alnus viridis (Chaix) DC. subsp. *crispa* (Ait.) Turrill	62.9	15.2	0.0	31.2	0.0	43.5	18.8[e]
Symphoricarpos albus (L.) Blake	20.6	0.0	0.0	0.0	0.0	8.7	15.8[e]
Salix spp.	42.1	0.0	0.0	0.0	17.5	27.3	15.0[e]
Mahonia aquifolium (Pursh) Nutt.	0.0	0.0	0.0	0.0	0.0	25.0	12.5
Vaccinium scoparium Leib.	0.0	62.6	0.0	0.0	21.0	56.0	9.6
Ribes oxyacanthoides L.	0.0	92.5	40.4	42.2	0.0	27.0	8.5
Arctostaphylos uva-ursi (L.) Spreng.	0.0	8.0	0.0	0.0	0.0	12.0	7.9
Sambucus racemosa L.	0.0	26.8	0.0	36.7	0.0	20.0	7.4
Lonicera utahensis S. Wats.	14.1	39.4	0.0	15.6	0.0	7.5	6.0
Vaccinium caespitosum Michx.	0.0	0.0	27.1	0.0	0.0	2.0	5.4
Shepherdia canadensis (L.) Nutt.	0.0	0.0	0.0	0.0	17.4	45.5	5.1
Ledum groenlandicum Oeder	0.0	0.0	0.0	0.0	16.6	80.0[d]	3.3
Ribes spp.	16.4	0.0	0.0	0.0	0.0	12.0	3.3
Vaccinium spp.	0.0	0.0	0.0	0.0	14.0	56.0	2.8
Rhododendron albiflorum Hook.	0.0	0.0	0.0	0.0	13.8	67.0[d]	2.8
Amelanchier alnifolia Nutt.	0.0	0.0	0.0	0.0	12.7	74.0[d]	2.5
Linnaea borealis L.	0.0	0.0	0.0	0.0	10.3	8.0	2.1
Lonicera involucrata (Richards.) Banks ex Spreng.	0.0	0.0	0.0	0.0	7.7	38.0	1.6

Note: Importance values for each site.

[a]Taxonomy and authorities are according to the E-Flora B.C.: electronic atlas of the plants of British Columbia, available from eflora.bc.ca [accessed 7 February 2007], and also the United States Dept. of Agriculture Natural Resources Conservation Service Plants Database, available from plants.usda.gov/ index.html [accessed 7 February 2007].

[b]The mean number of morels corresponding to plots having the plant species in the far left column.

[c]lucida (Dougl. ex Greene) Taylor & MacBryde.

[d]Means in bold in this column exceed the mean productivity of morels on a per species basis (43.4 ± 15.4, mean ± SE).

[e]Means in bold in this column are significantly greater than zero, using the LSD from Table 3 on transformed data. Data were transformed using the square root of the importance value + 0.5.

[f]*Rosa acicularis* subsp. *sayi* (Schwein.) W.H. Lewis.

MacBryde (birchleaf Spiraea) and *Menziesia ferruginea* Sm. (false azalea) had the highest importance values. All burn sites had morel-producing plots with *M. ferruginea*, and only the morel-producing plots at the Mission Creek burn site lacked *S. betulifolia*. Both of these shrubs were associ- ated with above-average morel productivity. *Rosa acicularis* Lindl. subsp. *sayi* (Schwein.) W.H. Lewis also had a signifi- cant (nonzero) importance value and an association with above-average morel productivity. Other

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shrubs with signifi- cant importance but no apparent association with high pro- ductivity included Vaccinium membranaceum Dougl. (black huckleberry), Rubus parviflorus Nutt. (thimbleberry), Alnus crispa Ait. (green alder), Symphoricarpus albus (L.) S.F. Blake (common snowberry), and Salix spp. (willows). Le- dum groenlandicum Oeder (Labrador tea), Rhododendron al- biflorum Hook. (white-flowered rhododendron), and Amelanchier alnifolia Mackey (Saskatoon berry) all had nonsignificant importance values, but each was associated with above-average morel production. Each of these three species occurred at less than four of the visited burn sites.

Trees with high importance in morel plots, which were also associated with high morel productivity (Table 6) in- cluded Pinus contorta var. latifolia Engelm. (lodgepole pine), Abies lasiocarpa Hook. Nutt. (subalpine fir), and Pi- cea glauca Â engelmannii (hybrid white and Engelmann spruce). These trees occurred throughout all of the burn sites, with the exception of Pinus contorta at Mission Creek.

Some very common plants had significant importance in plots with morels (Tables 4–6) and plots without morels (Table 7) at Lamb Creek. Calamagrostis rubescens (pine grass) was the most frequently occurring herb (4 burn sites). This grass species was commonly found throughout the study area; with significant importance in morel-producing plots (Table 4) and morel-free plots (Table 7), it was sig- nificantly ($t = -3.1$, $P = 0.036$) more proximate to the centre of morel-free plots (–0.044). Spiraea betulifolia and Rubus parviflorus were important in both morel-producing and morel-free plots (Tables 5 and 7); there were no significant differences in their proximity to the plot centres. Pinus

Table 6. The relative importance[a] of trees associated with morels occurring in five burned areas in the Rocky Mountain Forest District in 2004.

Species[a]	Importance values for each site: Lamb Creek	Plumbob Mt.	Middle Fork White R.	Mission Creek	Kootenay National Park	Morels per species[b]	Overall value
Pinus contorta Dougl. ex Loud.	156.5	133.3	149.4	0.0	63.5	229.3c	100.5d
Abies lasiocarpa (Hook.) Nutt.	150.3	0.0	14.2	173.5	102.1	227.8c	88.0d
Picea glauca (Moench) Voss Â engelmaniie	32.5	0.0	14.2	103.0	135.2	316.0c	57.0d
Pseudotsuga menziesii (Mirb.) Franco	0.0	99.6	0.0	0.0	0.0	51.0	19.9
Tsuga heterophylla (Raf.) Sarg.	47.0	0.0	0.0	0.0	0.0	38.0	9.4
Populus tremuloides Michx.	0.0	31.0	0.0	0.0	0.0	3.0	6.7
Larix occidentalis Nutt.	7.5	18.3	0.0	0.0	0.0	4.5	5.2
Populus balsamifera L. subsp. Trichocarpaf	19.6	0.0	0.0	0.0	0.0	7.0	3.9
Thuja plicata Donn ex D. Don	14.91	0.0	0.0	0.0	0.0	10.0	3.0

aTaxonomy and authorities are according to the E-Flora B.C.: electronic atlas of the plants of British Columbia, available from eflora.bc.ca [accessed 7 February 2007], and also the United States Dept. of Agriculture Natural Resources Conservation Service Plants Database, available from plants.usda.gov/ index.html [accessed 7 February 2007].

bThe mean number of morels corresponding to plots having the plant species in the far left column. cMeans in bold in this column exceed the mean productivity of morels on a per species basis (98.5 ± 82.1, mean ± SE). dMeans in bold in this column are significantly greater than zero, using the LSD from Table 3 on transformed data . Data were transformed using the square root of the importance value + 0.5.

ePicea engelmannii Perry ex Engelm. fPopulus balsamifera var. trichocarpa (Torr. & Gray ex Hook.) Brayshaw.

Table 7. The relative importance of herbs, shrubs, and trees in

munities in the morel-producing plots for each burn site, the morel-free plots at the Lamb Creek burn site in 2004.

resulting communities featured some changes from the

Plant type	Species	Importance[a]
Herb	*Calamagrostis rubescens*	62.7
	Unidentified (Gramineae)	62.5
	Equisetum arvense	27.9
	Chamerion angustifolium	18.6
	Carex sp.	17.5
	Hieracium albiflorum	10.8
Shrub	*Mahonia aquifolium*	52.7
	Spiraea betulifolia	46.6
	Amelanchier alnifolia	28.0
	Arctostaphylos uva-ursi	24.5
	Rubus parviflorus	21.5
	Cornus stolonifera	14.9
	Rosa acicularis	11.8
Tree	*Pinus contorta*	74.3
	Larix occidentalis	50.4
	Pseudotsuga menziesii	39.9
	Populus balsamifera subsp. trichocarpa	

standard communities for the appropriate biogeoclimatic zone (Table 8). Although post-fire shifts in the abundance of common species were expected, the relative importance of normally minor species such as Rosa acicularis and Er- ythronium grandiflorum is notable in the rankings. At Lamb Creek, a comparison of the ranked communities from morel- free plots (Table 7) vs. morel-producing plots and the expected plant community (Table 8) revealed different com- munities in all three cases, even in the top-ranked species. For example, Calamagrostis rubescens was the top-ranked herb in both morel-free plots and the expected plant com- munity, but Chamerion angustifolium, top-ranked in the morel-producing plots, had a minor rank in the morel-free plots and was not ranked in the expected community. Spiraea betulifolia was the top-ranked shrub in the morel- producing plots and the second-ranked shrub in morel-free plots and the expected community. However, Mahonia aqui-

35.4

folium (Pursh) Nutt., the top ranked shrub in morel-free plots, was not ranked among the plants in morel-producing plots, or the expected community. Pinus contorta was the aMeans in bold in this column are significantly greater than zero using

top-ranked tree species in both morel-producing

and morel- LSD

05

(=27.1 for herbs, 16.1 for shrubs, and 28.9 for trees).

free plots, and second-rated tree species in the expected community. Pseudotsuga menziesii (Mirb.) Franco, the top- contorta was important in both morel-producing plots

rated tree in the expected community, was ranked

third in (Table 6) and morel-free plots (Table 7); there was no sig-

the morel-free plots, and it was not ranked among

trees in nificant difference in the relative proximity of this tree

morel-producing plots. The reported habitat

characteristics species to the plot centres. Larix occidentalis Nutt.

of plants only important in morel-producing plots

could be (western larch) was significantly ($t = -2.4$, $P = 0.041$)

summarized as mesic, with a mean soil moisture

of 4.0 more proximate to morel-free plots (–0.005); this tree

(ranging from 3.5 to 4.2) on a scale of eight

(Table 9). The species had significant importance in morel-free plots

reported habitat characteristics of plants only

important in (Table 7), but nonsignificant importance in morel-producing

morel-free plots (Table 10) were mostly outside

these pa- plots (Table 6). Four out of the 10 morel-free plots at

rameters, either relatively hydric with a mean soil

moisture Lamb Creek included only one tree, and 2 were treeless.

of 5.3 (ranging from 4.9 to 5.6), or relatively xeric

with a When importance values were used to rank the plant com-

mean soil moisture of 3.3 (ranging from 2.9 to 3.6).

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Table 8. A comparison of ranked plant communities in morel producing plots vs. the average communities expected throughout the bio- geoclimatic ecozone and site series sampled.

Burn site, biogeoclimatic zone(s) Plant type Expected communitya

© 2008 NRC Canada Mid-range cover (%) Expected producing community

Morel importance Kootenay Trees Picea glauca Â engelmanii 20 Picea sp. 135 National Park Larix occidentalis 15 Abies lasiocarpa 102 ESSFdk, Pinus contorta 7 Pinus contorta 64 MSdk Pseudotsuga menziesii 2 Abies lasiocarpa 1 Shrubs Menziesia ferruginea 22 Spiraea betulifolia 77 Vaccinium myrtillus 8 Menziesia ferruginea 35 Vaccinium scoparium 6 Rosa acicularis 28 Ribes lacustre 5 Vaccinium scoparium 21 Betula glandulosa 5 Salix sp. 17 Ledum groenlandicum 3 Shepherdia canadensis 17 Shepherdia canadensis 2 Ledum groenlandicum 16 Symphoricarpos albus 1 Vaccinium sp. 14 Cornus stolonifera <1 Rhododendron albiflorum 13 Vaccinium membranaceum <1 Amelanchier alnifolia 13 Lonicera utahensis <1 Linnaea borealis 10 Vaccinium membranaceum 10 Lonicera involucrata 8 Herbs Arnica cordifolia 5 Arnica cordifolia 113 Cornus canadensis 4 Chamerion angustifolium 95 Carex spp. 4 Aster sp. 51 Thalictrum occidentale 3 Erythronium grandiflorum 28 Aster conspicuus 2 Petasites frigidus var. palmatus 22 Equisetum arvense 2 Calamagrostis rubescens 20 Arnica latifolia 2 Fragaria virginiana 19 Calamagrostis rubescens 1 Carex sp. 9 Othersb <1–1 Thalictrum occidentale 6 Middle Fork Trees Abies lasiocarpa 20 Pinus contorta 149 White River Picea engelmanii 20 Picea sp. 33 ESSFdk1 Pinus contorta 11 Pseudotsuga menziesii <1 Shrubs Menziesia ferruginea 25 Spiraea betulifolia 69 Vaccinium myrtillus 20 Rosa acicularis 40 Vaccinium scoparium 11 Vaccinium scoparium 27 Othersc <5 Symphoricarpos albus 21 Herbs Arnica cordifolia 11 Arnica cordifolia 113 Arnica latifolia 4 Aster sp. 32 Aster conspicuus 4 Calamagrostis canadensis 92 Cornus canadensis 4 Erythronium grandiflorum 87 Linnaea borealis 4 Calamagrostis rubescens 52 Othersd <4 Thalictrum occidentale 16 Plumbob Mt. Trees Pinus contorta 24 Pinus contorta 133 MSdk, Pseudotsuga menziesii 8 Pseudotsuga menziesii 100 IDFdm2 Larix occidentalis 5 Populus tremuloides 31 Otherse <4 Larix occidentalis 18 Shrubs Shepherdia canadensis 11 Rosa acicularis 93 Arctostaphylos uva-ursi 6 Spiraea betulifolia 73 Spiraea betulifolia 3 Mahonia aquifolium 63 Mahonia aquifolium 1 Arctostaphylos uva-ursi 39 Symphoricarpos albus 1 Symphoricarpos albus 37 Vaccinium scoparium 1 Vaccinium caespitosum 27 Juniperus communis 1 Salix sp. 15 Amelanchier alnifolia 1 Shepherdia canadensis 8 Lonicera utahensis <1 Herbs Calamagrostis rubescens >25 Calamagrostis rubescens 203 Aster conspicuus 4 Hieracium albiflorum 60 Arnica cordifolia 2 Festuca idahoensis 45 Linnaea borealis 2 Carex sp. 42 Cornus canadensis <1 Taraxacum officinale 40 Osmorhiza berteroi 40 Calochortus apiculatus 40

Table 8 (concluded).

Burn site, biogeoclimatic zone(s) Plant type Expected communitya

© 2008 NRC Canada Mid-range cover (%) Expected producing community

Morel importance Poa pratensis 19 Trifolium spp. 18 Mission Creek Trees Abies lasiocarpa >25 Abies lasiocarpa 174 ESSFwm Picea engelmanii >25 Picea glauca Âengelmanii 103

Othersf <1 Shrubs Menziesia ferruginea >25 Vaccinium membranaceum 94 Vaccinium membranaceum 16 Rubus parviflorus 89 Rhododendron albiflorum 7 Menziesia ferruginea 45 Alnus crispa 6 Sambucus racemosa 37 Lonicera utahensis 6 Alnus viridis subsp. crispa 31 Othersg <4 Lonicera utahensis 16 Herbs Gymnocarpium dryopterus 11 Viola sp. 92 Tiarella trifoliate v. unifoliata 11 Chamerion angustifolium 62 Arnica latifolia 7 Mitella breweri 54 Rubus pedatus 6 Senecio triangularis 44 Viola spp. 2 Valeriana sitchensis 43 Athyrium filix-femina <1 Thalictrum occidentale 36 Mitella breweri <1 Xerophyllum tenax 17 Othersh <1 Lamb Creeki Trees Pseudotsuga menziesii 14 Pinus contorta 157 IDFdm2, Pinus contorta 10 Abies lasiocarpa 150 ICHmw2, Larix occidentalis 10 Tsgua heterophylla 47 ESSFdk Thuja plicata 8 Picea sp. 32 Picea glauca Â engelmanii 4 Populus balsamifera 20 Tsuga heterophylla 3 Thuja plicata 15 Larix occidentalis 8 Shrubs Shepherdia canadensis 7 Spiraea betulifolia 104 Spiraea betulifolia 4 Menziesia ferruginea 82 Menziesia ferruginea 3 Alnus viridis subsp. crispa 63 Vaccinium membranaceum 2 Salix sp. 29 Amelanchier alnifolia 2 Vaccinium membranaceum 27 Vaccinium myrtillus 1 Symphoricarpos albus 21 Ribes lacustre <1 Ribes spp. 16 Lonicera utahensis <1 Rubus parviflorus 16 Othersi <1 Lonicera utahensis 14 Herbs Calamagrostis rubescens 6 Chamerion angustifolium 169 Linnaea borealis 4 Arnica cordifolia 71 Chimaphila umbellata 3 Calamagrostis rubescens 59 Arnica cordifolia 1 Clintonia uniflora 41 Clintonia uniflora <1 Equisetum arvense 21 Arnica latifolia <1 Fragaria virginiana 21 Arctostaphylos uva-ursi <1 Xerophyllum tenax 15 Othersj <1 Pyrola picta 15

Note: Plants in morel-producing plots are ranked by importance value, while the standard ecozone community is ranked by estimated cover for species in the appropriate site series. For each burn site, plants are grouped as trees, shrubs and herbs.

aExpected community refers to the plants listed for corresponding ecozones in British Columbia Ministry of Forests (1992); authorities for binomial plant names were not included in these lists.

bOrthilia secunda, Linnaea borealis, Tiarella trifoliate var. unifoliata, Veratrum viride, Petasites saggitatus. cShepherdia canadensis, Ribes lacustre, Lonicera utahensis. dCalamagrostis rubescens, Orthilia secunda, Thalictrum occidentale. ePicea glauca x engelmanii, Pinus ponderosa, Betula papyrifera, Abies lasiocarpa. fTsuga heterophylla, Pinus contorta. gRibes lacustre, Paxistima myrsrnites, Vaccinium ovaliflolium, Rubus parviflorus. hOrthilia secunda, Vaccinium scoparium, Lycopodium annotinum. iVaccinium scoparium, Paxistima myrsrnites, Juniperus communis, Symphoricarpos albus, Mahonia aquifolium. jAster conspicuus, Cornus canadensis, Orthilia secunda, Thalictrum occidentale, Tiarella trifoliate var. unifoliata, Veratrum viride.