

MANAGING MAMMAL DAMAGE AGENTS IN MPB- KILLED STANDS & PROTECTION OF NEW PLANTATIONS

NIFR 2009-10

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Forests For Tomorrow

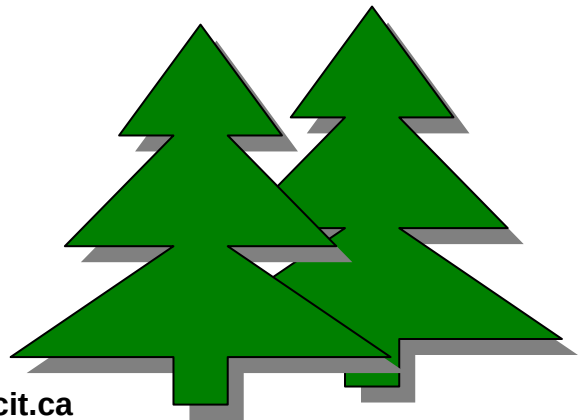
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EXECUTIVE SUMMARY

The problem of feeding damage to forest and agricultural crops by herbivorous small mammals has a long history in temperate and boreal ecosystems of North America. In forestry, voles of the genera *Microtus* and *Myodes* are considered the major mammalian species affecting coniferous and deciduous tree plantations. Populations of some species of voles (*Microtus* spp.) tend to have cyclic fluctuations in abundance in northern latitudes with a peak every 3 to 5 years, although these periods may be interspersed with annual fluctuations in abundance. Another potentially major problem species is the snowshoe hare (*Lepus americanus*) which has a 9- to 11-year fluctuation in abundance. The next anticipated peak in abundance of hares is 2009-2011.

It is primarily during overwinter periods when high populations of microtines (voles) feed on plantation trees. Voles feed on bark, vascular tissues (phloem and xylem), and sometimes roots of trees. Hares damage seedlings by clipping the leader and lateral shoots. Direct mortality may result from girdling and clipping of tree stems. In terms of conservation and sustainability of temperate forests, feeding damage may: limit regeneration of appropriate tree species in certain forest ecosystems; increase cost of reforestation to meet Free Growing Status; decrease net productive forested area; and, result in loss of Mean Annual Increment.

There is concern that underplantings in MPB-killed stands in the Northern Interior Forest Regions (*NIFR*) may experience significant damage from snowshoe hares and voles. However, population fluctuations of voles (both *Microtus* spp. and *Myodes gapperi*) are poorly known in these areas. Similarly, status of snowshoe hare populations is not clear.

Monitoring of voles and snowshoe hares was initiated in six locations: three areas in MPB-killed non-merchantable pine stands (Quesnel, Prince George, and Vanderhoof) and three locations for MPB-killed merchantable pine stands (West Quesnel, Fort Fraser, and Fort St. James). Monitoring was initiated in 2006 using a combination of live trapping for voles and hares (non-merchantable stands) and pellet plots for hares (non-merchantable & merchantable stands).

Objectives in 2009-10:

Objectives from the 2009-2010 FFT proposal:

- (1) Continue monitoring vole populations in MPB-killed non-merchantable stands and control sites. Are we heading towards an irruption of voles?

- Typically, in forested habitats, long-tailed voles (*Microtus longicaudus*) reach their highest abundance in clearcuts where grasses and herbaceous vegetation are highest. Abundance of long-tailed voles were highest on clearcuts (MPB salvage harvest), with intermediate densities in MPB-killed stands in 2006 and 2007. By 2008 and 2009, abundance of long-tailed voles in MPB-killed stands was similar to, or exceeded that, in clearcut stands. This indicated that habitat quality of MPB-killed stands for long-tailed voles has increased and is similar to that provided by clearcuts. Thus, plantings in MPB-killed stands may suffer the same damage previously recorded in clearcuts when vole populations irrupt. However, abundance of long-tailed voles has decreased from 2007 to 2009; thus, potential of damage to recently planted seedlings is low at this time. It should be noted that we have not seen a peak in the vole cycle during this 4-year monitoring program. Since they have a 3- to 5-year cycle, we may see an irruption in their number in the near future.
 - Abundance of red-backed voles (*Myodes gapperi*) is typically highest in mature stands and lowest in clearcuts, as supported by our monitoring. MPB-killed stands contained an intermediate number of red-backed voles. Overall, their abundance was highest in 2006 and 2007 and decreased significantly in 2008 and 2009; although their numbers appeared to be building again in September 2009 (as was long-tailed voles).
- (2) Continue monitoring snowshoe hare populations in MPB-killed non-merchantable stands, and relative habitat use by hares in both MPB-killed non-merchantable and merchantable stands and control sites. Are we still heading towards a peak in abundance of hares?
- Abundance of hares continued to increase from 2006 to 2008 based on pellet-plot surveys and live trapping. However, abundance of hares appeared to be similar between 2008 and 2009 based on live trapping and pellet-plot surveys for most study sites. Whether this indicates the peak has been reached requires at least another year of monitoring. It is unknown whether this lull is the result of 2009 environmental conditions (i.e., a temporary lull) or whether hares have reached their peak.
 - There is a high probability that it is safe to plant this coming year on many sites; (see Objective 3 below) and damage levels should not exceed those seen in the previous two years.
- (3) Assess whether abundance of voles and hares is related to percent cover of vegetation. If there is a relationship between these species and vegetation, this information can be used to predict which sites are most susceptible to damage.

- The increase in voles in MPB-killed non-merchantable stands, relative to clear cuts, may have resulted from the increase in herbaceous vegetation seen between 2007 and 2008 in non-merchantable stands. The herbaceous layer increased significantly in MPB-killed stands during this time period, which also paralleled the increase in meadow voles, relative to clearcuts. These results indicated that controlling vegetation prior to peaks in vole abundance may reduce their abundance in MPB-killed stands.
 - Should vole abundance irrupt in the next year or two, controlling herbaceous and low-shrub cover prior to planting may reduce their abundance and susceptibility of planted seedlings to vole damage.
 - Use of MPB-killed non-merchantable stands by snowshoe hares appears strongly linked to percent cover of shrubs and trees. A strong regression was found between density of pellets (as indicative of habitat use) and percent cover of trees and shrubs. This is consistent with many studies that have concluded that hares prefer densely-vegetated sites.
 - On those sites with high hare abundance or shrub and tree cover, controlling this vegetation should substantially reduce hare abundance in treated stands and proportions of seedlings damaged by hares (see Objective 5 below).
- (4) Continue monitoring damage trials to quantify damage to freshly planted seedlings in the NIFR by snowshoe hares and voles. Does damage occur in year two after planting or is it restricted to the fall following planting?
- Little additional damage has been noted from hares in the spring following planting or the year following planting. The damage period for seedlings is primarily limited to the few months following planting.
 - However, hares are preferentially feeding on planted seedlings (i.e., seedlings are preferred food items for many months following planting); thus, damage may always be present in these stands and not limited to the over-winter period during peak abundances commonly associated with hare damage. Hare damage will always be present; the extent of damage will depend upon the density of hares in planted sites.
 - On most sites with moderate to low levels of hare use, seedling survival is very high (75 to 95% survival) even though damage levels on many sites exceeded 75%. On sites with moderate to low levels of hare use, planting could continue as seedlings appear to survive moderate levels of clipping following planting.

- Plant larger, older trees to further enhance survival of seedlings following hare clipping (see trials by Gord Dow, Ministry of Forests and Range, Prince George).
 - Since hares are preferentially feeding on newly planted seedlings, the nutritional appeal of seedlings has surpassed that of the natural vegetation. Planting nursery-grown trees with reduced fertilization (see trials by Gord Dow, Ministry of Forests and Range, Prince George) may reduce the appeal of seedlings to hares, reducing the incidence of clipping.
- (5) Complete monitoring seedling survival in trials treated by brushing and diversionary food. Did brushing or diversionary food enhance seedling survival?
- Brushing appeared to be an effective treatment to reduce stand use by hares. Pellet densities were reduced by 50 and 95% on brushed sites when compared to controls. Similarly, clipping by hares was reduced by 50 and 90% on brush sites when compared to unbrushed sites.
 - On most sites with low to moderate use by hares, seedlings appear to survive clipping by hares (> 90% survival).
 - Seedling survival on sites with high hare abundance and high cover is much lower. Brushing these sites prior to planting should reduce both abundance of hares and damage to seedlings. However, the above recommendation is based on results from one trial with two replicates. Additional replication is needed to strengthen these results.
 - Since abundance of voles decreased in 2008-2009, their abundance was too low to assess the effectiveness of diversionary food to reduce seedling damage by voles. Diversionary food should be reapplied just prior to an irruption in vole numbers to evaluate this method.

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1.0 BACKGROUND

1.1 The Problem of Feeding Damage in Plantations

1.1.1 Voles

The problem of feeding damage to forest and agricultural crops by herbivorous small mammals has a long history in temperate and boreal ecosystems of North America and Eurasia (Moore, 1940; Myllymäki, 1977; Byers, 1984; Getz, 1985; Conover, 2002). In forestry, voles of the genera *Microtus* and *Myodes* are considered the major mammalian species affecting coniferous and deciduous tree plantations in North America (Sartz, 1970; Radvanyi, 1980; Bergeron and Jodoin, 1989; Sullivan et al., 1990), Europe (Hansson, 1985; 1991), and Asia (Shu, 1985; Sullivan et al., 1991). Populations of some species of voles tend to have cyclic fluctuations in abundance in northern latitudes with a peak every 3 to 5 years, although these periods may be interspersed with annual fluctuations in abundance (Krebs and Myers, 1974; Taitt and Krebs, 1985; Körpimäki and Krebs, 1996; Boonstra et al., 1998).

Voles of the genus *Microtus* are considered one of the major mammalian pests in coniferous tree plantations in the Southern Interior Forest Region (SIFR) and Northern Interior Forest Region (NIFR) of B.C. Diets of voles consist primarily of grasses, sedges, and forbs. However, these rodents will feed on tree seedlings and saplings, particularly during winter months of peak years in abundance. Voles may feed on bark, vascular tissues, and sometimes roots of trees. This damage may result in direct mortality from girdling and clipping of tree stems or reduced growth of surviving trees which have sub-lethal injuries (Fig. 1). Planted trees, with their nursery fertilization regime and enhanced palatability and nutrition, are nearly always preferred by voles over wildlings arising from natural regeneration (Sullivan and Martin, 1991). In terms of conservation and sustainability of temperate forests, this feeding damage may limit regeneration of appropriate tree species in certain forest ecosystems. In addition, this damage increases the cost to reforest these stands in order to obtain Free Growing Status, decreases net productive forested area, and results in loss of Mean Annual Increment. Feeding damage appears to be associated with high populations of voles in early successional habitats that develop after harvesting. The problem is widespread throughout the southern and central interior of B.C.

Three species of *Microtus*, long-tailed voles (*M. longicaudus*; Fig. 2a), meadow voles (*M. pennsylvanicus*; Fig. 2b), and montane voles (*M. montanus*) have been implicated

as major consumers of tree seedlings. A fourth species, heather voles (*Phenacomys intermedius*; Fig. 2c) is also present in these small mammal communities but exists at low abundance (< 5 animals/ha). In addition, populations of the southern red-backed vole (*Myodes gapperi*; formally *Clethrionomys gapperi*; Fig. 2d) occur primarily in mature stands of timber (Merritt, 1981) but may spill over into recently cut areas for 1-2 years after harvest. It is likely that these voles lived on the forested site prior to logging and continued there for a few years afterward, possibly feeding on lodgepole pine seed from cone slash. Red-backed voles disappear from harvested sites by 2 years post-logging, probably because their preferred food source, hypogeous fungi, are in short supply (Sullivan and Sullivan, 2001; Klenner and Sullivan, 2003; Ransome et al., 2008).

Preference of *M. longicaudus* and *M. pennsylvanicus* for early-successional habitats (e.g., clearcut and seed-tree sites) may be explained by abundance of herbs and grasses providing food and cover (Reich, 1981; Getz, 1985). Occurrence of *M. longicaudus* on clearcut and seed-tree sites, and to some degree on patch-cut sites, fits the variety of habitats occupied by this vole (Halvorson, 1982; Van Horne, 1982; Morris, 1984; Smolen and Keller, 1987). Habitats with some open areas and shrub and sapling cover at 7 to 10 years after clearcutting, appeared optimum for *M. longicaudus* in Alaska (Van Horne, 1982). Later seral stages with less understorey vegetation and thick canopies had lower densities of *M. longicaudus*.

Myodes gapperi prefer mesic habitats in coniferous, deciduous, and mixed forests with abundant organic debris composed of stumps, logs, and exposed roots (Martell and Radvanyi, 1977; Merritt, 1981; Yahner, 1986). These habitat conditions provide a substrate for maintenance of hypogeous ectomycorrhizal fungi, which are a major food supply for *M. gapperi* (Maser et al., 1978; Ure and Maser, 1982). Presumably, as reviewed by Hayward et al. (1999) and Sullivan et al. (1999), a reduction in moisture and insufficient coniferous tree cover result in extirpation of *M. gapperi* from recent clearcuts.

Because of these differences in habitat preferences, *Microtus* spp. occur frequently on forested areas harvested by clearcutting, up to almost 10 years after logging. In contrast, *M. gapperi* may be present for 1 - 2 years after clearcut logging, but persist in small patch-cuts (Sullivan and Sullivan, 2001; Ransome et al., 2008) and potentially within the understory of snags, whether created by wildfire or attack by mountain pine beetle (MPB). There has been much research on the importance of habitat heterogeneity in population dynamics of small mammals.

Thus, feeding damage appears to be associated with: 1) high populations of voles; 2) seedlings in the first year after planting; and, 3) early successional habitats that develop after harvesting or wildfire. The problem is widespread, but localized, throughout the northern, southern and central interior of B.C. Wildfire and some types of prescribed burning may convert unavailable mineral nutrients into forms more available to plants, thereby resulting in higher nutrient availability. This process may result in early-successional vegetation that has high forage quality for herbivores. The flush of vegetative growth may be related to nutrient availability, and the addition of range seeding that adds several grasses and herbs to the plant community. In particular, voles may thrive on the food and cover provided by this flush of vegetative growth.

To date, severe feeding damage by voles has been reported to seedlings planted on large (> 100 ha) contiguous openings created by harvesting (e.g., near Golden, Summerland, Invermere, Quesnel, Houston) or wildfire (e.g., Silver Creek Fire, Salmon Arm, McLure fire, Okanagan Mountain Park fire, and McGillivray fire). However, population fluctuations of *Microtus* are generally unknown in many of these geographic areas, and in some cases, it appears that vole populations may be high on some sites every year (e.g. Golden). In addition, significant habitat alteration may induce peak populations (and concomitant damage) that are out of phase with voles in unaltered populations.

1.1.2 Snowshoe hares (*Lepus americanus*)

Another potentially major problem species to forest plantations is the snowshoe hare (*Lepus americanus*: Fig. 3), which is considered a keystone species in the boreal forest of North America (Boutin et al., 2003). This leporid has a 9- to 11-year fluctuation in abundance (Fig. 4) (Keith 1963) and represents the main prey for many vertebrate predators in northern forests, such as Canada lynx (*Lynx canadensis*), coyotes (*Canis latrans*), and great horned owls (*Bubo virginianus*). Loss of snowshoe hares from northern forest ecosystems would likely lead to elimination of these predators (Boutin et al., 2003). It is not clear if this cycling behaviour of hares also occurs in the montane western coniferous forests of B.C. and the northwestern United States. Limited information on population dynamics of hares in this southern part of their range indicates that hare numbers may continue to cycle but at densities less than half of those in northern regions (Keith, 1990; Hodges, 2000), or they are irruptive, or largely stable (Murray, 2000).

Hares also feed on newly planted coniferous seedlings (Fig. 5a & b) and saplings during overwinter periods of peak populations when alternative natural foods may be in short supply. Hares damage seedlings by clipping the leader and lateral shoots, leaving an oblique cut surface at a 45° angle (Fig. 5c). Damage to young seedlings in plantations is usually most severe in or near areas having sufficient cover to provide suitable habitat (often 10-25 years post-harvest) (Sullivan, 1994). Snowshoe hares also remove bark from the base of stems and low branches of large seedlings and sapling trees up to about 6.0 cm in diameter (Fig. 5d). Feeding damage may occur higher on stems and branches, depending on snow depth. The gnawed sapwood has a shaggy or ragged appearance and complete girdling of the stem may occur. Toothmarks are indistinct, with an average width of 2 mm in a horizontal or diagonal pattern on exposed sapwood. Fecal pellets, which are slightly flattened spherical disks 10 mm in diameter, are usually present at feeding sites.

1.2 Residual Stands after MPB

1.2.1 Habitat for voles

There is little information available on responses of voles to residual stands killed by fire or insect epidemics. McDonough and Rexstad (2005) reported on the responses of northern red-backed voles (*C. rutilus*) in Alaska to three levels (1-3%, 15-42%, and 38-48%) of spruce beetle (*Dendroctonus rufipennis*) induced mortality at 10 years post-infestation. Vole abundance and recruitment were inversely related to the level of spruce mortality, but there was no difference in survival across these levels of spruce tree mortality. Interestingly, vole food resources and vegetative cover were reasonably similar across infestation levels. These authors concluded that spruce mortality levels likely need to be > 50% before habitat and population dynamics of *C. rutilus* are affected. These results contrast markedly with studies in lodgepole pine forests in northern Utah where tree mortality over 90% was common and microtine rodents responded positively to the beetle outbreak (Stone, 1995; Stone and Wolfe, 1996).

1.2.2 Habitat for snowshoe hares

There are several reports relating presence/absence of snowshoe hares to cover attributes in recently harvested forest sites (Ferron et al., 1998; de Bellefeuille et al., 2001). However, except for the studies by Sullivan and Sullivan (1988), and Sullivan et al. (2002), there are no published reports on responses of understory vegetation and habitat use by snowshoe hares to stand management treatments in young (15- to 30-

year old) commercial forests. Stand thinning, with and without fertilization, is used to enhance tree growth in young forests, and these treatments also may promote development of complex vegetative understories (Thomas et al., 1999; Lindgren et al., 2006). Silvicultural treatments such as pre-commercial thinning (PCT) have been viewed as having potentially negative impacts on snowshoe hares as reduction in stand density reduces cover, increasing susceptibility of hares to predation (Koehler, 1990b; Ausband and Baty, 2005).

Snowshoe hare abundance and feeding damage to lodgepole pine stems tend to be greater at high than low stand densities. Hares likely prefer the increased food and cover associated with heavily overstocked stands. This pattern fits that described for hare habitat in Section 1.1.2. Young (20-30 years) unmanaged lodgepole pine stands are preferred forest habitat for hares, providing both food and cover when interspersed with younger successional stages (Sullivan and Sullivan, 1983; Koehler, 1990a, b). Sullivan et al. (2006) studied relative habitat use by hares in PCT and fertilized stands over a range of treatments. During both summer and winter periods, relative habitat use by snowshoe hares in the nine treatment stands (based on counts of fecal pellets) followed a clear trend of higher use in the high- than low-density stands, as well as higher use in fertilized than unfertilized stands. Crown volume index of trees (primarily lodgepole pine) was the most important habitat variable affecting pellet counts of hares. A major concern with the onset of PCT in young pine stands is a decline in habitat suitability for hares. Heavy thinning to densities ≤ 1000 stems/ha reduced the carrying capacity of pine stands for hares, at least up to 10 years after initiation of treatments. Thinning to 2000 stems/ha with repeated fertilization seemed to maintain habitat for hares, in both summer and winter seasons. Stands thinned to 2000 stems/ha without fertilization and 1000 stems/ha with fertilization also began to develop habitat features attractive to hares, when annual pellet numbers reached ~50% of those in the 2000 stems/ha with fertilization and unthinned stands. These results generally correspond to a period of relatively high numbers of hares, based on other B.C. studies documenting high hare populations near to the start of a given decade, in 1980 (Sullivan and Sullivan, 1988) and in 1990 (Sullivan, 1994).

Forest management, particularly clearcut harvesting, has been documented as having a negative influence on snowshoe hare populations because of the loss of food and cover on harvested areas (Ferron et al., 1998; Potvin et al., 1999). Although subsequent vegetative succession on clearcut areas would likely benefit hares, particularly in dense stands of regenerating lodgepole pine, “intensive management” of young stands would

likely reduce understory cover for hares (Mowat and Slough, 2003). This prediction was accurate for our low- to medium-density stands, with or without fertilization, and for the stands reported by Sullivan and Sullivan (1988). However, even the 1000 stems/ha fertilized and 2000 stems/ha unfertilized stands had increased habitat suitability for hares up to 10 years after intensive thinning and fertilization.

2.0 OBJECTIVES

Objectives from the 2009-2010 FFT Proposal:

- (1) Continue monitoring vole populations in MPB-killed non-merchantable stands and control sites.
- (2) Continue monitoring snowshoe hare populations in MPB-killed non-merchantable stands, and relative habitat use by hares in both MPB-killed non-merchantable and merchantable stands and control sites.
- (3) Assess whether abundance of voles and hares is related to percent cover of vegetation. If there is a relationship between these species and vegetation, this information can be used to predict which sites are most susceptible to damage.
- (4) Continue monitoring damage trials to quantify damage to freshly planted seedlings in the NIFR by snowshoe hares and voles. Does damage occur in year two after planting or is it restricted to the fall following planting?
- (5) Complete monitoring seedling survival in trials treated by brushing and diversionary food. Did brushing or diversionary food enhance seedling survival?
- (6) Expand damage-reduction trials to include:
 - a. Additional brushing trials (2 treatments and 2 controls)
 - b. Additional diversionary food trials (2 treatments and 2 controls)
 - c. Initiate a fertilization trial (2 treatments and 2 controls)

Objectives 1 to 5 were completed this year. Objective 6 was not initiated to accommodate a reduced budget. Objective 6 required new trials; thus, was not a funding priority for this current year.

3.0 PROJECT AREAS and DESIGN

The monitoring program encompassed monitoring locations from Quesnel to Fort St. James (Fig. 6).

3.1 Objective 1: Continue monitoring vole populations in MPB-killed non-merchantable stands and control sites.

To monitor voles within the NIFR, three geographic locations were selected: Dunkley (Fig. 7), Prince George (Fig. 8), and Vanderhoof (Fig. 9). There were 5 sampling sites within each location: 3 MPB-killed non-merchantable stands (site A, B, & C); 1 salvage clearcut (site D); and 1 uncut forest (E). To monitor the increase in abundance of voles, 1-ha live-trapping grids were established in the 3 MPB-killed non-merchantable stands and 2 control stands (salvage clearcut & uncut forest). Establishing trends was based on total abundance of individuals captured during each trap session. Monitoring control sites (mature stands and clearcuts) documented abundance of voles in their optimum habitat. Abundance of these damaging agents typically increases in favourable habitats (control sites; source populations) prior to increasing in abundance in less-favourable habitats (MPB-killed non-merchantable stands; sink populations).

MPB-killed non-merchantable stands ranged in size from 26 ha to 170 ha, and age from 25 to 36 years old for majority of the stands (Table 1). Sites were typically dominated by lodgepole pine (65% to 100% species composition) with varying amounts of understory vegetation (Fig. 10). Many of the sites had been spaced and pruned prior to beetle kill (Table 1). Salvage clearcuts were recently harvested (2004-2005) MPB-killed stands and represented a control (optimal habitat) for monitoring of *Microtus* species. Clearcuts were a minimum of 20 ha and were located close to MPB-killed stands. Uncut forests were non-MPB-killed stands, primarily composed of spruce and represent control (optimal habitat) sites for *M. gapperi*.

3.2 Objective 2: Continue monitoring snowshoe hare populations in MPB-killed non-merchantable stands, and relative habitat use by hares in both MPB-killed non-merchantable and merchantable stands and control sites.

To monitor abundance of snowshoe hares within non-merchantable stands in the NIFR, the same sites used to monitor voles (Objective 1) were used to monitor trends in abundance of hares. Relative habitat use surveys for snowshoe hares using pellet plots were conducted on the same live-trapping sites and unthinned control site. Abundance of these damaging agents typically increase in favourable habitats (unthinned controls; source populations) prior to increasing in abundance in less-favourable habitats (MPB-killed non-merchantable stands; sink populations).

To monitor snowshoe hares within MPB-killed merchantable timber in the NIFR, three geographic locations were selected: Quesnel (Fig. 11), Fort Fraser (Fig. 12), and Fort St. James (Fig. 13). There were four sampling sites within each location: 3 MPB-killed merchantable stands (site A, B, & C) and 1 live overstocked stand of young pine or spruce (Unthinned control). Relative habitat use surveys for snowshoe hares (using pellet plots) were conducted on these sites, and unthinned controls to document changes in their abundance as we approach the projected peak in their cycle.

MPB-killed merchantable stands ranged in size from 22 ha to 163 ha, and age from 75 to 140 years old (Table 1). Sites were typically dominated by lodgepole pine (68% to 100% species composition). Unthinned control sites were represented by overstocked young (< 20 years old) pine- or spruce-dominated stands.

3.3 Objective 3: Assess whether abundance of voles and hares is related to percent cover of vegetation. If there is a relationship between these species and the vegetation, this information can be used to predict which sites are most susceptible to damage.

Vegetation was monitored on all non-merchantable stands and control sites (mature, clearcut, and unspaced stands) in 2007, 2008, and 2009. Vegetation was also monitored on all merchantable stands in 2008.

3.4 Objective 4: Continue monitoring damage trials to quantify damage to freshly planted seedlings in the NIFR by snowshoe hares and voles. Does damage occur in year two after planting or is it restricted to the fall following planting?

To monitor survival of seedlings planted in young MPB-killed non-merchantable timber in the NIFR, 4 stands were selected (Figs. 14 & 15). Sites ranged in size from 10.5 ha to 67.7 ha and in age from 31 to 52 years old (Table 1). Sites were planted with a mixture of lodgepole pine, spruce, and Douglas-fir in July 2006.

3.5-Objective 5: Complete monitoring seedling survival in trials treated by diversionary food and brushing. Did diversionary food or brushing enhance seedling survival?

For the diversionary food trial two non-merchantable MPB-killed stands each at Prince George and Vanderhoof were selected for this trial. These sites were also being used to address objectives 1 and 2 above. Sites were planted in July 2008 and survival trials

were superimposed on the current monitoring program. Site A at each location had diversionary food applied in September 2008. Site B at each site functioned as a control for the treatment. Comparison of seedling survival between food-added and control sites was used to evaluate the effectiveness of diversionary food in reducing damage to seedlings.

Two locations were selected by the Ministry of Forests for the brushing trial: Teardrop 600 Road (Fig. 16; opening # 093J025-27) 40 km northwest of Prince George, and Kwitzel Lake (Fig. 17; opening #093G084-5) 34 km west of Prince George along Highway 16. Sites range from 65 to 105 ha in size. Teardrop 600 Road site was a 25-year-old site dominated by lodgepole pine (81%) with varying amounts of spruce and alder. The Kwitzel Lake site was a 33-year-old stand dominated by lodgepole pine (50%) and alder (40%). Both sites contained a significant amount of shrub cover in the understory. A rationale for the brushing trial can be found in Appendix A.

4.0 METHODS

4.1 Vole Population Monitoring

Vole populations (and other forest-floor small mammal species) were sampled at 4-week intervals from June to September 2006 and May to September 2007 to 2009 at the vole and hare monitoring sites in the NIFR (Figs. 7 – 9). Live-trapping grids (1 ha) had 49 (7 x 7) trap stations at 14.3-m intervals with one Longworth live-trap at each station. Traps were supplied with whole oats, and cotton as bedding. Traps were set on the afternoon of day 1, checked on the morning and afternoon of day 2 and morning of day 3, and then locked open between trapping periods. All individuals captured were ear-tagged with an individually-numbered tag, and species, gender, reproductive condition, and location recorded. Forest floor small mammal species sampled by this procedure include (damaging agents in bold) the **long-tailed vole**, **meadow vole**, **red-backed vole**, heather vole, deer mouse (*Peromyscus maniculatus*), northwestern chipmunk (*Tamias amoenus*), montane shrew (*Sorex monticolus*), common shrew (*S. cinereus*), and short-tailed weasel (*Mustela erminea*). Abundance estimates for each small mammal species were derived from number of individuals captured in each trapping period. These methods corresponded to the following standard:

Resources Inventory Committee Publications

Standards for Components of British Columbia's Biodiversity No. 31

Inventory Methods for Small Mammals: Shrews, Voles, Mice & Rats (Version 2.0)

- 3.7.1 Recommended Method: Mark Recapture
- 3.7.2 Objectives of Surveys
- 3.7.3 Open vs. closed populations
- 3.7.5 Recommended Models
- 3.7.6 Office Procedures
- 3.7.7 Sampling Design
- 3.7.8 Sampling Effort
- 3.7.9 Equipment
- 3.7.10 Field Procedures

4.2 Snowshoe Hare Population Monitoring

A reasonably rapid and economical survey method to estimate population densities of hares in MPB-killed lodgepole pine stands and other forest types involves the use of index-lines of live-traps. In some situations, these lines can be compared with a standard set of index-lines superimposed on a grid system (Sullivan and Sullivan, 1983; Sullivan 1994). This approach has been used for several rodent species (Hansson, 1967; Petticrew and Sadleir, 1970; Smith et al., 1971; O'Farrell et al., 1977), and line counts, trapping, and tracking of snowshoe hares (Dolbeer and Clark, 1975; Thompson et al., 1989; and others).

One index-line composed of two parallel lines (each 300 m long and 30 m apart) were established in each of the three MPB-killed non-merchantable monitoring sites at each of the three project areas in the NIFR. There were 10 stations per line with one live trap (23 x 23 x 80 cm) at every station. Traps were supplied with an apple and alfalfa cubes and locked open for the pre-bait period. For the survey, index-line traps were set on the afternoon of day 1, checked on the morning of day 2 and 3, and then closed until the next trapping period. Hares captured were processed in an identical manner to the vole sampling procedure.

4.3 Relative Habitat Use – Hare Pellet Counts

Estimates of relative habitat use by snowshoe hares were measured for the initial sampling period by counting all fecal pellets on permanent sample plots (Litvaitis et al. 1985; Koehler 1990a; Ferron et al., 1998). Permanent sampling plots for Objective 2 were established in June 2006 in non-merchantable stands, and in June 2007 in merchantable stands (see section 3.2 for study site descriptions). We used 1.0-m² circular plots recommended by McKelvey et al. (2002) and Murray et al. (2002). One

hundred plots were located systematically (Fig. 24), in 5-plot arrays installed at 20 stations located systematically every 50 m throughout each of the four stands at each of the six NIFR project areas (3 areas for Objective 1; 3 areas for Objective 2; Fig. 6). Plots were permanently marked with a flagged aluminum “pig-tail” stake and a small painted rock was located in the plot center. Counts of pellets used a rope of 0.56-m radius attached to the center stake and rotated around the plot. Plots were cleared of all pellets at the initial sampling time. Pellet counts will continue on an annual basis following this procedure. Pellet degradation was not an issue as only new pellets deposited during a given year were counted since all previous pellets were cleared at each survey. Pellets were not included if they were incorporated into the duff and litter layers. Such pellets are typically darker colour with a lack of light brown or green material in the center of the pellets when broken open (Krebs et al. 1987). Pellets located near the plot circumference were included if a majority of the pellet was in the plot. Density of pellets was estimated per 1 m² plot and then converted to a per-ha basis.

Pellet-plot data may also be used to estimate number of snowshoe hares per ha as per the linear regression equation ($y=1.112+1.047x$), for 1-m² circular plots, calculated by Murray et al. (2002) for their study areas in northern Idaho. Our study areas and those of Murray et al. (2002) appeared reasonably similar in terms of forest types, elevations, and general range of successional stages. Mean number of pellets in 1-m² circular plots may be used in the above equation to provide a rough approximation of the range of hare abundances per ha in target treatment stands (Sullivan et al., 2006).

4.4 Survival Trial

To monitor the level of damage to newly planted seedlings, 25 damage plots were systematically established (30-m intervals) along transects in each of four MPB-killed non-merchantable stands in the Prince George Forest District. At each damage plot, the four closest seedlings were marked with a pig-tail stake and individually numbered tree tag. Species and damage (vole or hare, terminally clipped, laterally clipped, debarked) were noted for each seedling. Damage will be re-assessed each year of the project.

4.5 Understory Vegetation

Three 25-m transects, consisting of five 25-m² circular plots were systematically located in each stand following the method of Stickney (1980). Each plot contained three sizes

of nested subplots: a 25-m² plot for sampling trees, a 9-m² subplot for sampling shrubs; and a 1-m² subplot for sampling herbs. Tree, shrub, and herb layers were subdivided into 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. A visual estimate of percentage cover of the ground was made for each species and height class combination within the appropriate nested subplot. Total percentage cover for each layer was also estimated. These data were used to calculate crown volume index (m³/0.01 ha) for each plant species (Stickney, 1980). The product of percent cover and representative height yields volume of a cylindroid which represents the space occupied by the plant in the community. Crown volume index values were then averaged by species for each plot size and converted to a 0.01-ha base to produce the tabular value given for each species and layer (herbs, shrubs, and trees). Sampling was conducted in July – August 2007 and 2008. All visual estimates were made by the same person to minimize error. All vascular plants were identified to species. Plant species were identified in accordance with Hitchcock and Cronquist (1973) and Parish et al. (1996).

In 2009, densiometer readings were taken at 15 of the 20 pellet-plot stations on all non-merchantable stands and unspaced control sites used to monitor hare abundance. A concave densiometer was placed on a 75-cm platform at one subplot for each of 15 pellet-plot stations and percent vegetation cover (shrubs and trees) was estimated. Densiometer readings were averaged to represent average tree and shrub cover for each stand. A regression analysis was conducted to evaluate whether there was a relationship between cover and habitat use by hares.

4.6 Brushing Trial

The study design was a split-plot design with two replicates and two treatments. Each replicate had a 10-ha area brushed (square configuration) 3 to 4 weeks (June 2008) prior to planting. This time period should have been sufficient to result in hares leaving the treatment area to find better cover prior to planting. All alder and willow (0 - 2.5 m) were cut down to reduce security cover for hares. Downed shrubs were further reduced in size, resulting in material lying flat on the ground to reduce cover for hares, and to facilitate planting. Brush was not piled to avoid creating security cover for hares. Control areas were located in the same stand, adjacent to brushed treatments, but sufficiently removed from influence of the brushing (edge effect). The split-plot design ensured similarity of habitat use by hares prior to brushing. Following completion of the planting (July 2008), permanent pellet plots and survival plots were established in both brushed and control treatments as described above (section 4.3 and 4.4, respectively).

Pellet plots and survival plots will be reassessed in May of each year of the project. Comparisons of pellet-plot data indicated whether snowshoe hares avoided brushed sites relative to control sites. Comparison of seedling survival indicated whether brushing resulted in a significant reduction in damage to planted seedlings.

4.7 Diversionary Food Trial

The study designed included a randomized complete block design with two blocks (PG and Vanderhoof) and two treatments (diversionary food and control). Study sites were those sites used in Objective 1 (grids A & B). Sites were planted in July 2008. Survival trials as described section 4.5 (above) were established in September. Diversionary food was manually applied in October covering each 10-ha treatment site. Pellet plots and survival trials were re-surveyed in the spring of 2009.

5.0 RESULTS and MANAGEMENT RECOMMENDATIONS

5.1 Relating Mammal Abundance to Levels of Damage

How many voles need to occur in a given plantation to create a serious damage problem? A risk rating for feeding damage to trees, based on an index-line or grid survey of voles, is derived from the significant ($F_{1,17}=8.86$; $P<0.01$) positive relationship between percentage tree mortality and abundance of voles (*Microtus* spp.) (Fig. 25; see Sullivan and Sullivan, 2007):

<u>Number of voles on index-line</u>	<u>Number voles/per ha</u>	<u>Risk of damage to trees</u>
< 5	< 7.2	Low
5-10	7.2 – 34.3	Moderate
10-20	34.3 – 88.5	High
> 20	> 88.5	Very High

Thus, as determined from Fig. 25 and the above table, the number of voles captured on an index-line survey, for a given unit, can be related to the potential for feeding damage to trees on that particular unit (Sullivan and Sullivan, 2007).

The data in Fig. 25 were derived from several study areas in B.C. where number of voles per ha was known in October of a given year. Newly planted tree seedlings (primarily Douglas-fir, lodgepole pine, and some interior spruce) were available on the same sites where vole abundance had been measured and overwinter damage to trees (percentage mortality) by voles was then related to the October population estimate. It is important to note that in some cases there can be relatively high numbers of voles (in the moderate category), but little damage to tree seedlings. Conversely, a relatively low number of voles may, in certain situations, can damage a high percentage of trees. These two outliers are indicated with a circle on the data points in Fig. 25.

5.2 Objective 1: *Continue monitoring vole populations in MPB-killed non-merchantable stands and control sites.*

There is little work reported on responses of small mammals to insect infestations in boreal and temperate forests. Thus, the installation of monitoring grids at three project areas in the NIFR will help alleviate this information void. Monitoring grids were established in 2006 and monitored on a monthly basis from June to September, 2006 & May to September, 2007 to 2009.

Meadow Voles: Abundance of meadow voles appeared similar in 2006 and 2007 in clearcut MPB salvage sites (optimal habitat) for all three monitoring areas (Dunkley, Prince George, and Vanderhoof; Fig. 26; Table 2, Appendix B). However, their abundance declined on all sites at Dunkley in 2008 and 2009. In Prince George, numbers dropped in 2008, but appeared to be increasing in 2009, especially in MPB-killed non-merchantable stands. In Vanderhoof, abundance of meadow voles remained relatively similar to that of previous years. Typically, there were fewer than 10 individuals in dead standing non-merchantable lodgepole pine stands; thus, indicating a low to moderate risk of damage (Fig. 25).

It is worth noting that initially, abundance of meadows voles was highest in clearcut stands (optimal habitat) and lowest in mature stands (poorest habitat). Abundance in MPB-killed non-merchantable stands was intermediate to these extremes in 2006 and 2007. However, by 2008 and 2009, abundance of meadow voles in MPB-killed non-merchantable stands was similar to, or exceeded that in, clearcuts. This observation indicated that MPB-killed stands are developing into potentially suitable habitat for meadow voles. This observation was consistent for all study sites in all three monitoring areas: Quesnel (Dunkley), Prince George, and Vanderhoof.

Meadows voles often have cyclic fluctuations in abundance in northern latitudes with a peak every 3 to 5 years, with densities exceeding 40 to 50 individuals per hectare. At these densities, significant damage can occur to planted seedlings (Fig. 25). However, density of meadow voles have typically been less than 10 per hectare for 4 years (Fig. 26). If meadow voles continue to increase (for example, the Prince George area; Fig. 26) to peak densities in the next few years, there is a possibility of significant damage to underplanted seedlings.

Red-backed Voles: The opposite trend in habitat preference was noted for red-backed voles. Highest numbers occurred in uncut mature forests (optimal habitat) while MPB salvage sites (clearcuts) had the lowest abundance (Fig. 27; Table 2, Appendix B). Dead standing MPB-killed stands provided habitat of intermediate quality. Significantly more red-backed voles were found in Prince George and Vanderhoof (~ 50 voles/mature site) than Dunkley (~ 10 voles/mature site) in 2006 and 2007. However, in 2008 and 2009, numbers of red-backed voles decreased on all study sites to fewer than 10 individuals. However, by the last trap session in 2009, red-backed voles had increased substantially in both dead and mature stands in Prince George and Vanderhoof.

Recommendations: Given that:

- Voles typically have cyclic fluctuations in abundance in northern latitudes with a peak every 3 to 5 years.
- Abundance of voles was low in 2009.

Management Recommendation:

1. Sites planted to date should be safe from vole damage.

However,

- Abundance of meadow voles in non-merchantable stands is equal to, or exceeds, that in clearcut stands (optimal habitat for meadow voles). MPB-killed non-merchantable stands have developed into optimal habitat for meadow voles.
- We have not seen peak abundance of voles over the 4 years of the monitoring program.

Thus, it is likely that:

- Voles may peak in abundance in the next year or two.
- MPB-killed non-merchantable stands will provide optimal habitat for voles.

- Damage to seedlings planted prior to the peak may be susceptible to significant damage from voles in these stands.

Monitoring Recommendation:

2. Continue monitoring vole populations in MPB-killed non-merchantable stands and control sites. Are we heading towards an irruption in abundance?

5.3 Objective 2: *Continue monitoring snowshoe hare populations in MPB-killed non-merchantable stands, and relative habitat use by hares in both MPB-killed non-merchantable and merchantable stands and control sites.*

Snowshoe Hares: Captures of snowshoe hares were quite variable from trap session to trap session (Fig. 28). In general, abundance of hares increased for 2006 to 2008. In 2009, abundance of hares appeared to decrease slightly in Dunkley, while in PG and Vanderhoof, they remained the same as that in 2008. The decrease in Dunkley was primarily due to extensive disturbance by black bears (*Urus americanus*) throughout the 2009 monitoring season.

There was a 2.5-fold increase in pellets encountered in pellet plots from 2006 to 2007 for Prince George and Vanderhoof; a significant increase from one-year to the next ($F_{1,3} = 12.6$; $P = 0.038$; Fig. 29). Similarly, there was a significant increase in abundance of fecal pellets encountered on study sites in 2008 from 2006 and 2007 ($F_{2,12} = 9.07$; $P < 0.01$). The 2006 sampling period was the initial plot clearing; thus, numbers in 2006 may have represented more than a 12-month deposition period. On average, there was a 35% increase in number of fecal pellets encountered from 2007 to 2008. For Dunkley, all sites showed an increase in use by hares from 2007 to 2008. In contrast, number of fecal pellets encountered on the Vanderhoof sites appeared similar to that documented in 2007. Grids A and B in Prince George showed a slight increase in number of pellets encountered in 2008 than 2007, while grid C did not.

In 2009, the density of hare pellets (7.3 pellets/m²: a measure of habitat use) was similar to that noted in 2008 (7.1 pellets/m²: Fig. 29 and 30). Overall, density of pellets in unthinned controls (optimal habitat) for non-merchantable stands (Fig. 29) remained the same or decreased slightly when compared to 2008. Potentially, this change may indicate that the optimal habitat (source habitats) for hares has been saturated; thus,

their abundance in sub-optimal habitats (sink habitats) will start increasing as dispersing individuals are looking for new stands to inhabit.

Overall use of MPB-killed merchantable stands continued to be low in 2009 and was similar to that noted in 2008 (Fig. 30). The *unthinned* control stands showed a continued increase in pellet density from 2007 to 2009. This trend indicates that populations of hares may still be building in optimal habitat in these areas.

Recommendations: Given that

- Abundance of hares continued to increase from 2006 to 2008 based on pellet-plot surveys and live trapping.
- Abundance of hares appeared to be similar between 2008 and 2009 based on live trapping and pellet-plot surveys.

Management Recommendations:

3. It is safe to plant in 2010 and short-term damage levels should not exceed those seen last fall.

However,

- It is unknown whether this lull is the result of 2009 environmental conditions (i.e., a temporary lull) or whether hares have reached their peak.

Monitoring Recommendation:

4. Continue monitoring hare populations in MPB-killed non-merchantable stands and control sites. Are we still heading towards a peak in abundance?

5.4 Objective 3: *Assess whether abundance of voles and hares is related to percent cover of vegetation. If there is a relationship between these species and the vegetation, this information can be used to predict which sites are most susceptible to damage.*

Vegetation monitoring was initiated in 2007 to monitor development of the understorey within MPB-killed non-merchantable stands. Volume of herbaceous vegetation increased substantially from 2007 to 2008 in MPB-killed non-merchantable stands for all three locations (Fig. 31). Potentially, this change reflects response of the herbaceous layer to the dead pine. Loss of competition for moisture, light, and nutrients by the dead pine would result in an enhanced herbaceous layer. Little change in volume of herbs

was noted in unthinned and mature stands. The lack of a change in these stands would be expected as little change to the overstory occurred.

The volume of herbaceous plants in MPB-killed non-merchantable stands exceeded that found in clearcut sites, which paralleled a similar pattern for meadow voles, for Dunkley and Prince George. However, a similar pattern was not observed for Vanderhoof where the clearcut (MPB-killed salvage site) had the greatest volume of herbaceous plants while the MPB-killed stands had the greatest abundance of meadow voles. However, meadow voles appear to be responding to the enhanced herbaceous understory noted in non-merchantable MPB-killed stands in 2008. With future monitoring, we'll be able to determine if these stands continue to develop into optimal habitat for meadow voles; thus, potentially resulting in a high risk to planted seedlings.

Typically, voles will increase in abundance in optimal habitats prior to dispersing into less-optimal habitats: optimal habitat for meadow voles is open grass- and herb-dominated sites and optimal habitat for red-backed voles in mature uncut forests. As seen in Figure 26, abundance of meadow voles was highest in the salvage-logged areas in 2006 and 2007. Abundance of red-backed voles was highest in mature uncut forests. As MPB-killed stands age, potentially, the understorey will respond with a greater abundance of herbs (as seen in Fig. 31) and shrubs resulting from greater light penetration to the forest floor and less competition for moisture. Consequently, based on their preference for early-successional habitat (section 1.1.1), abundance of meadow voles may continue to increase in MPB-killed stands as supported by the 2008 and 2009 data. Thus, MPB-killed non-merchantable stands may be developing an understory vegetative layer that will provide optimal habitat for meadow voles. Red-backed voles can often persist in disturbed sites for 1 to 2 years following disturbance (section 1.1.1). However, given the slow general change that is occurring in the MPB-killed stands, they may be able to persist indefinitely within these stands. Should this occur, seedlings planted in these stands may risk a high rate of clipping. However, currently, both species have declined in abundance on all sites in 2008, and remained low for 2009.

Volume of shrubs appeared to be related to the abundance of hares as determined through live-trapping. For both Dunkley (2006: A & C; 2007 Grid A) and Prince George (Grids B & C in 2007 and 2008) those sites with the greatest volume of shrubs had the highest number of hares caught in the fall trap sessions (Fig. 32; Appendix B).

Although, some sites had reasonably good shrub volume, the low abundance of hares on these sites (e.g., Vanderhoof grid B) may be due to the overall lower abundance of hares in that area. Although trees are dead, the needles are still on the trees. Consequently, total canopy volume of trees was still relatively similar to a live stand (Fig. 33). Once the needles fall, the volume of trees, and the cover they provide, will decrease significantly. Potentially, the shrub layer will increase over time, providing better cover for snowshoe hares.

The density of pellets in merchantable stands (Fig.30) appeared to be unrelated to the volume of herbs (Fig. 36), shrubs (Fig. 37), and trees (Fig. 38). However, snowshoe hares are known to inhabit young, often overstocked or vegetation-dense stands with good shrub or tree cover. Volume of shrubs in MPB-killed merchantable stands varied between 10 and 20 m³/0.01ha; while the shrub volume varied between 20 to 60 m³/0.01ha in non-merchantable stands. Thus, the vegetative cover in MPB-killed merchantable stands may be insufficient to provide suitable cover for snowshoe hares.

In 2009 we estimated the total cover of shrubs and trees to better represent the overall structural cover of the MPB-killed non-merchantable stands and all 6 *unthinned* stands. Estimation was based on densitometer (concave) readings at 15 systematically placed stations in each stand. The 15 readings were averaged to provide an overall estimate of cover for each site. This value was then regressed against average pellet density for these sites to identify if higher cover resulted in greater stand use by hares, as indicated by a higher density of pellets. There was a strong relationship between density of pellets and percent cover of shrubs and trees (Fig. 39). As density of cover increased, density of pellets (habitat use) increased. The coefficient of determination for the relationship is relatively strong given that the monitoring sites are quite heterogeneous with respect to density of pellets (Figs. 29 & 30) and cover (Figs. 31 to 33 & 36 to 38). Snowshoe hares appear to be limited by availability of food in safe foraging areas (predator-sensitive foraging theory). Thus, many of the non-merchantable stands vary significantly in cover within the stand. Snowshoe hares will preferentially reside and forage in denser areas of the stand. As pellet plots and cover plots are established systematically, they capture the average density of pellets and cover for the stand. However, many of the plots sampled probably landed in areas deemed unsafe for foraging by hares, generating the observed variability. Despite this variability, the relationship is strong indicating that hares are positively correlated with density of cover supplied by trees and shrubs.

Recommendations: Given that:

- Increase in voles in MPB-killed non-merchantable stands, relative to clear cuts, may have resulted from the increase in herbaceous vegetation seen between 2007 and 2008 in non-merchantable stands.
- Use of MPB-killed non-merchantable stands by snowshoe hares appears strongly linked to percent cover of shrubs and trees.

It is likely that:

- Controlling the herbaceous understory may reduce susceptibility of trees to vole damage in MPB-killed non-merchantable stands.
- Controlling shrub and tree cover will reduce susceptibility of trees to hare damage in MPB-killed non-merchantable stands.

Management Recommendation:

5. Should vole abundance irrupt in the next year or two, controlling herbaceous and low-shrub cover prior to planting may reduce their abundance and susceptibility of planted seedlings to vole damage.
6. On those sites with high hare abundance or shrub and tree cover, controlling this vegetation should substantially reduce hare abundance in the stands and proportion of seedlings damaged by hares (see objective 5 below)

Monitoring Recommendations:

7. Pending availability of funding, monitor voles on MPB-killed non-merchantable stands where vegetation control has been implemented. This would provide an evaluation of the effectiveness of vegetation control to reduce abundance of voles; thus, reducing susceptibility of planted seedlings to vole damage.
8. Continue monitoring the development of understory and canopy cover in MPB-killed non-merchantable stands. Specifically, the detailed vegetation survey conducted in 2008 should be repeated in 2010 (1 additional year of data).

5.5 Objective 4: *Continue monitoring damage trials to quantify damage to freshly planted seedlings in the NIFR by snowshoe hares and voles. Does damage occur in year two after planting or is it restricted to the fall following planting?*

Four sites were monitored for clipping by snowshoe hare and voles on freshly planted seedlings in the NIFR (Figs. 14 & 15). Sites were planted in mid to late July 2007 and

assessed for damage the first week of August 2007. Block 93G056-030 suffered a high level (36%) of damage within a few weeks after planting (Fig. 5 & 40). Block 93G043-524 suffered lower levels of damage (6%) than the previous block. Of those seedlings damaged, 95% were clipped by snowshoe hare and 5% by voles (Appendix C). Damage was reassessed in May 2008. Damage ranged from 24% to 98% (Fig. 40). Since much of the damage observed in the spring of 2008 was old, a significant portion of the damage occurred immediately following planting and into the fall. This is in sharp contrast to typical damage documented elsewhere. Snowshoe hares typically feed on young trees in winter during peaks in their population cycle. However, damage is occurring immediately after planting. Consequently, snowshoe hares are preferentially feeding on newly planted seedlings; even in the presence of significant abundance of their natural food resources. Consequently, the nutritious appeal of newly planted seedlings surpasses that of their natural food resources and hares are selecting newly planted seedling to feed upon. Therefore, damage will not be limited to the typical over-winter period during peak populations. A low abundance of hares could cause significant damage to newly planted seedlings. For example, the highest number of hares captured on grid B in Prince George was 6 (Fig. 28). Similarly, the average density of fecal pellets encountered on this site was low relative to unthinned stands (Fig. 29). However, these few individuals accounted for 24% of newly planted seedlings being clipped within a few weeks following planting.

Selectivity of newly planted seedlings by hares is, in all likelihood, associated with the nutrient regime used to grow the seedlings. Fertilization of seedlings elevates their nutritional content and suitability as a preferred food item, relative to the other food resources available in these stands. Potentially, if seedlings could be grown for a period of time without fertilization prior to planting, this should reduce damage by hares.

Two of the original four sites were re-surveyed in May 2009. These two sites had sufficient number of seedlings surviving to 2009 to assess whether damage continued past the initial year of planting. Very little additional damage occurred the second year following planting. It appeared that seedlings are primarily susceptible to damage from hares in the immediate months following planting. Those that survive through the fall to winter suffered little additional damage. This observation supports the theory that once seedlings exhaust their nutritional content provided by the nursery environment, they are less susceptible to damage by hares.

In addition to documenting the level of damage caused by hares, the status of trees (alive or dead) was also recorded. When initial damage was intermediate or low, (Fig. 40: Blocks 100 Road & 93G043-524) many of the clipped seedlings survived. However, when damage was initially severe, fewer trees survived (93G056-030). Based on personal observations, those sites with the greatest initial damage (Fig 40; block 93G056-030) had higher amounts of cover; thus, lower amounts of herbaceous vegetation (food). Consequently, high cover and low food on these sites likely resulted in planted seedlings providing an important source of nutrients to hares.

Management Recommendations: Given that:

- Damage to seedlings by hares is primarily restricted to the few months following planting.
- Hares are preferentially feeding on planted seedlings (i.e., seedlings are preferred food items for many months following planting).
- On most sites with moderate to low levels of hare use, seedling survival is very high.

Management Recommendation:

9. On sites with moderate to low levels of hare use, planting could continue as seedlings appeared to survive moderate levels of clipping following planting.
10. Plant larger, older trees to further enhance survival of seedlings following hare clipping (see trials by Gord Dow, Ministry of Forests and Range, Prince George).
11. Plant nursery-grown trees with reduced fertilization regimes (see trials by Gord Dow, Ministry of Forests and Range, Prince George).

However,

- Susceptibility of seedlings to damage by voles is unknown.

Monitoring Recommendation:

12. Continue monitoring seedling survival in MPB-killed non-merchantable stands *if* abundance of voles appear to be irrupting to high densities.

5.6 Objective 5: *Complete monitoring seedling survival in trials treated by brushing and diversionary food. Did brushing or diversionary food enhance seedling survival?*

Brushing was evaluated as a potential damage reduction technique (Appendix A). Damage to young seedlings in plantations is usually most severe in or near areas having sufficient cover to provide suitable habitat for hares (often 10-25 years post-harvest; Sullivan, 1994; this study, Fig. 39). Removing this cover should reduce the potential for seedlings to be damaged by hares. Many studies have found a strong correlation between habitat use by hares and density of understory cover (see Appendix A for review).

Prediction: brushing young, MPB-killed stands with high brush will remove security cover for snowshoe hares; thus, reduce damage to under-planted seedlings.

Two (Figs. 16 and 17) 10-ha sites were brushed in June 2008 (Fig. 41). Sites were planted one month later to provide sufficient time for hares to disperse from treatment sites. Pellet plot and survival trials were established as detailed above (Section 4.3 and 4.4, respectively). Both survival trials and pellet plots were re-assessed in spring 2009.

Initially, planned brushing sites had slightly higher density of hare pellets than the planned controls (Unbrushed sites; Fig. 42). However, following brushing, unbrushed sites tended to have more pellets ($F=54.6$, $P = 0.086$; red bars in Fig. 42) than brushed sites; thus, use of brushed sites by hares was lower than unbrushed sites. The high density of pellets for the north PG site (NPG) in Fig. 42 resulted from a few pellet plots landing in dense spruce patches within the brushed stand north of Prince George. Outside of these patches, density of pellets was significantly reduced – paralleling the results for west PG (WPG).

Damage to seedlings shortly following planting was minimal (black bars; Fig. 43). However, as fall progressed, hares clipped a significant proportions of seedlings; ranging from 53% to 80% on unbrushed sites compared to 27% to 9% on brushed sites. Two freshly clipped seedlings were noted in May 2009, but all other damage appeared to have occurred the previous fall; further supporting previous observations that damage primarily happened in the months immediately following planting. Similar to results reported for pellet densities, seedling damage was high adjacent to the spruce patches within the brushed treatment at NPG. However, despite high levels of damage on the unbrushed sites, average survival of seedlings ranged from 93 to 99% (Fig. 43).

Brushing appeared to be an effective treatment to reduce hare damage to freshly planted seedlings. Given high survival of clipped seedlings, brushing may not be required on sites with low to intermediate use by hares. However, on those sites with

very high abundance of hares and poor understory, damage can be severe (Fig. 40). Brushing these sites may enhance survival of seedlings while reducing competition for resources. Brushing may also promote growth of the herbaceous layer providing an alternative food source for hares. On these very dense sites, brushing should also be combined with removal of the lower branches of trees (especially spruce) to reduce security cover for hares.

Diversionary Food: Grid A at both Prince George and Vanderhoof were treated with diversionary food (composed of alfalfa pellets, fine grain Douglas-fir bark mulch with wax and canola oil (Sullivan and Sullivan, 2008)). Diversionary ‘pucks’ were spread evenly over the 10-ha planted area in November 2008. Survival plots were established in September 2008 as detailed in section 4.4. Grid B was the control to evaluate effectiveness of diversionary food to reduce damage to newly planted seedlings. Damage to seedling was re-assessed in the spring of 2009.

Prediction: diversionary food should provide an alternative food source to damaging agents yielding reduced damage to under-planted seedlings.

Survival of seedlings was re-assessed in May 2009. Prior to the application of diversionary food, damage ranged from 7 to 24%. Damage to seedlings by spring 2009 ranged from 21% to 79% indicating that the diversionary food was ineffective in reducing hare damage.

Unfortunately, abundance of voles decreased significantly throughout the 2008 season, and remained low during the 2009 monitoring year. Consequently, this low abundance of voles did not permit a suitable evaluation of the effectiveness of the treatment to reduce vole damage (the primary target of the diversionary food). However, despite the high levels of damage on these sites, survival of seedlings ranged from 80 to 92% (Fig. 44). Consequently, seedling survival on these sites with intermediate cover and abundance of hares is good.

Recommendations: Given that:

- Brushing appeared to be an effective treatment to reduce stand use by hares and to significantly reduce clipping of freshly-planted seedlings by hares.
- On most sites with low to moderate use by hares, seedlings appear to survive clipping by hares.

- Seedling survival on sites with high hare abundance and high cover was much lower.

Management Recommendation:

13. Consider brushing those sites with a high abundance of hares (as evaluated by the density of pellets seen on the ground) or high cover of shrubs and trees (i.e., low herbaceous (food) layer).

Monitoring Recommendation:

14. Consider additional brushing trials as results are based on two replicates. If sites are to be brushed, establish pellet-plot and survival trials prior to planting to provide further support for the observed results noted above.

And given that:

- Vole abundance, and susceptibility of planted seedlings to damage, may increase to peak abundance in the next two years.
- Damage occurs over a relatively short time period and stops following the crash in abundance of voles.

Monitoring Recommendation:

15. Evaluate the effectiveness of diversionary food as a damage-reduction technique. This technique can be applied in late fall (if peak abundance is expected), when other techniques are not available – namely, reducing ground cover prior to peak populations. Many vole species have cyclic fluctuations in abundance in northern latitudes with a peak every 3 to 5 years, although these periods may be interspersed with annual fluctuations in abundance. Evaluating diversionary food or vegetation control as effective damage-reduction techniques will provide useful management tools throughout the next anticipated peak, and those that may follow, until these dead MPB stands are re-established.

5.7 Reporting and Future Work

A mid-year progress report was prepared in August 2009 outlining results, to date, in terms of meeting the modified objectives of the current year. A progress report and presentation outlining the results, management recommendations, and progress to date will be made to project partners early in 2010.

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7.0 Figures

Figure 1. Examples of feeding damage by voles to lodgepole pine and Douglas-fir seedlings.



Figure 2. Voles species that commonly cause damage to newly-planted lodgepole pine plantations: (a) Long-tailed vole; (b) Meadow vole; (c) Heather vole; (d) Red-backed vole.

A)



B)



C)



D)



Figure 3. Photographs of snowshoe hares (*Lepus americanus*) in a live trap.



Figure 4. Ten-year population cycle of snowshoe hares.

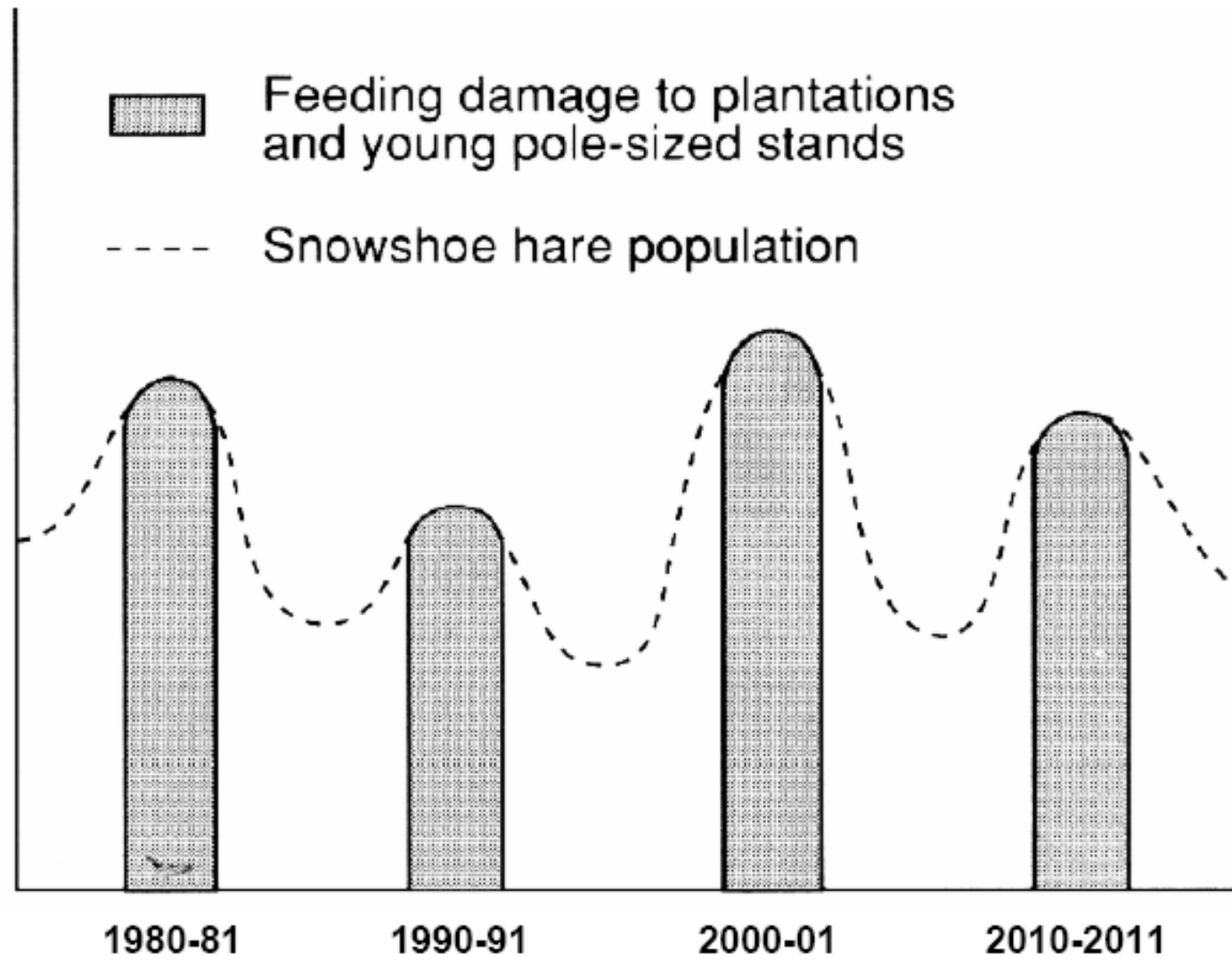


Figure 5. Examples of feeding damage by snowshoe hares to lodgepole pine and Douglas-fir seedlings: (a) terminal clipping of seedlings (from 93G056-030 planted 2007); (b) lateral clipping of seedlings; (c) oblique cut surface of a seedling; and, (d) trees debarked up to 6-cm DBH.

A)



B)



C)



D)



Figure 6. Overview of the location used for the monitoring program. Sites identified include 3 areas containing MPB-killed non-merchantable stands (★); 3 areas containing MPB-killed merchantable stands (★); and 4 MPB-killed non-merchantable stands containing the survival plots (★).

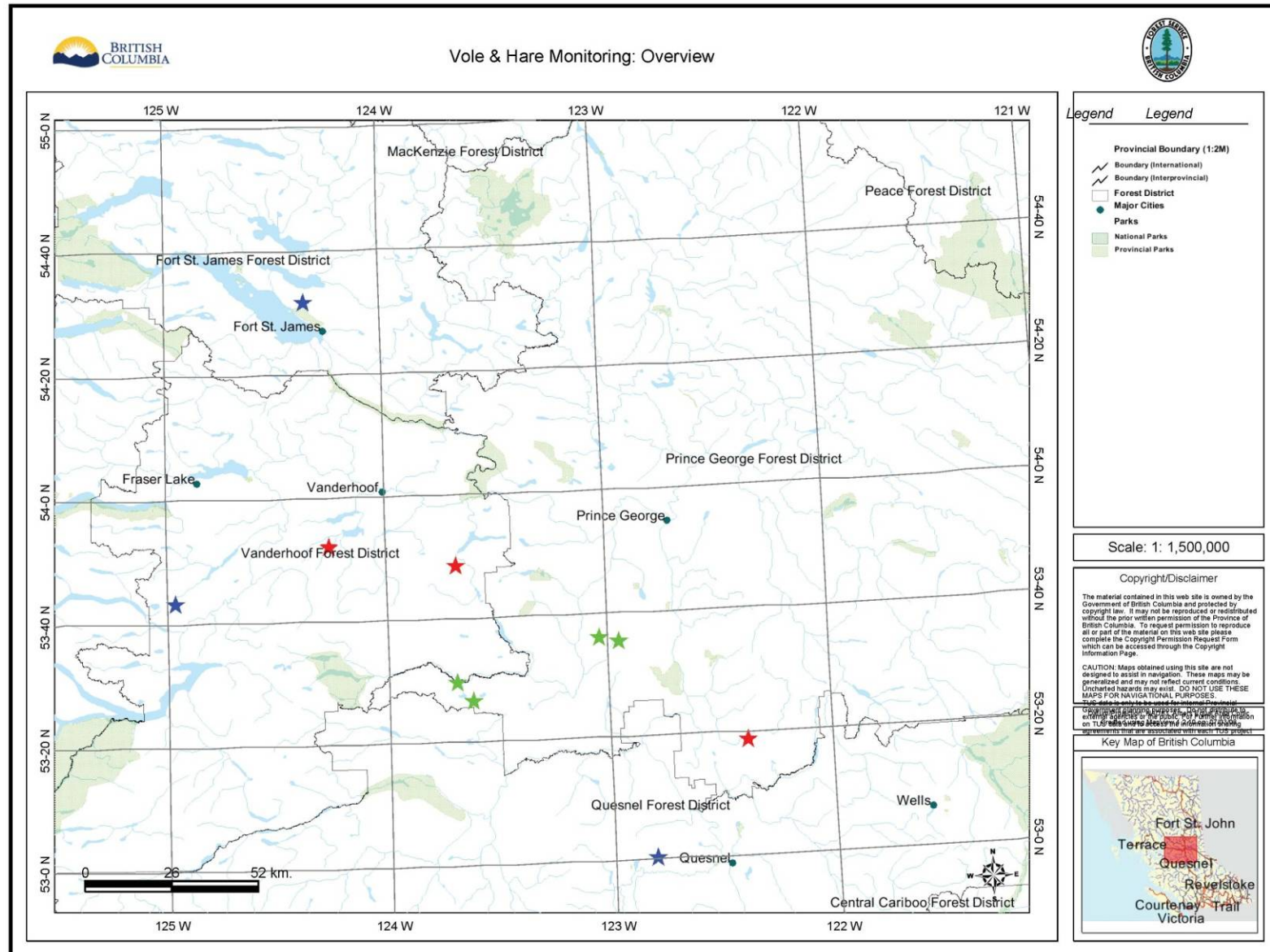


Figure 7. Overview of the Dunkley monitoring sites 2007-2008. Sites identified include 3 MPB-killed non-merchantable stands (site A, B, & C); 1 salvage clearcut (site D); 1 uncut forest (E); and 1 live overstocked stand (Unthinned).

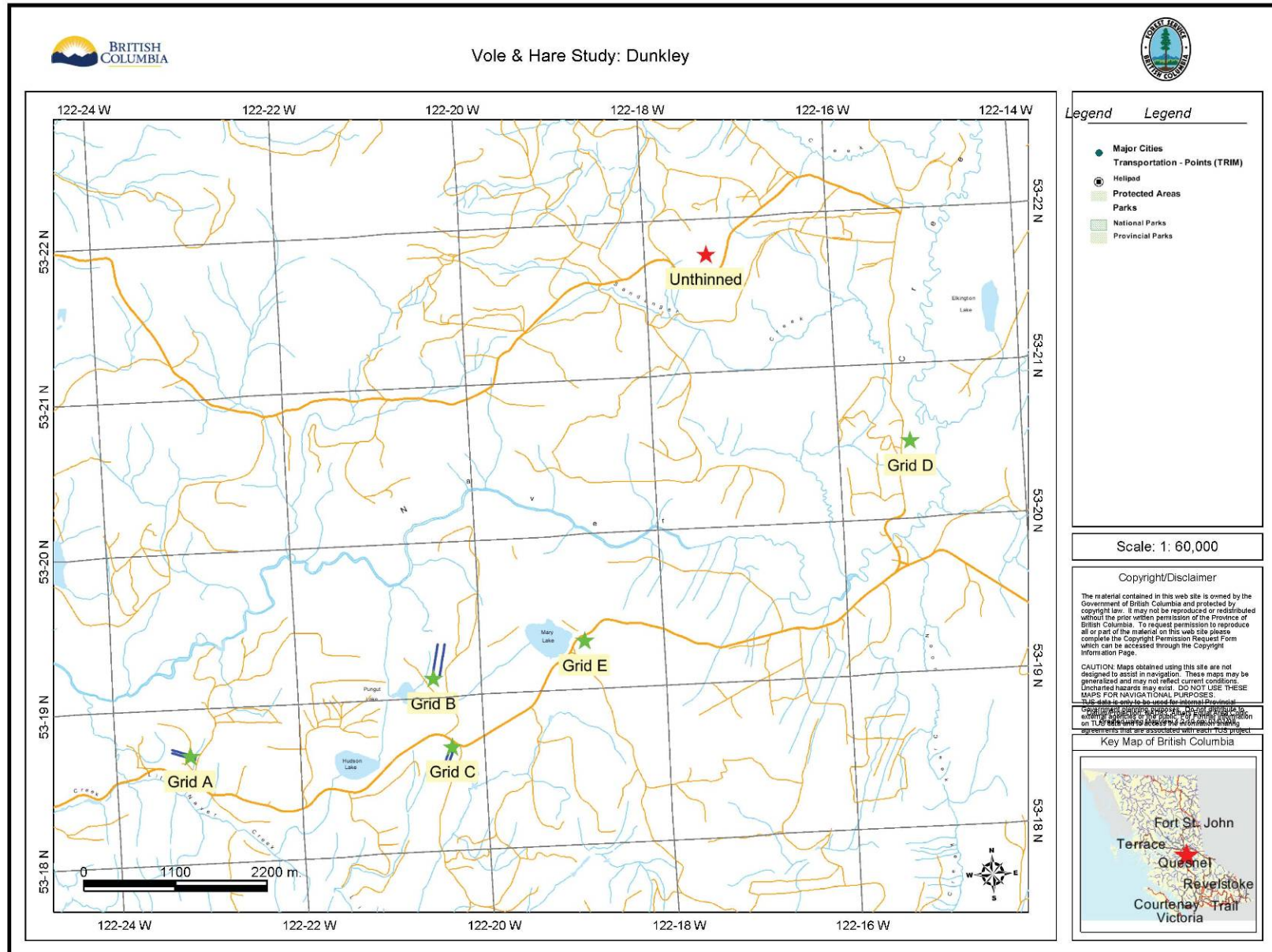


Figure 8. Overview of the Prince George monitoring sites 2007-2009. Sites identified include 3 MPB-killed non-merchantable stands (site A, B, & C); 1 salvage clearcut (site D); 1 uncut forest (E); and 1 live overstocked stand (Unthinned).

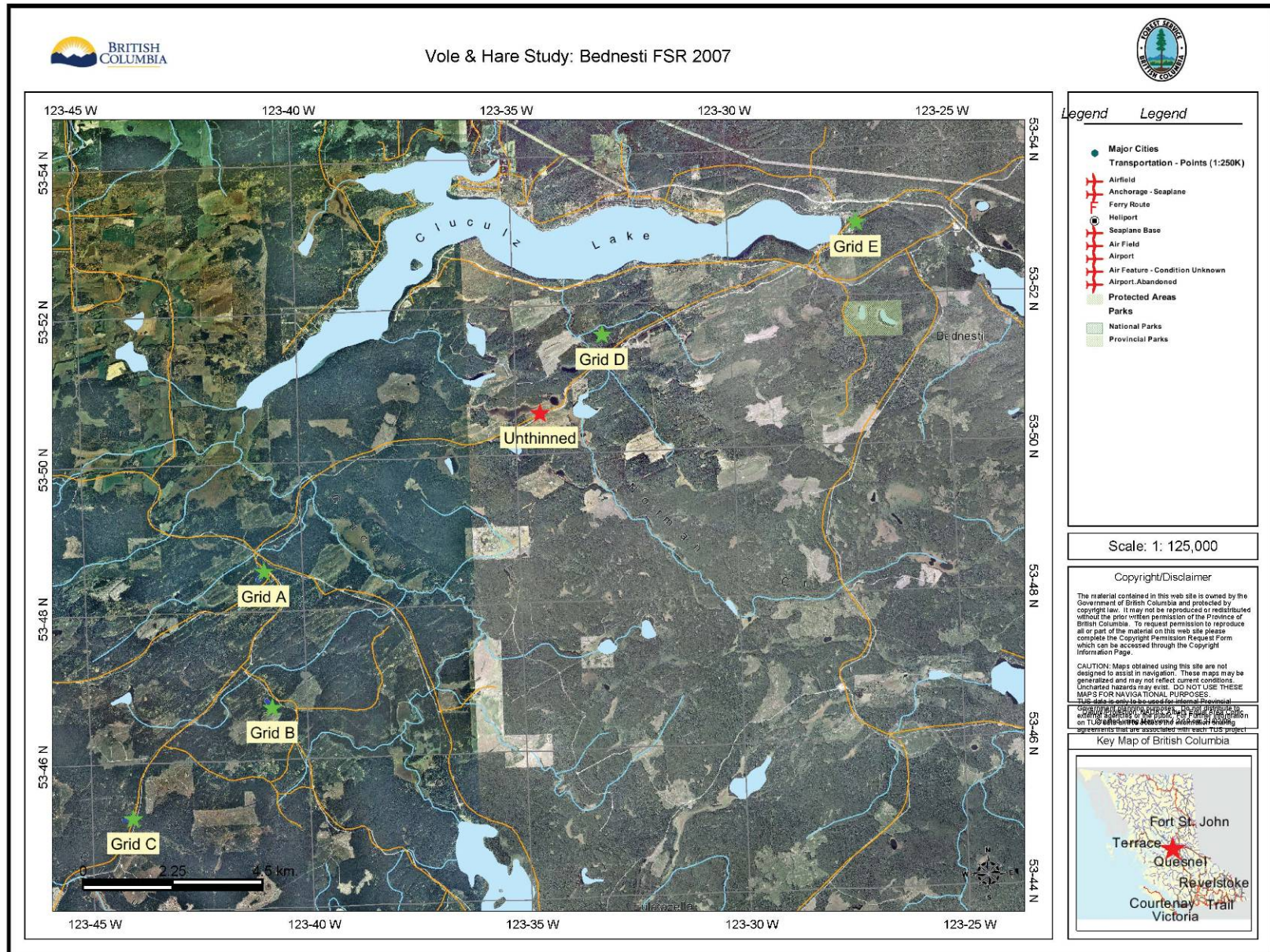


Figure 9. Overview of the Vanderhoof monitoring sites 2007-2009. Sites identified include 3 MPB-killed non-merchantable stands (site A, B, & C); 1 salvage clearcut (site D); 1 uncut forest (E); and 1 live overstocked stand (Unthinned).

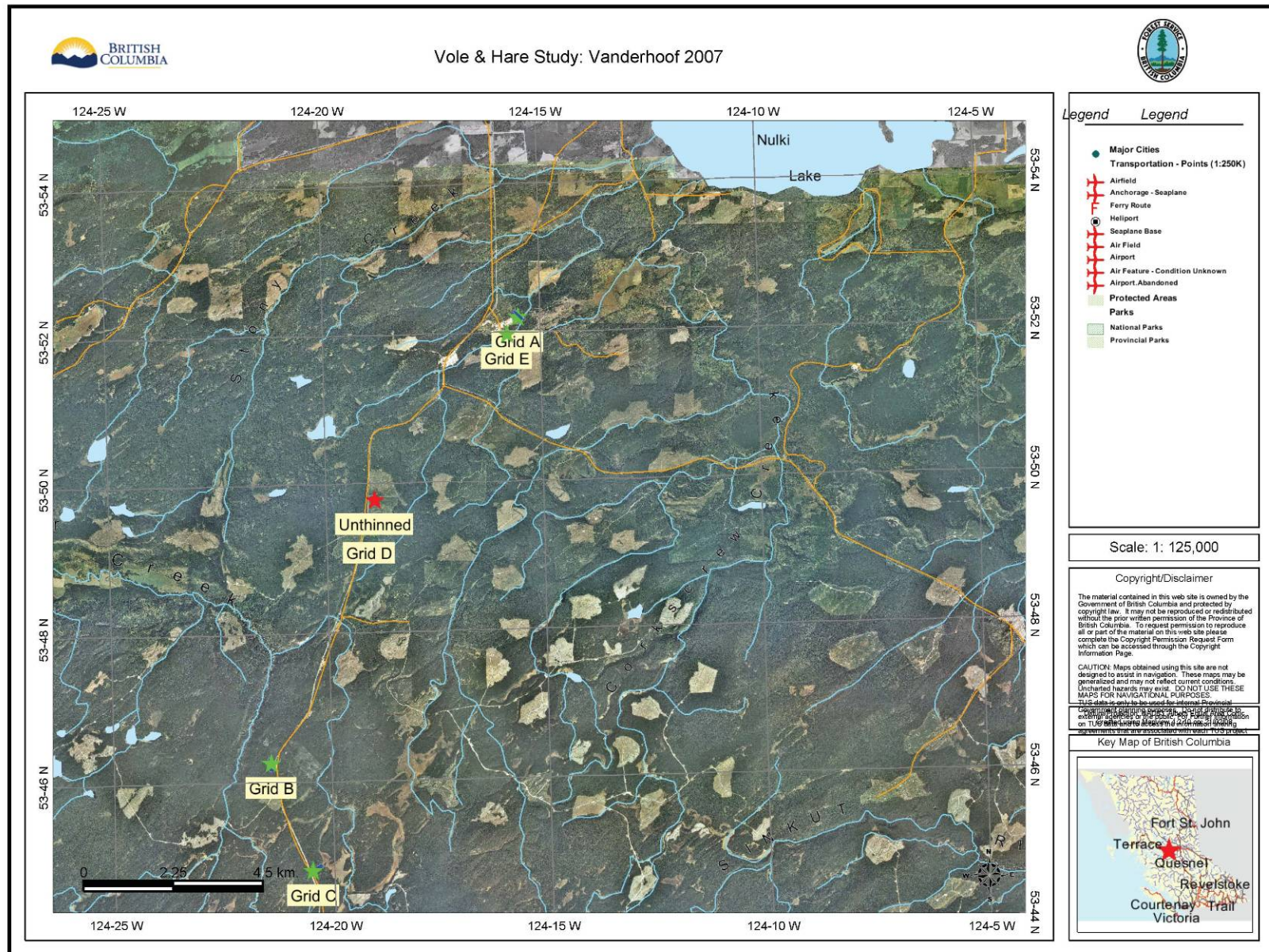


Figure 10. Photographs of young MPB-killed stands used to monitor the abundance of voles and snowshoe hares, NIFR 2007-2009. Note variation in understory cover: (a) Dunkley, (b) Prince George, (c) Vanderhoof.

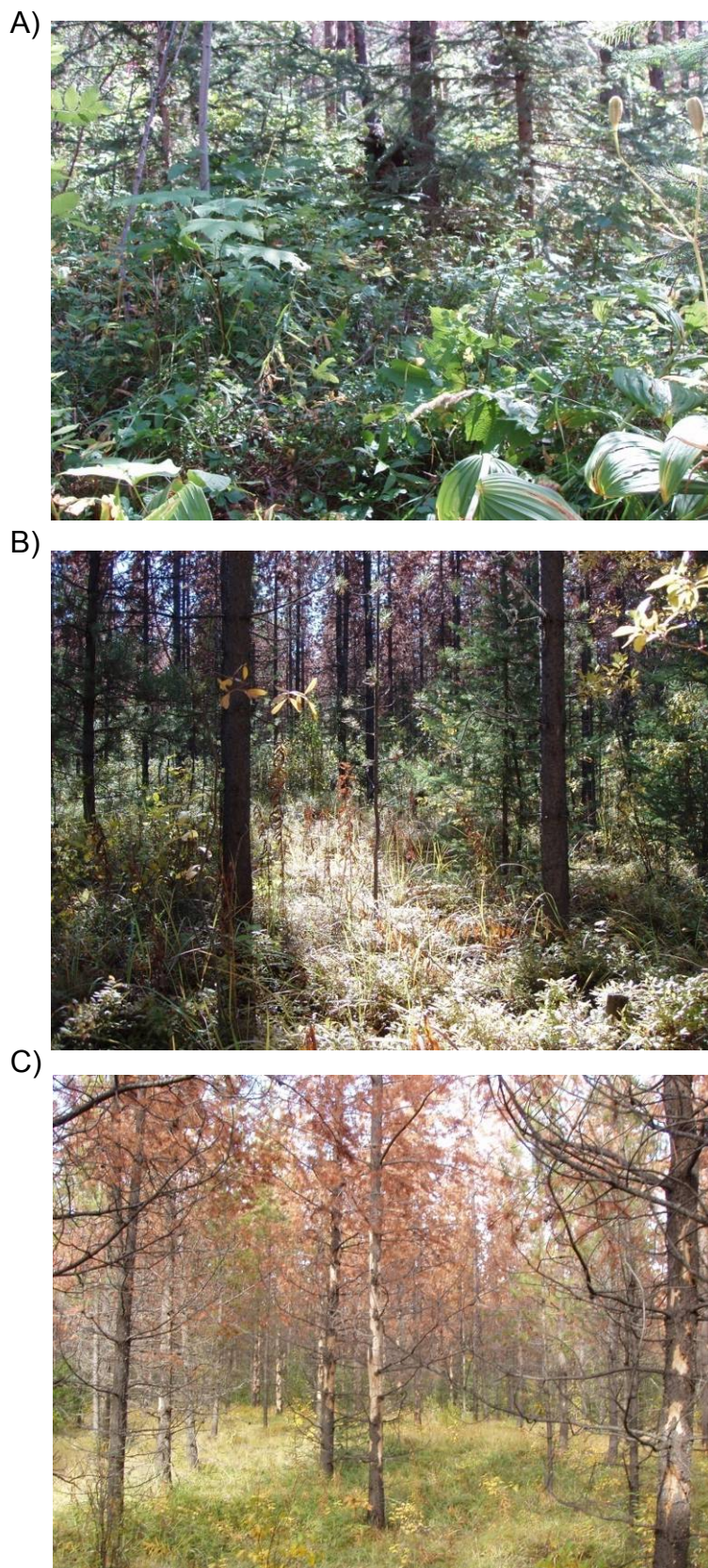


Figure 11. Overview of the Quesnel monitoring sites 2007-2009. Sites identified include 3 MPB-killed merchantable stands (site A, B, & C) and 1 live overstocked stand (Unthinned).

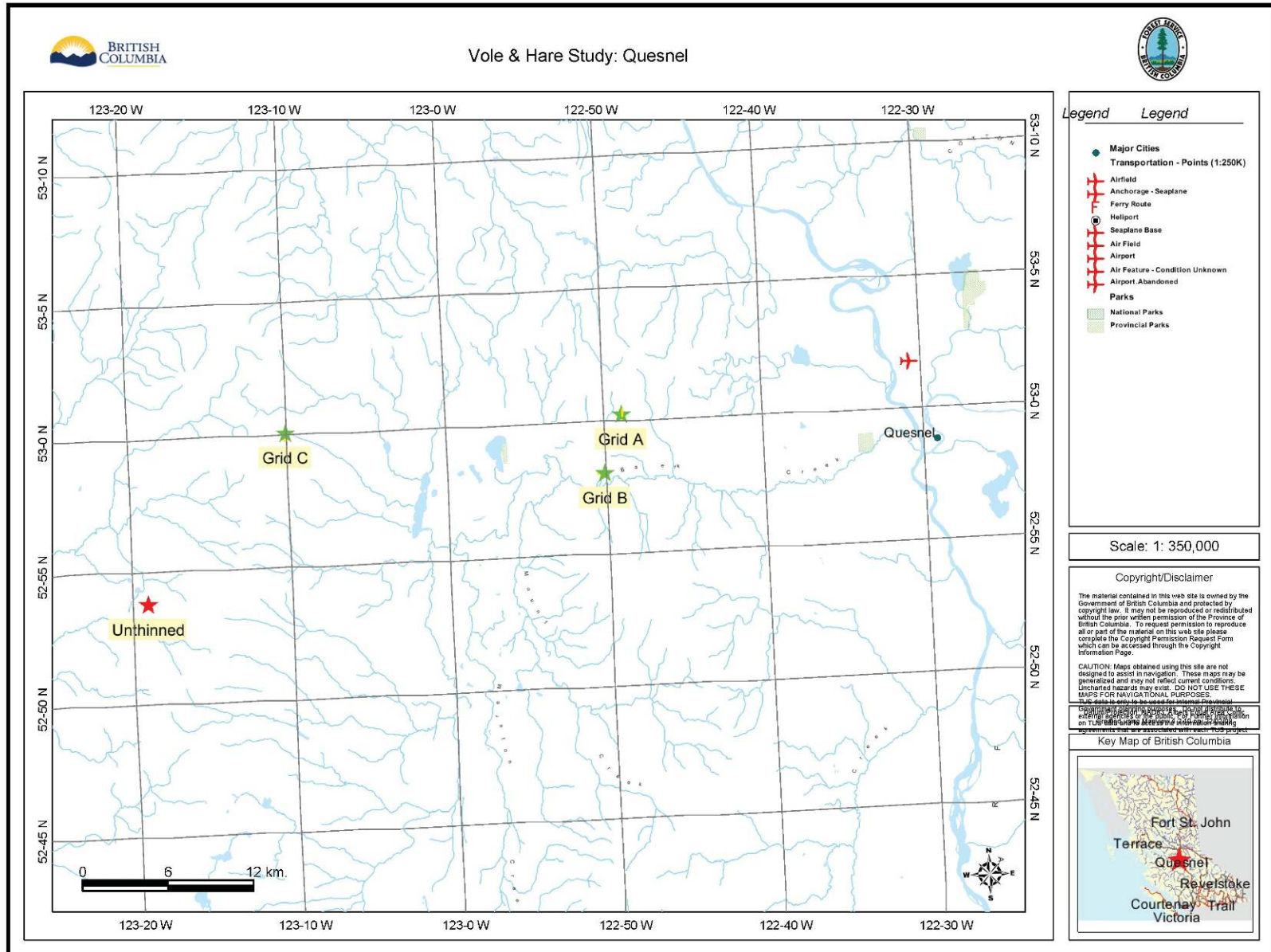


Figure 12. Overview of the Fort Fraser monitoring sites 2007-2009. Sites identified include 3 MPB-killed merchantable stands (site A, B, & C) and 1 live overstocked stand (Unthinned).

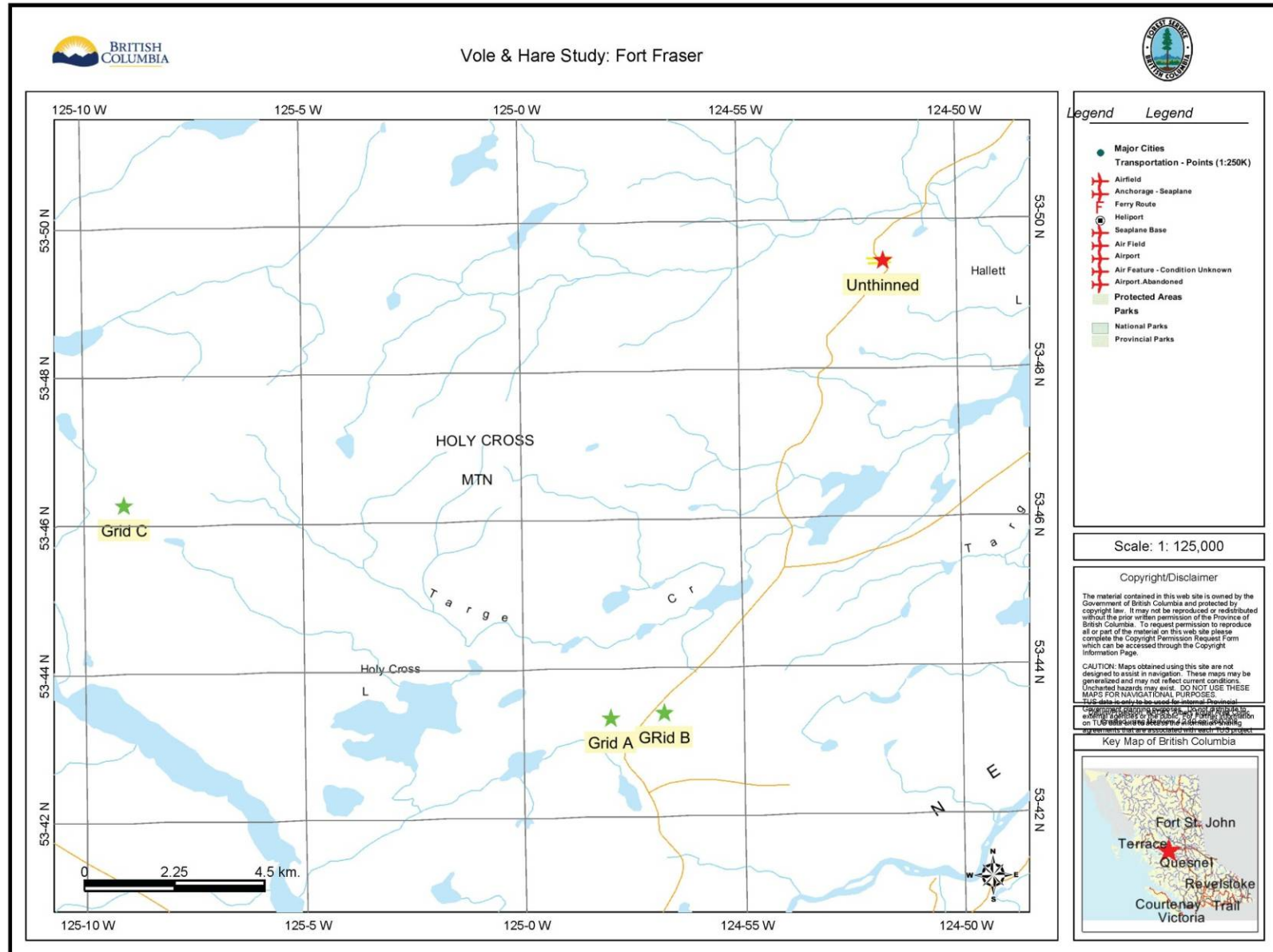


Figure 13. Overview of the Fort St. James monitoring sites 2007-2009. Sites identified include 3 MPB-killed merchantable stands (site A, B, & C) and 1 live overstocked stand (Unthinned).

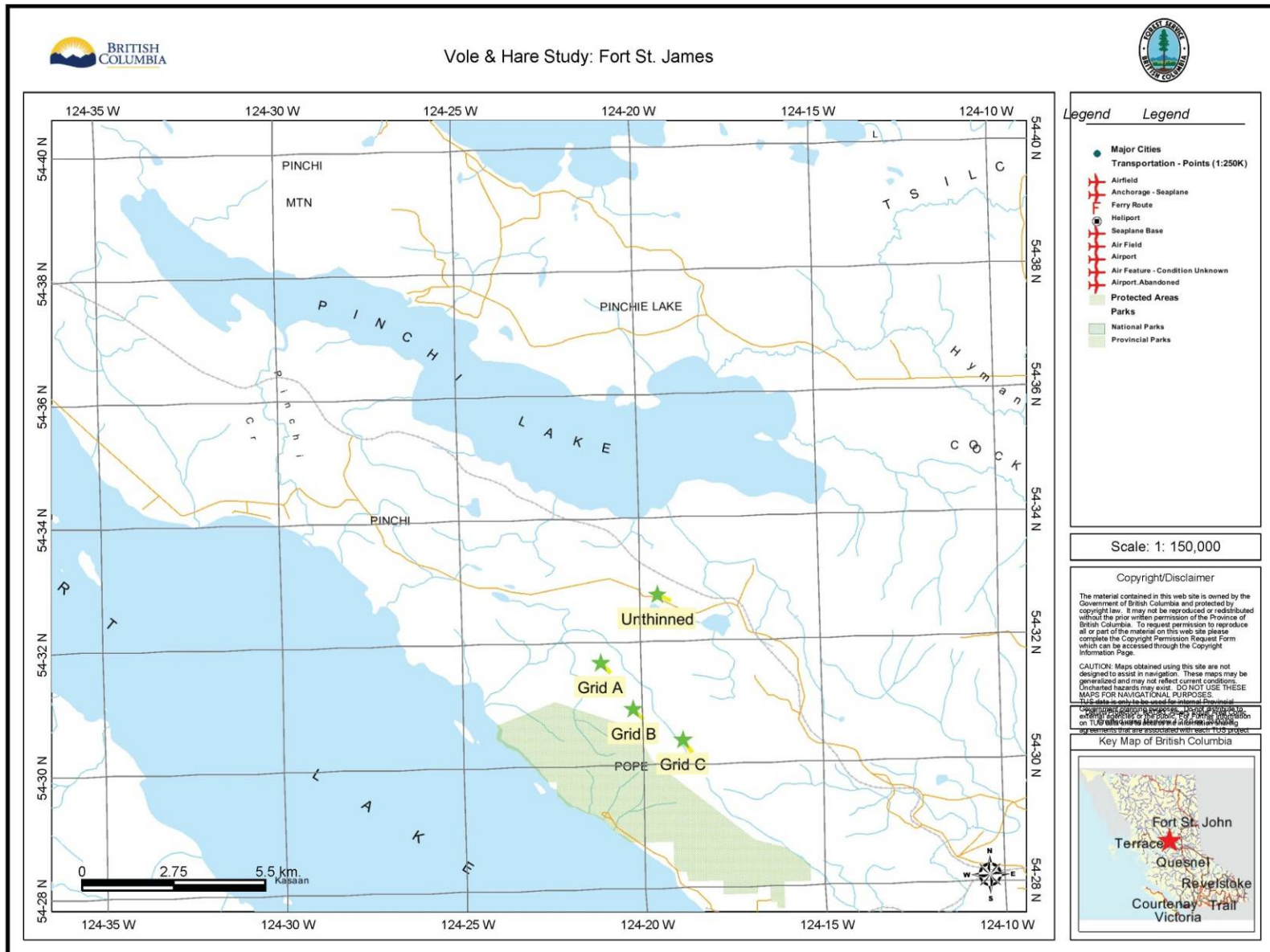


Figure 14. Overview of the survival monitoring sites: 92G042 and 92G043-052, 2007-2009 in the Prince George Forest District.

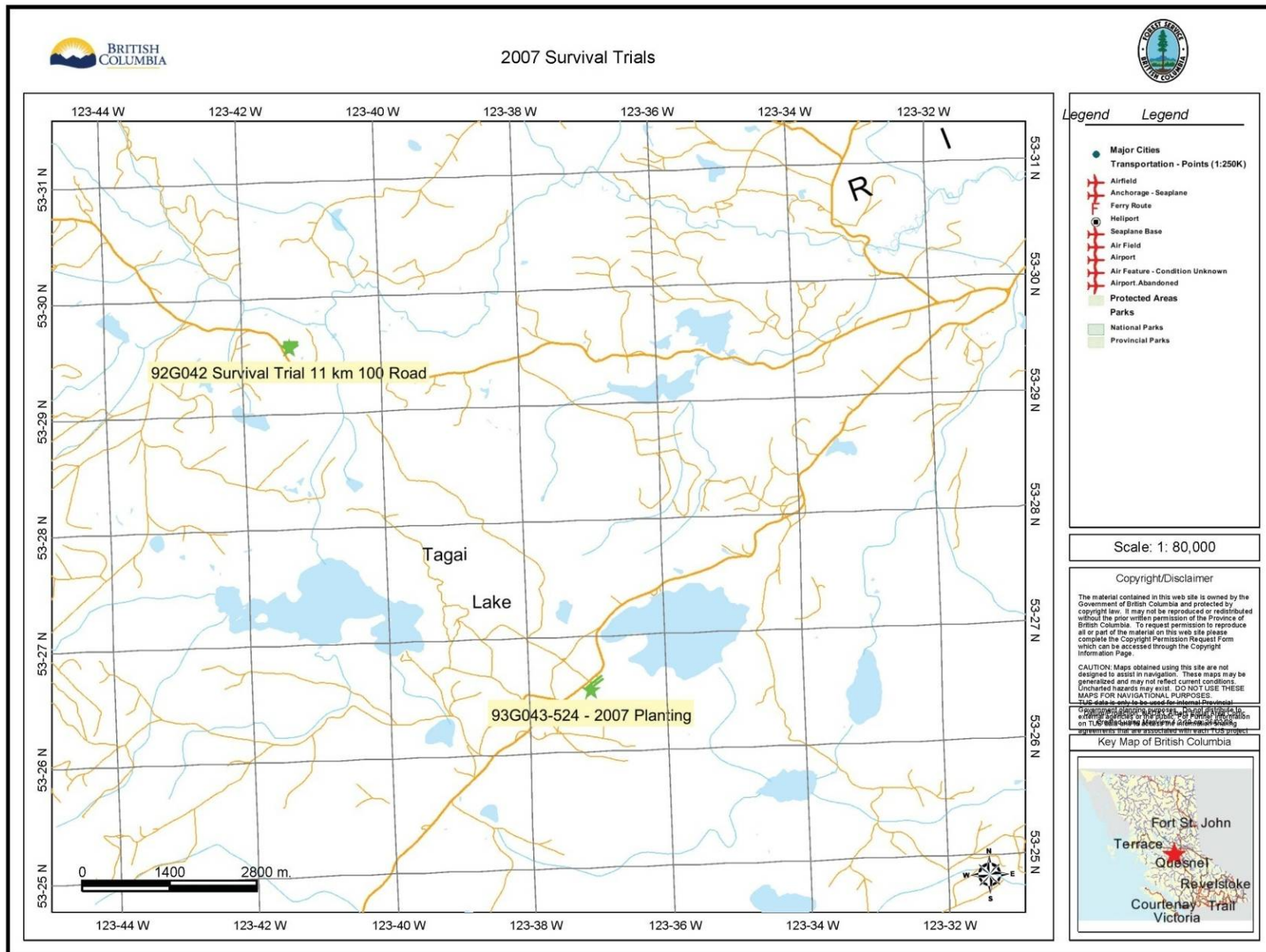


Figure 15. Overview of the survival monitoring sites: 93G065-035 and 93G056-030, 2007-2009 in the Prince George Forest District.

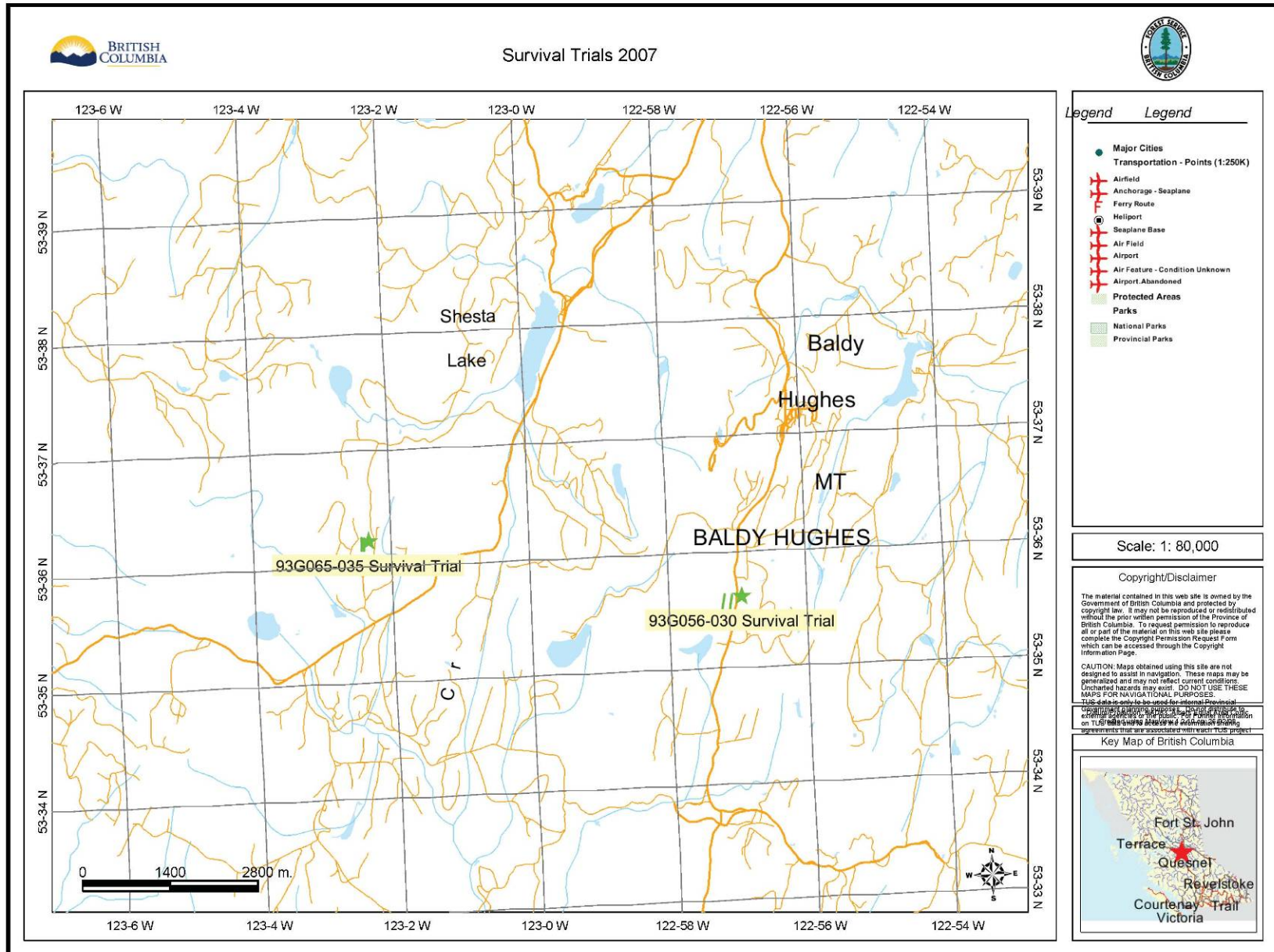


Figure 16. Overview of the brushing trial 40 km northwest of Prince George in the Prince George Forest District. Grey area represents the 10-ha brushing treatment.

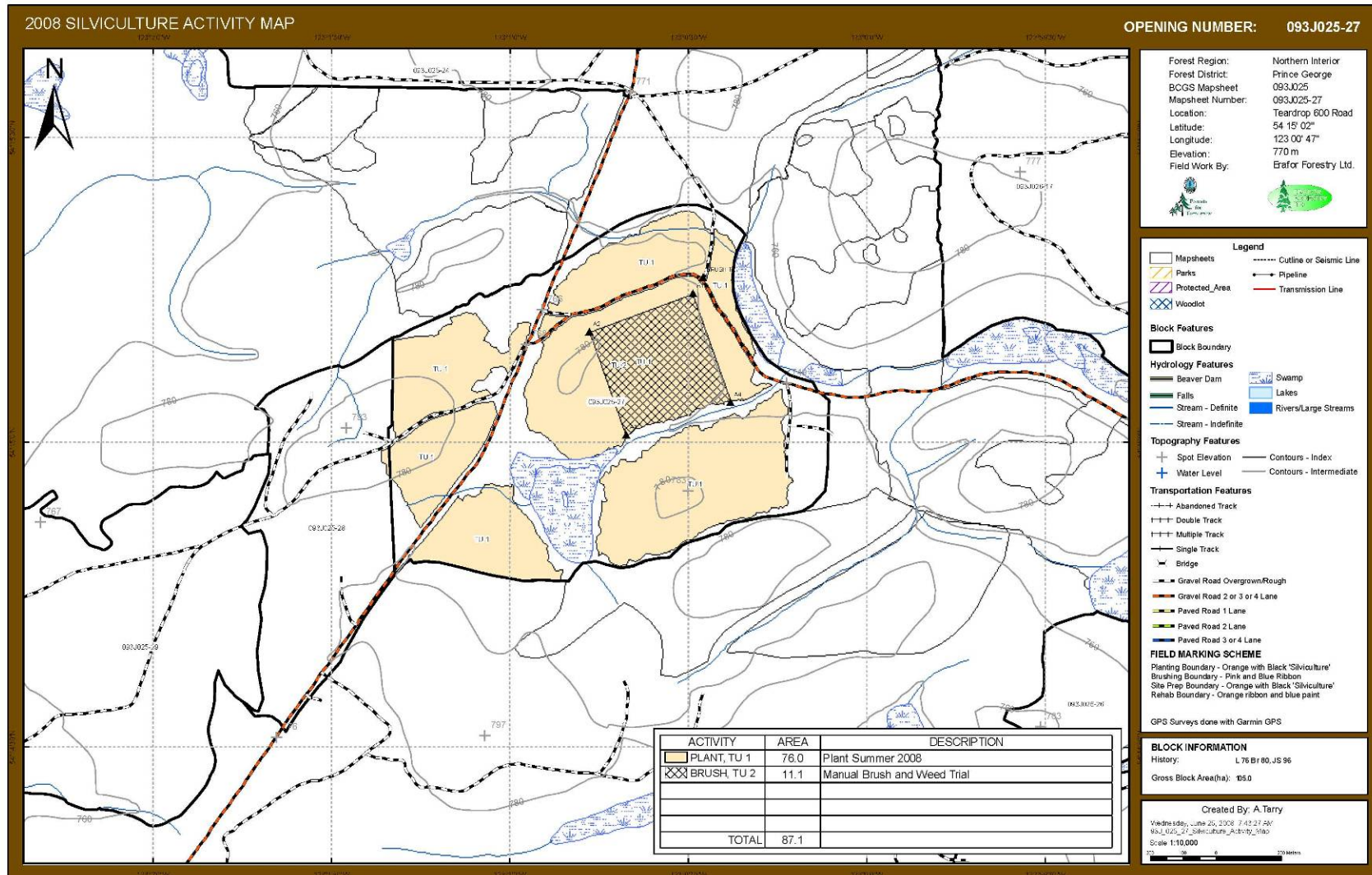


Figure 17. Overview of the brushing trial at Kwitzel Lake 34 km west of Prince George in the Prince George Forest District. Grey area represents the 10-ha brushing treatment.

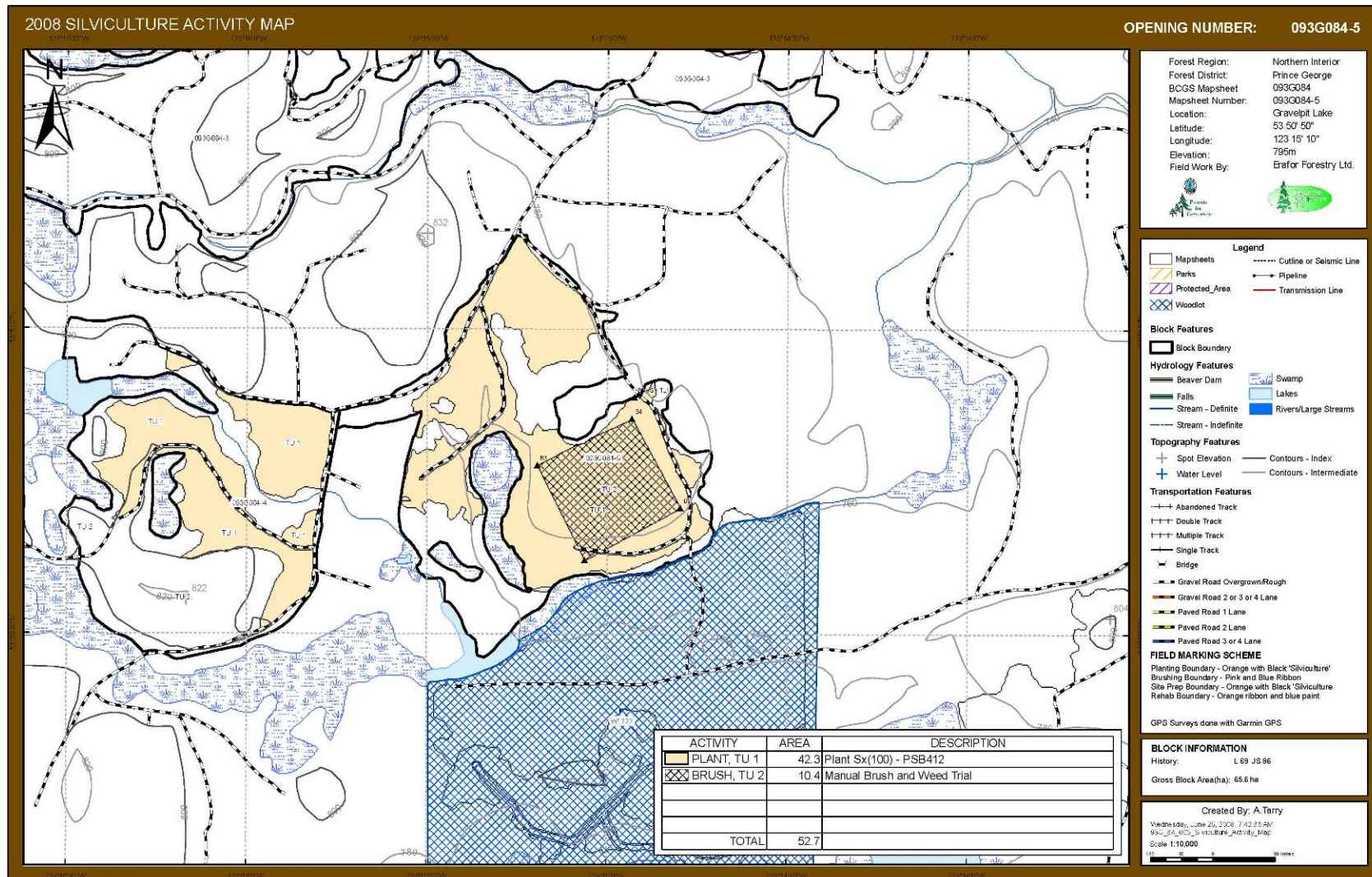


Figure 24. Sampling protocol for snowshoe hare pellets in a given site or stand. 100 sample plots: 20 stations with 5 plots per station.

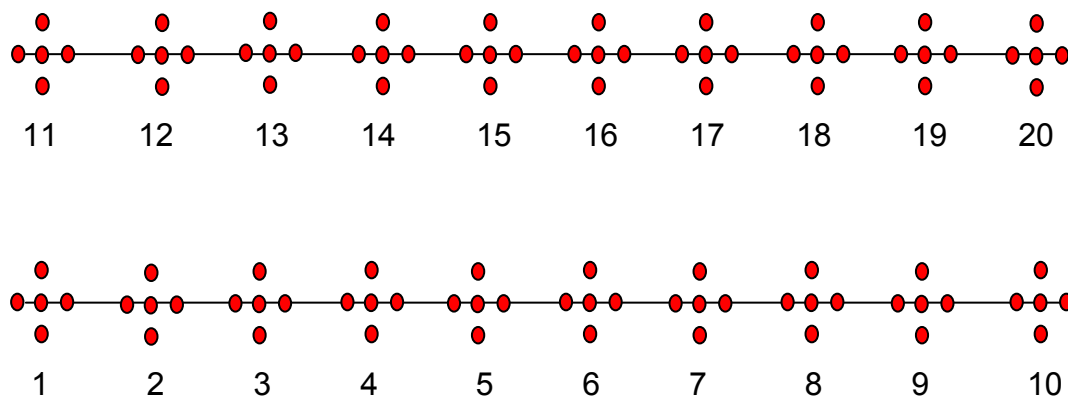


Figure 25. Relationship of percentage tree mortality to abundance of voles. The two datapoints with circles were considered outliers and were not part of the regression analysis.

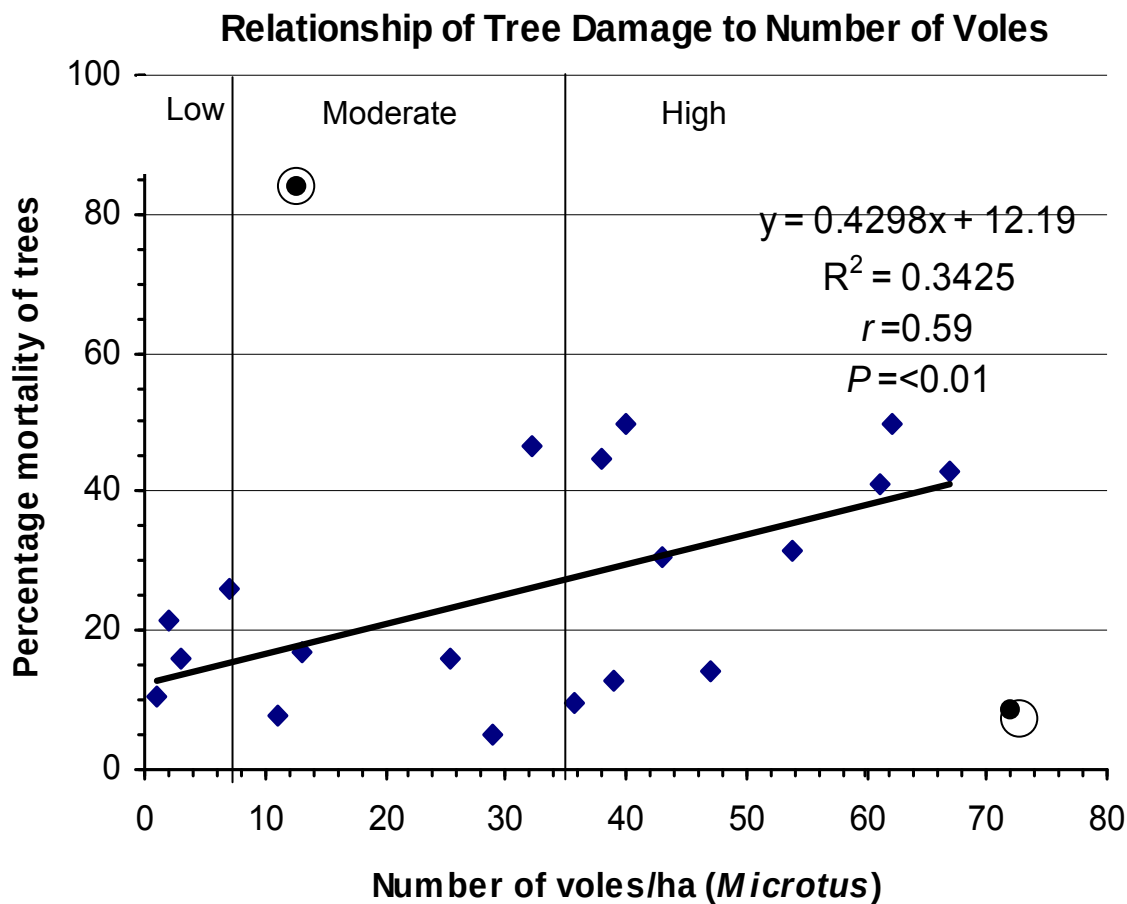


Figure 26. Number/ha of meadow voles (*Microtus pennsylvanicus*) in MPB-killed non-merchantable stands from 2006 to 2009.

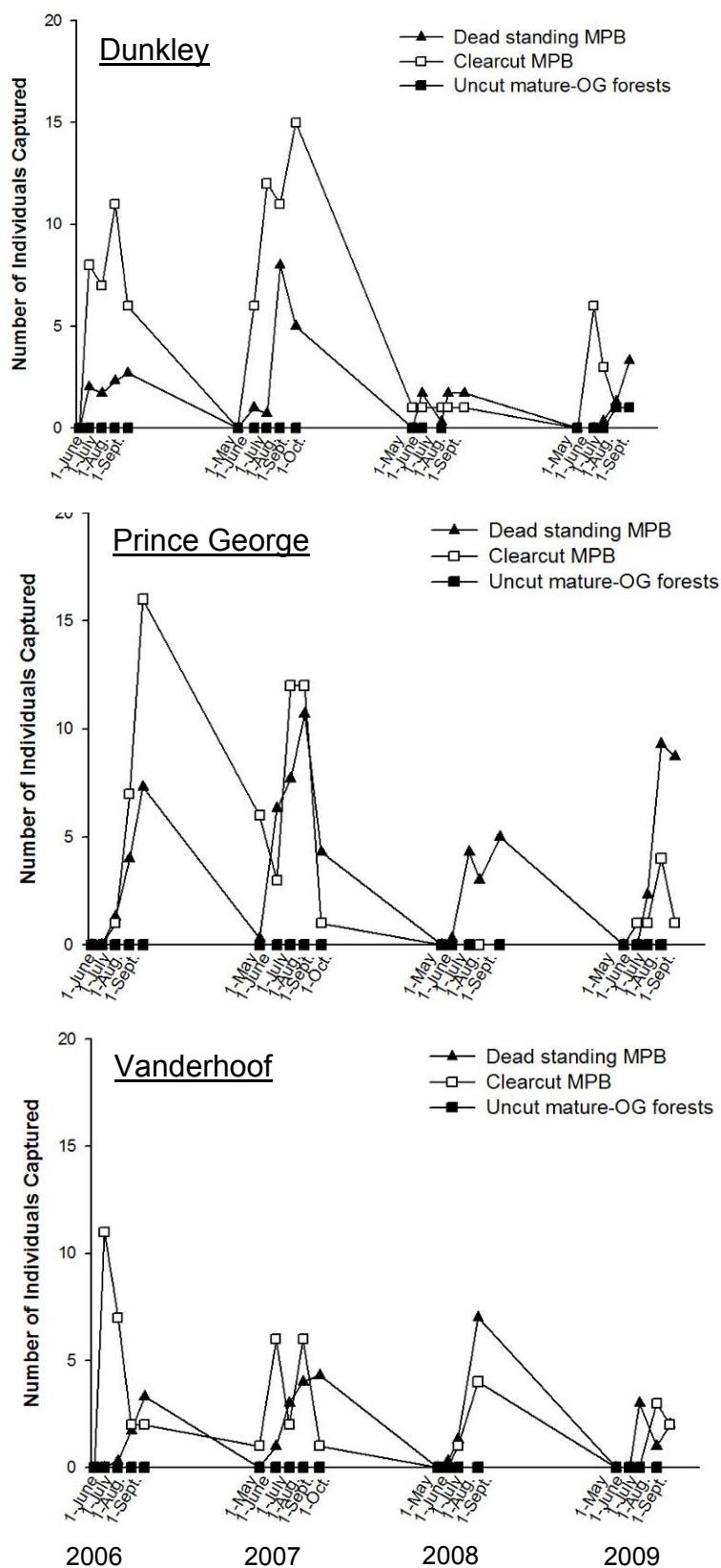


Figure 27. Number/ha of red-backed voles (*Myodes gapperi*) in MPB-killed non-merchantable stands from 2006 to 2009.

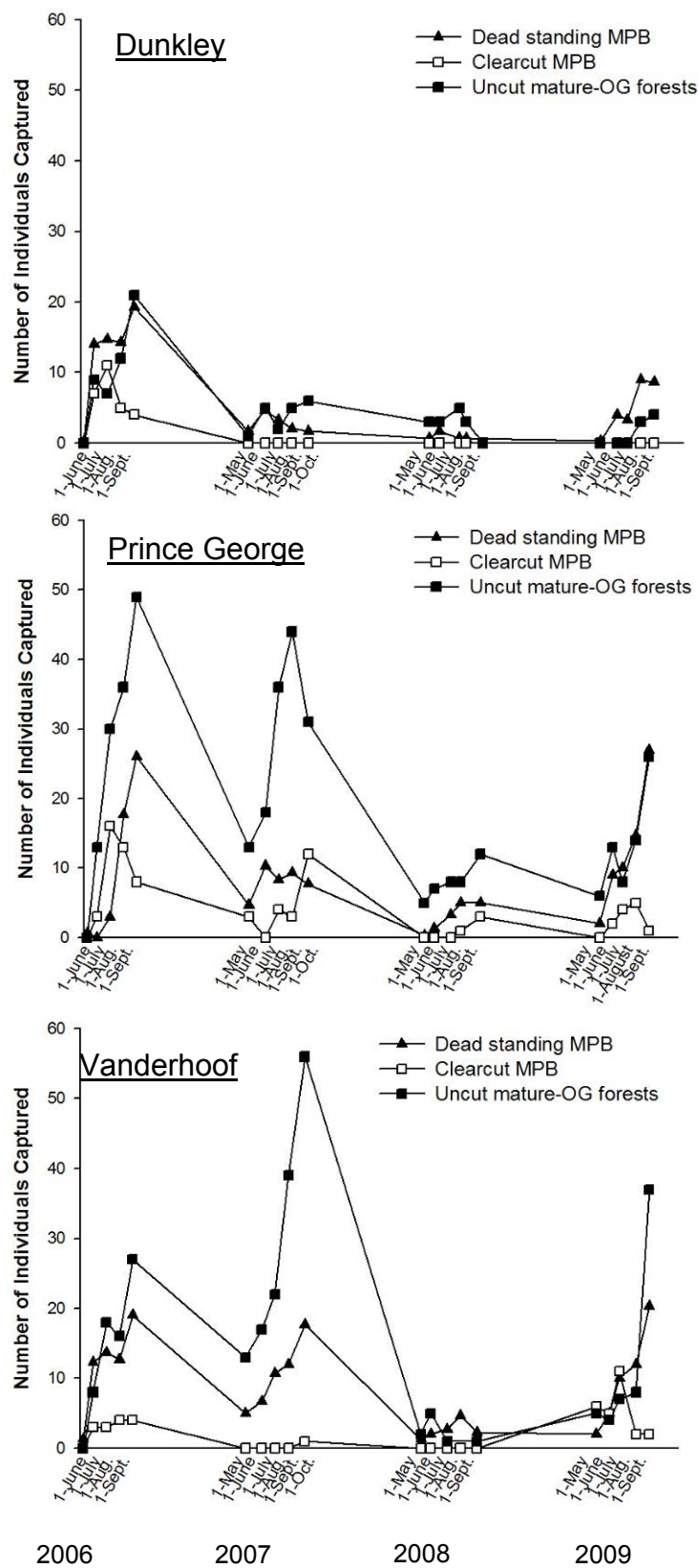


Figure 28. Number/ha of snowshoe hares (*Lepus americanus*) captured in MPB-killed non-merchantable stands from 2006 to 2009.

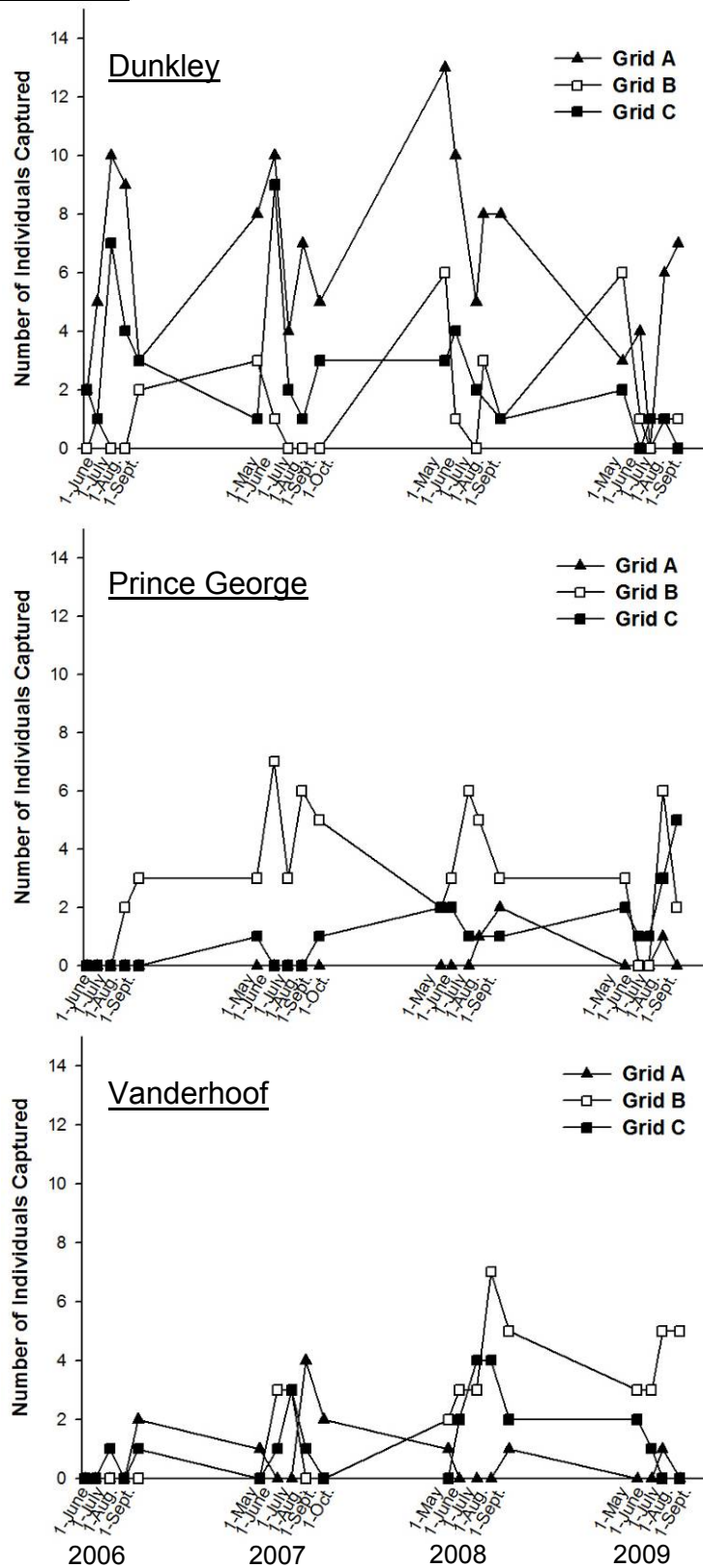


Figure 29. Mean ($\pm$ 95% CI) number of snowshoe hare pellets/ha (x 1000) in the three MPB-killed non-merchantable stands (A, B, & C) and an unthinned (UT) live stand at each of the sites in the three NIFR areas from 2006 to 2009.

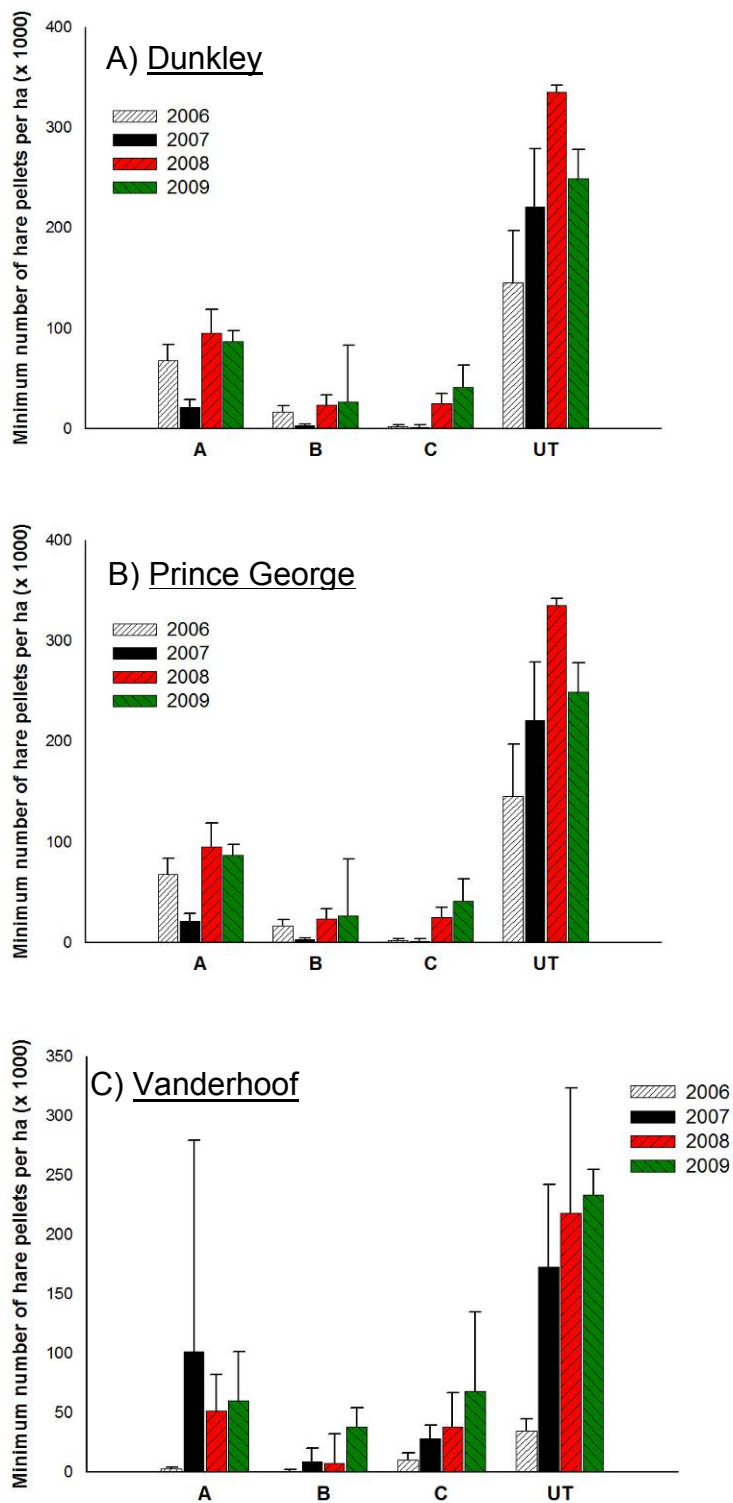


Figure 30. Mean ($\pm$ 95% CI) number of snowshoe hare pellets/ha ($\times$ 1000) in the three (A,B, & C) merchantable MPB-killed stands and an unthinned (UT) live stand at each of the sites in the three NIFR areas for 2007 to 2009.

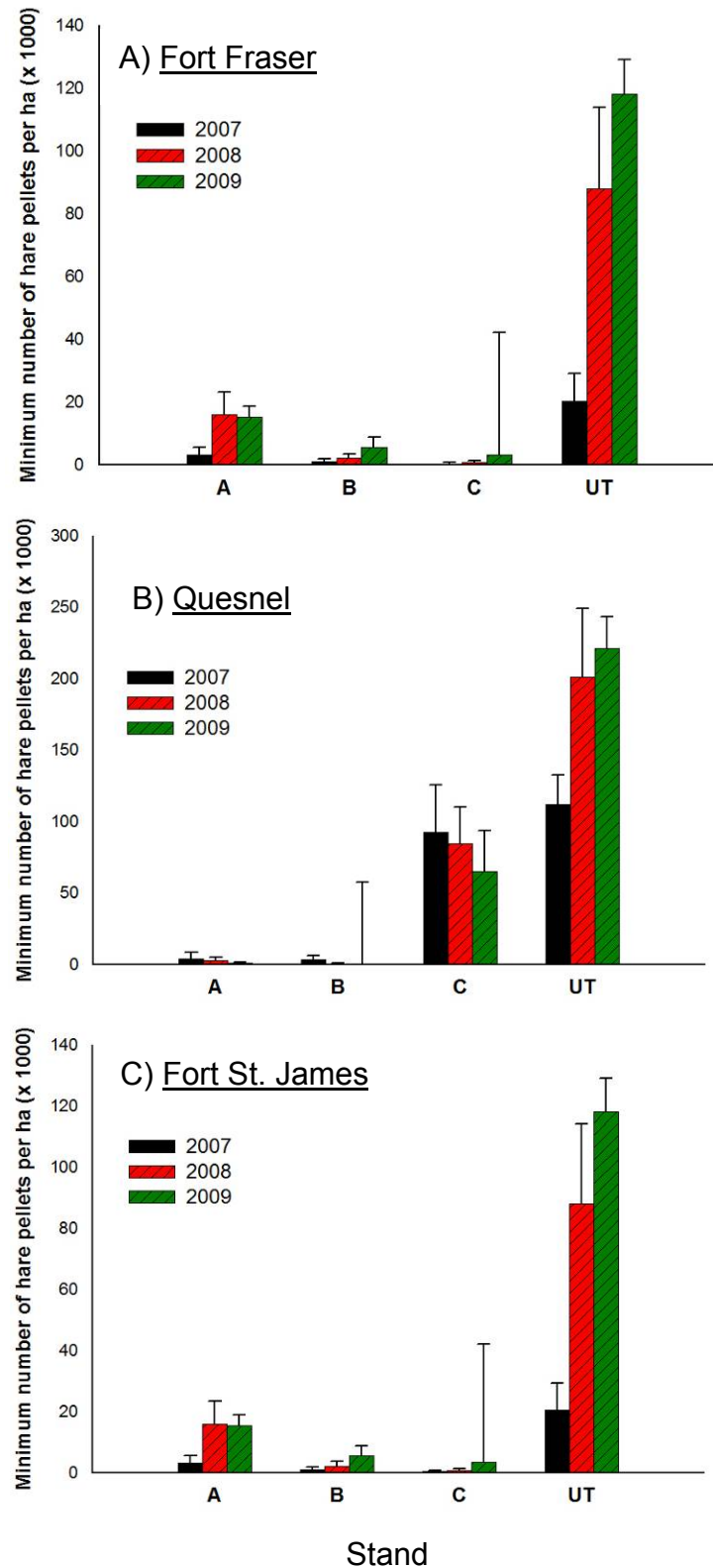
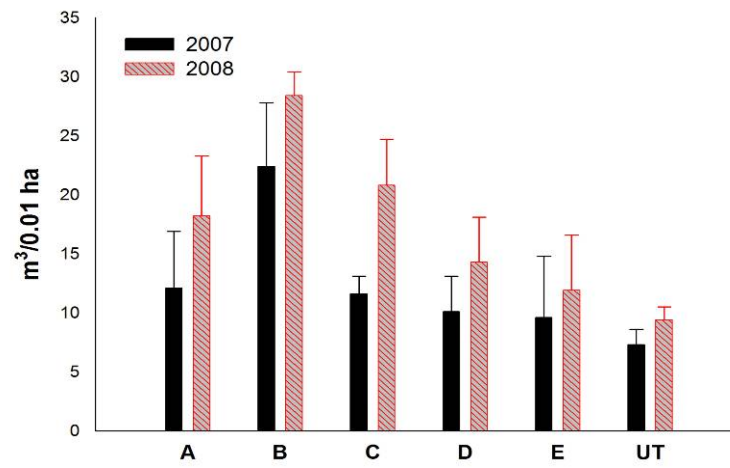
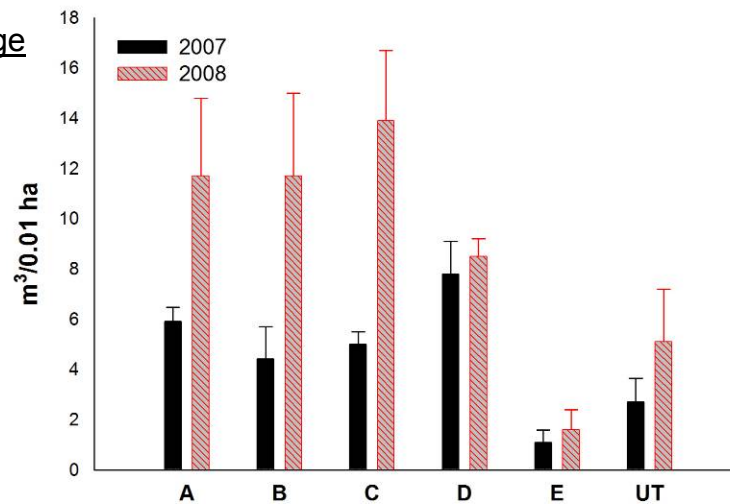


Figure 31. Mean ($n=3$; ± 1 SE) total volume of herbs in three MPB-killed stands (A, B, & C), 1 salvage clearcut (site D); 1 uncut forest (E); and 1 live overstocked stand (Unthinned) at each of the sites in the three NIFR areas for 2007 and 2008.

A) Dunkley



B) Prince George



C) Vanderhoof

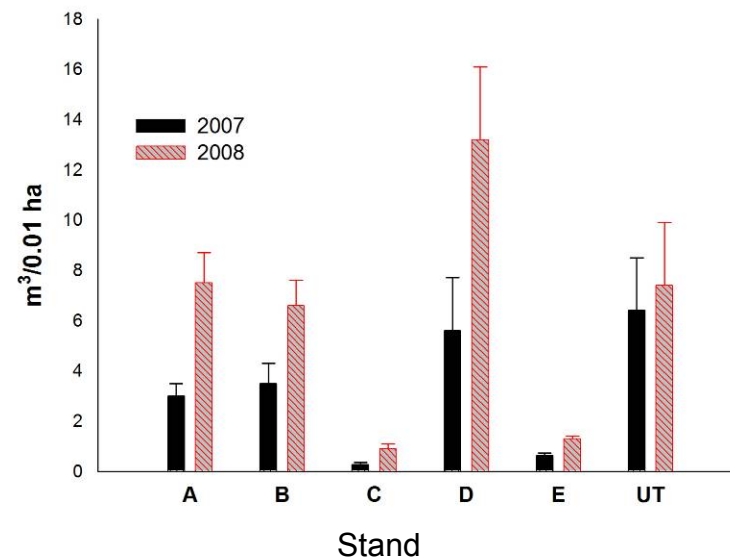


Figure 31. Mean ($n=3$; ± 1 SE) total volume of shrubs in three MPB-killed stands (A, B, & C), 1 salvage clearcut (site D); 1 uncut forest (E); and 1 live overstocked stand (Unthinned) at each of the sites in the three NIFR areas for 2007 and 2008.

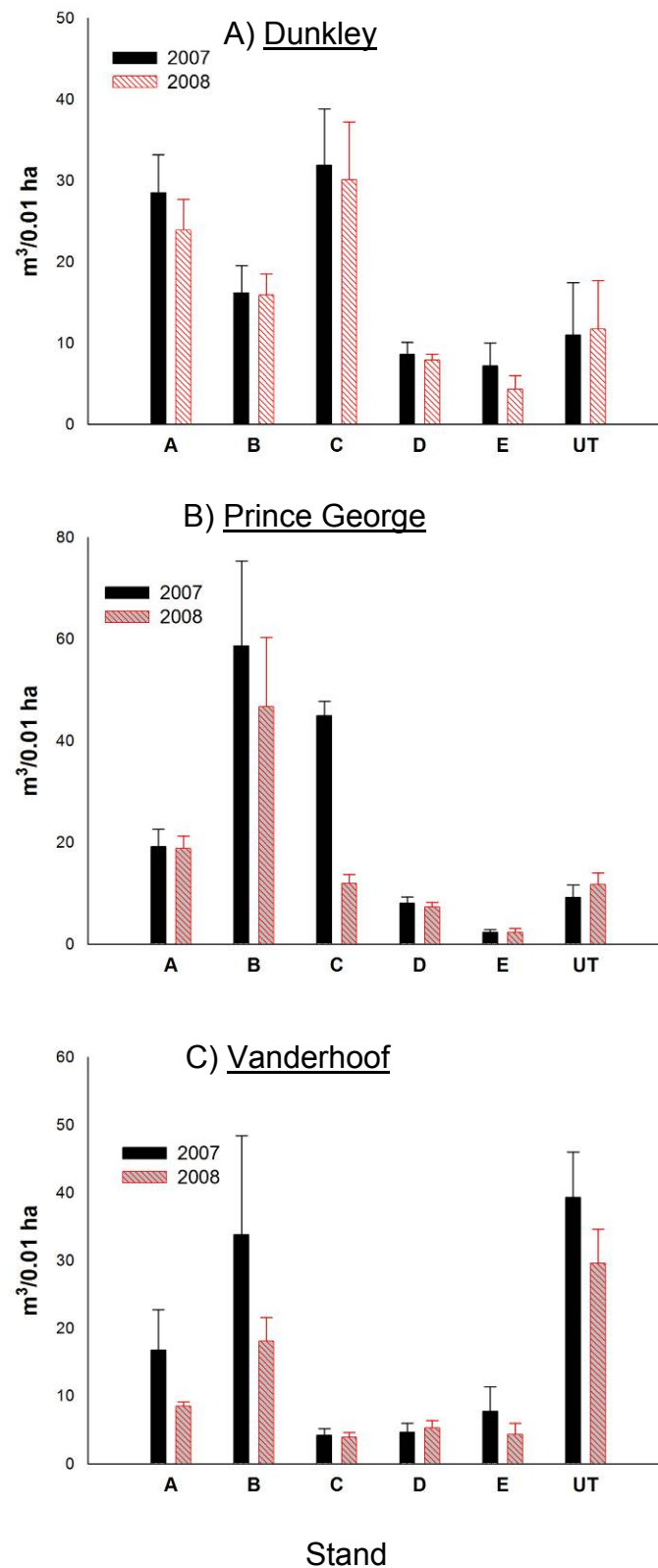


Figure 32. Mean ($n=3$; ± 1 SE) total volume of trees in three MPB-killed stands (A, B, & C), 1 salvage clearcut (site D); 1 uncut forest (E); and 1 live overstocked stand (Unthinned) at each of the sites in the three NIFR areas for 2007 and 2008.

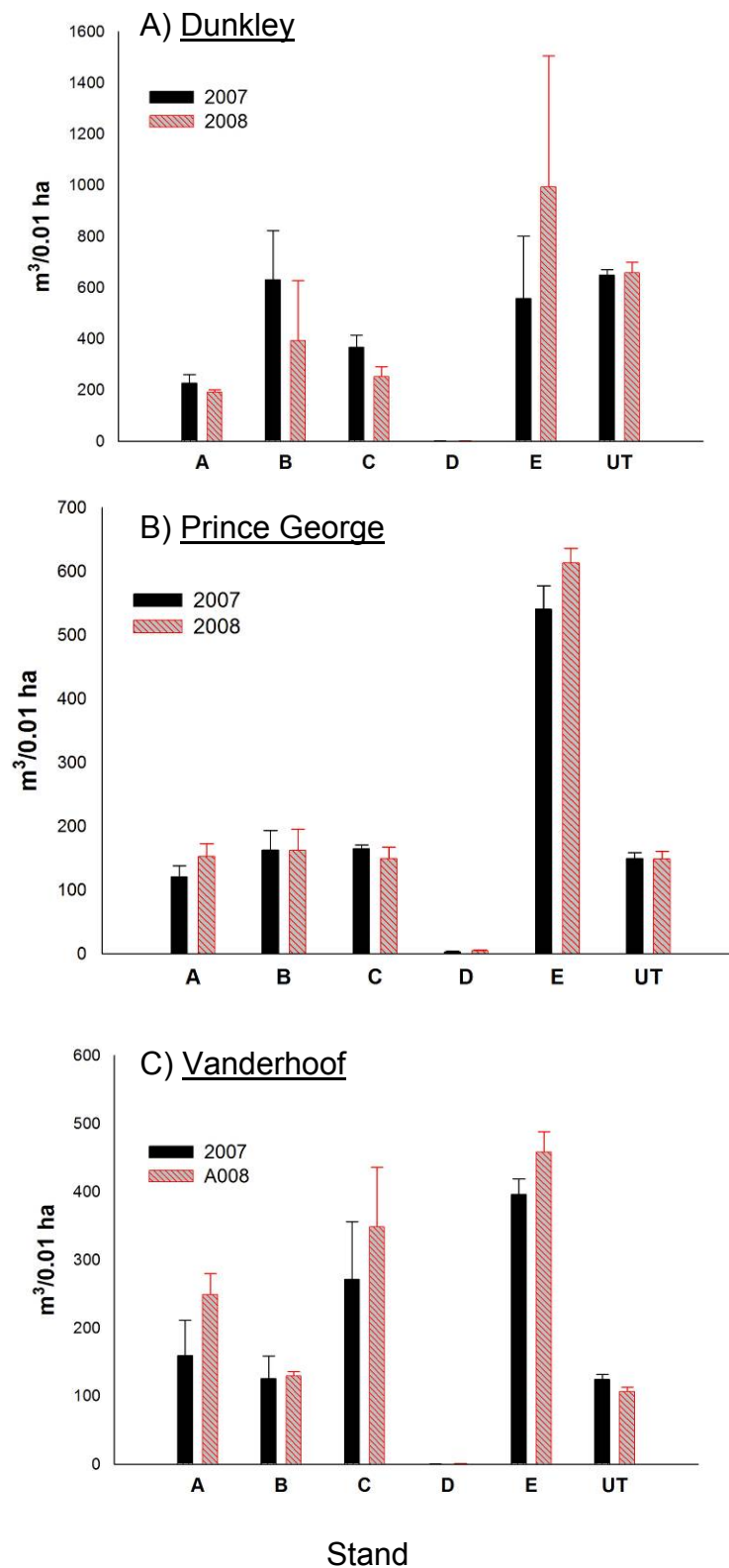


Figure 33. Number/ha of deer mice (*Peromyscus maniculatus*) in MPB-killed non-merchantable stands from 2006 to 2009.

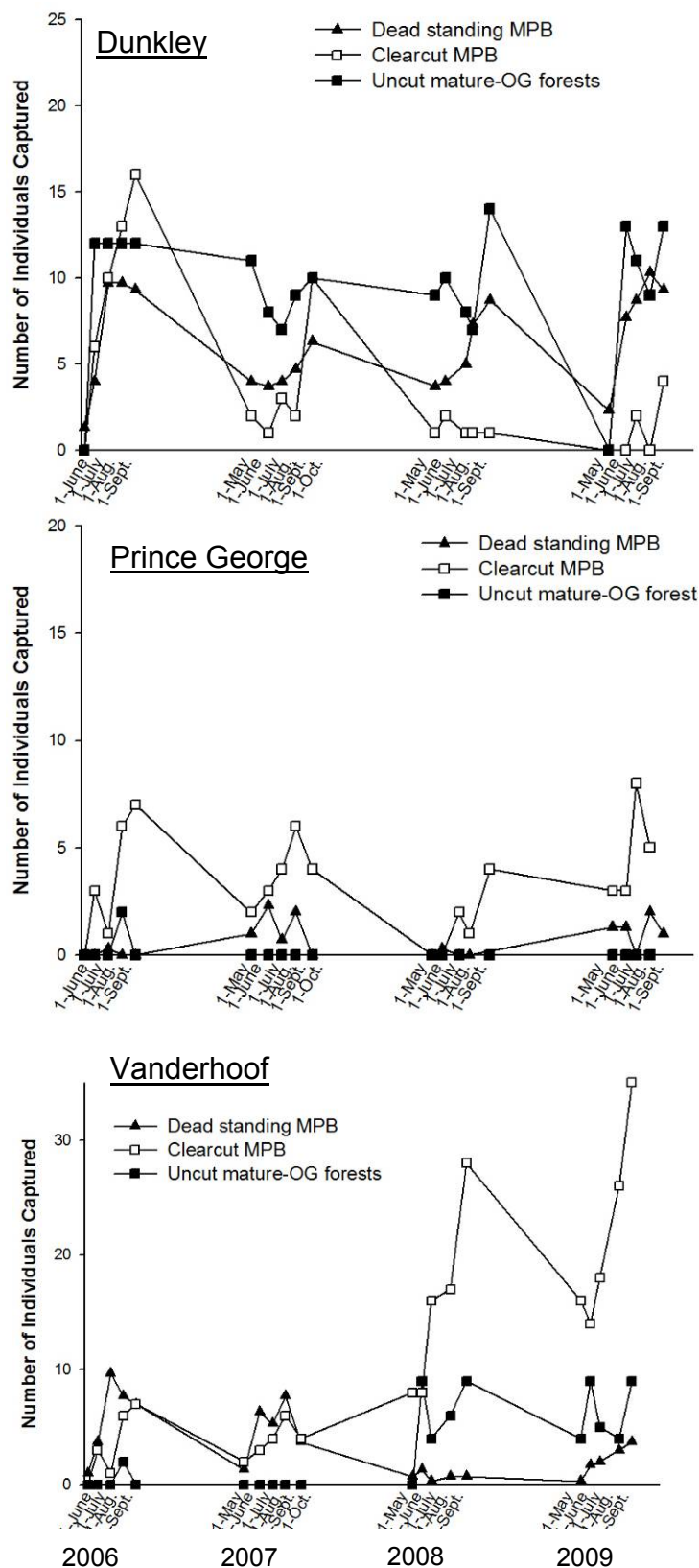


Figure 34. Number/ha of shrews (*Sorex*) in MPB-killed non-merchantable stands from 2006 to 2009.

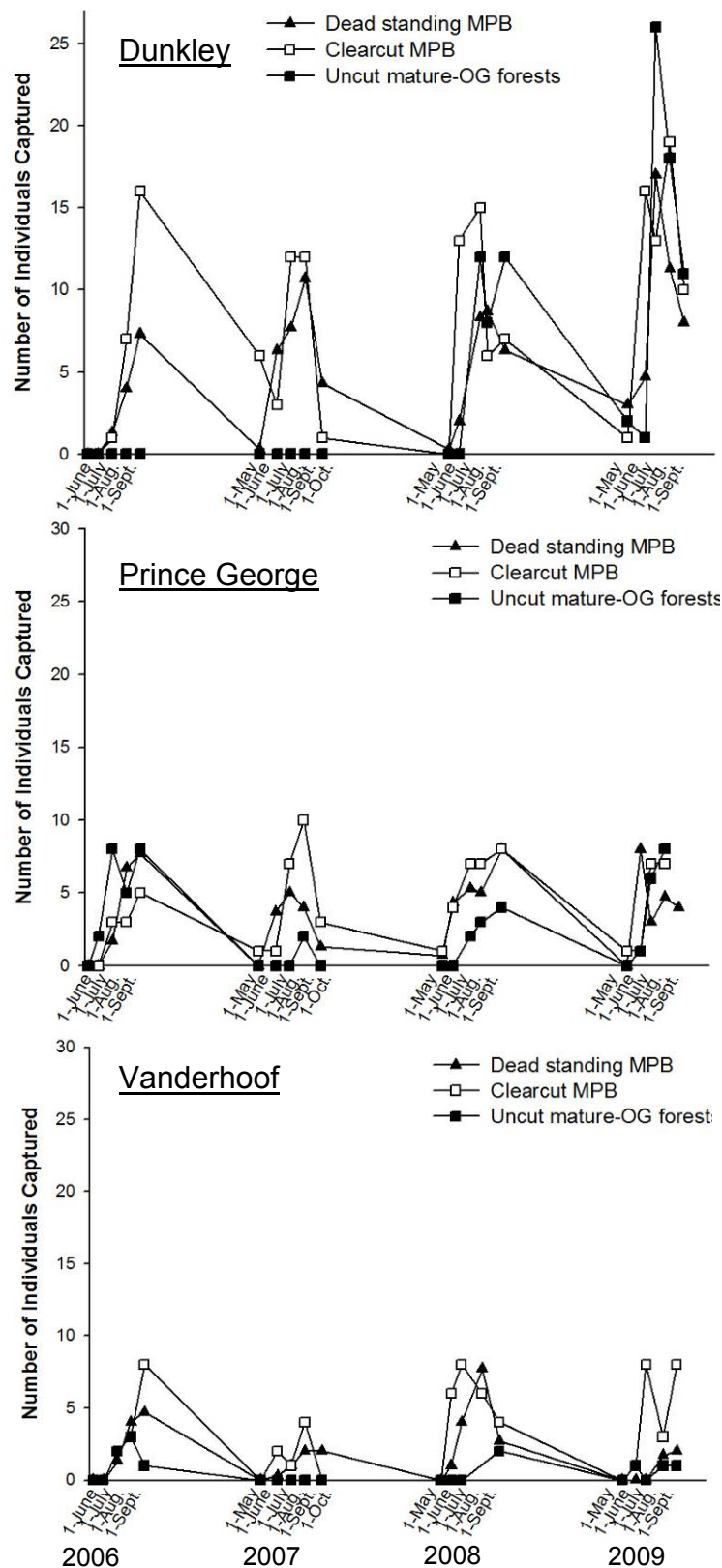
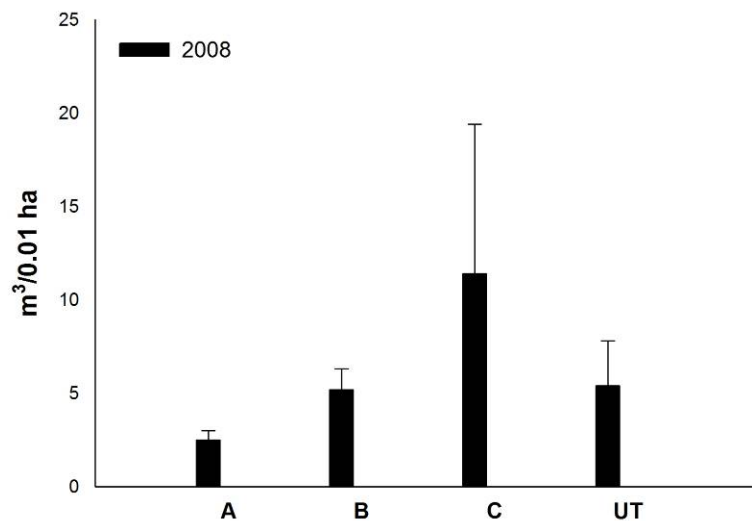
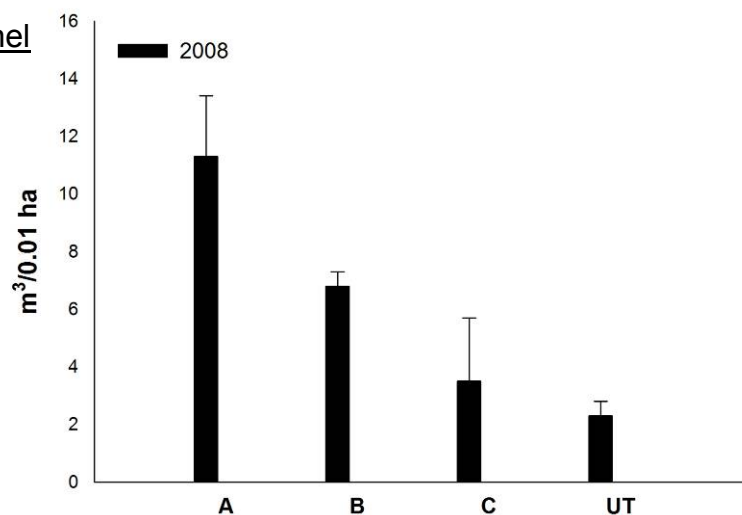


Figure 36. Mean ($n=3$; ± 1 SE) total volume of herbs in three MPB-killed merchantable stands (A, B, & C) and 1 live overstocked stand (Unthinned) at each of the sites in the three NIFR areas for 2008.

A) Fort Fraser



B) West Quesnel



C) Fort St. James

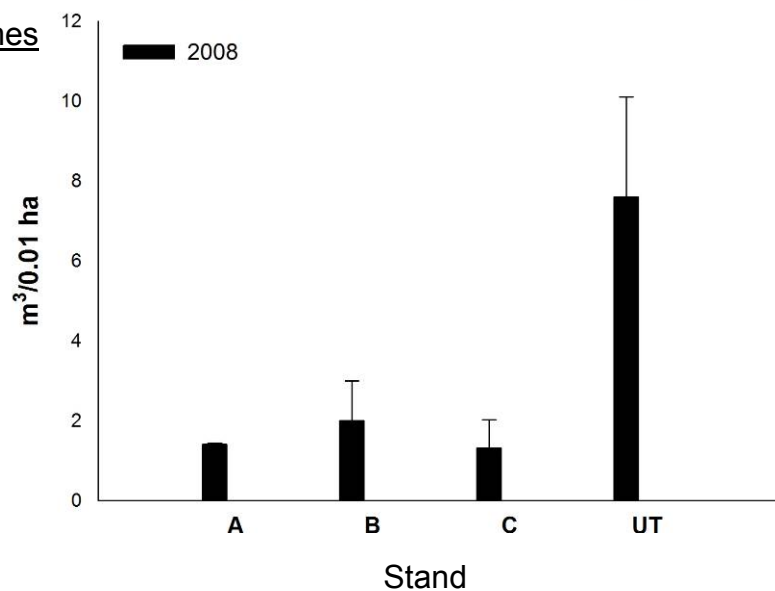
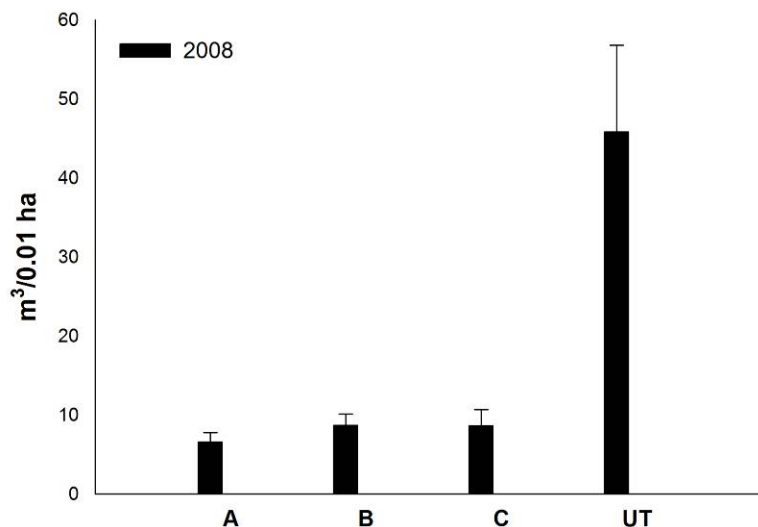
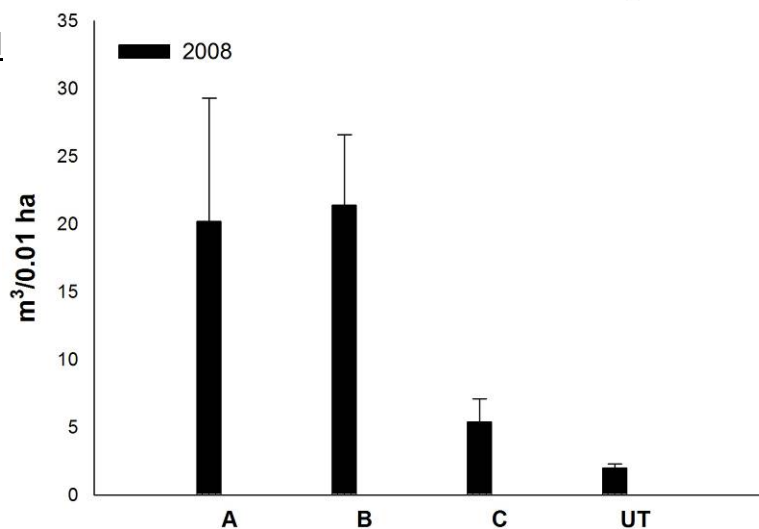


Figure 37. Mean ($n=3$; ± 1 SE) total volume of shrubs in three MPB-killed merchantable stands (A, B, & C) and 1 live overstocked stand (Unthinned) at each of the sites in the three NIFR areas for 2008.

A) Fort Fraser



B) West Quesnel



C) Fort St. James

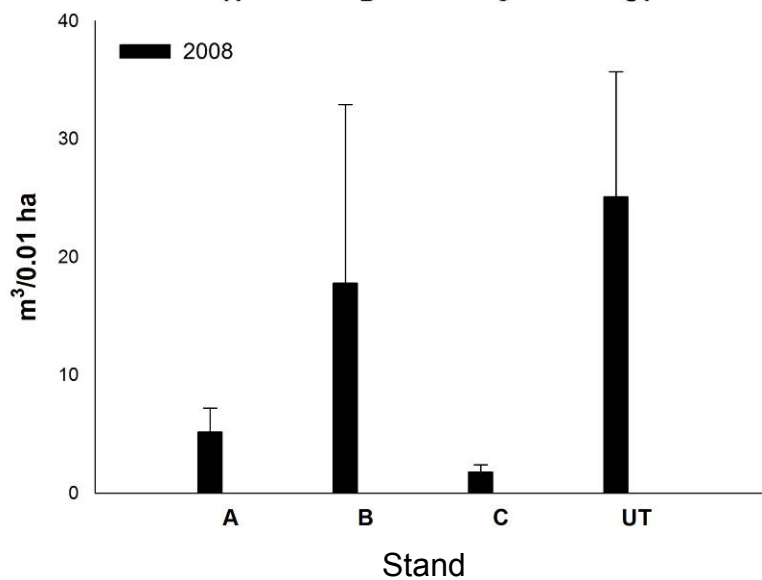


Figure 38. Mean ($n=3$; ± 1 SE) total volume of trees in three MPB-killed merchantable stands (A, B, & C) and 1 live overstocked stand (Unthinned) at each of the sites in the three NIFR areas for 2008.

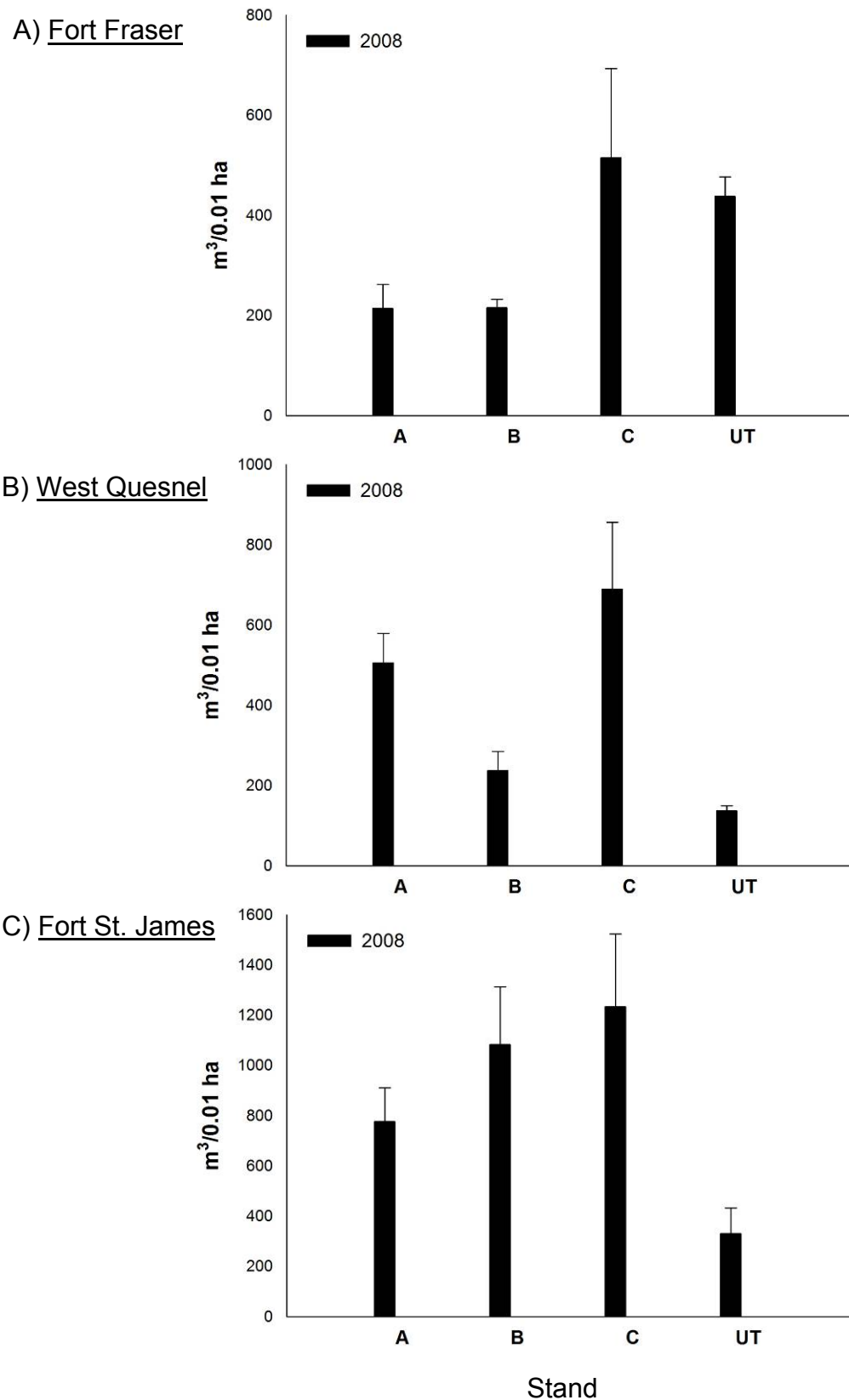


Figure 39. Mean number of hare pellets (per m²) for **A**) 2009 and **B**) averaged over all years (2006-2009) versus percent cover of trees and shrubs (based on 2009 data). Values (+ arrows) on graph **A** represent proportion of seedlings damaged on four sites planted for Objective 5 and parallel those values displayed in Figure 44.

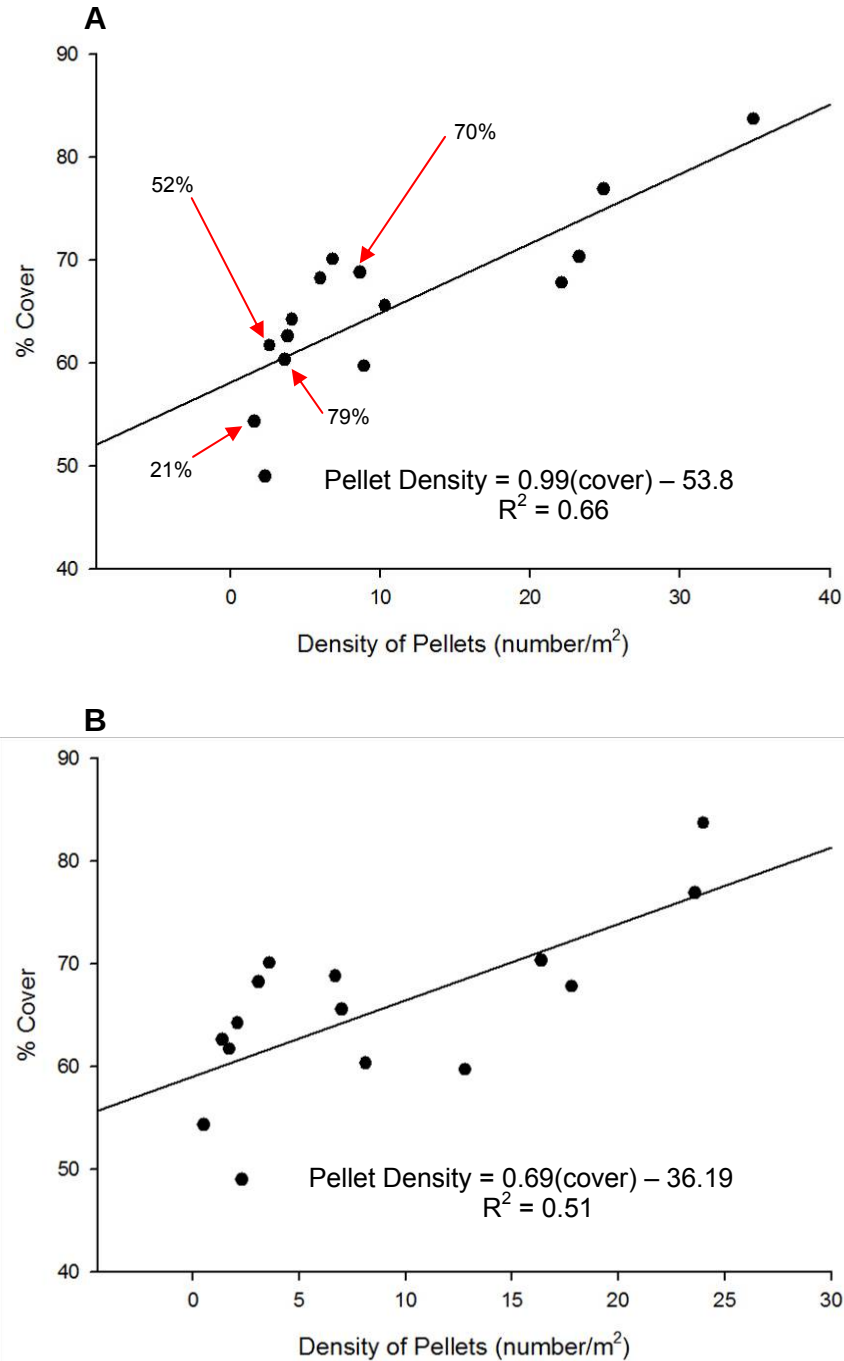


Figure 40. Mean ($\pm$ 95% CI) number of seedlings damaged in four MPB-killed non-merchantable stands in the NIFR region in August 2007 to May 2009. Surveys for 93G056-030 and 93G065-035 were not conducted in 2009. The percentage of trees alive include both trees not clipped by hares and clipped trees (if alive). Thus, even though damage may have exceeded 50%, many trees survived the clipping resulting in higher survival rates than permitted by enumerating just un-clipped seedlings.

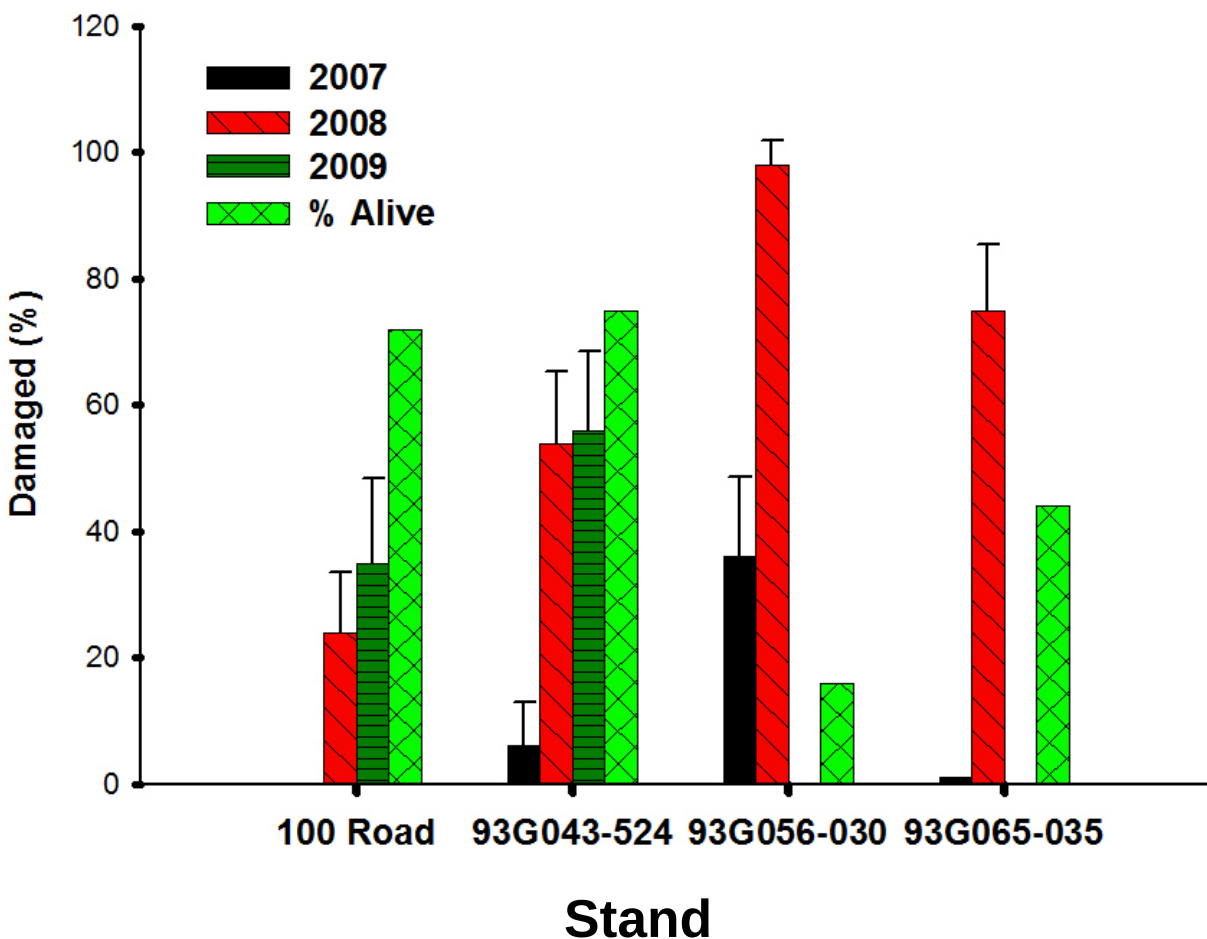


Figure 41. Photos of (A) an unbrushed control site and (B) brushed treatment site used to evaluate effectiveness of removing shrubs to reduce hare habitat and reduce seedling damage caused by hares.



Figure 42. Mean ($\pm$ 95% CI) number of hare pellets (per ha) in two brushed and two unbrushed sites located north (NPG) and west (WPG) of Prince George, B.C. from 2008 (pre-brushing) to 2009 (post brushing).

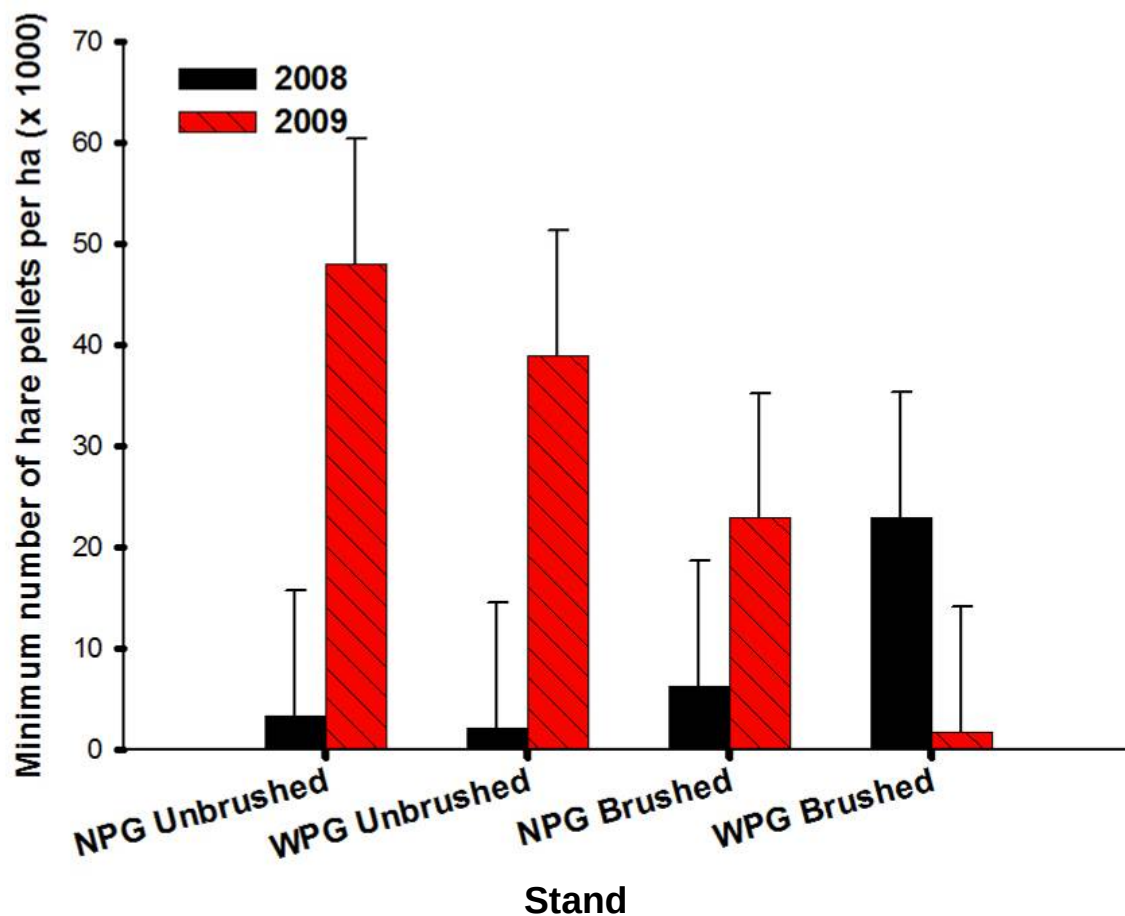


Figure 43. Mean ($\pm$ 95% CI) number of seedlings damaged in two brushed and two unbrushed sites located north (NPG) and west (WPG) of Prince George, B.C. from 2008 (time of planting) to 2009 (1 year post planting). Green cross-hatched bars represent the percentage of live trees present (clipped and unclipped) in 2009.

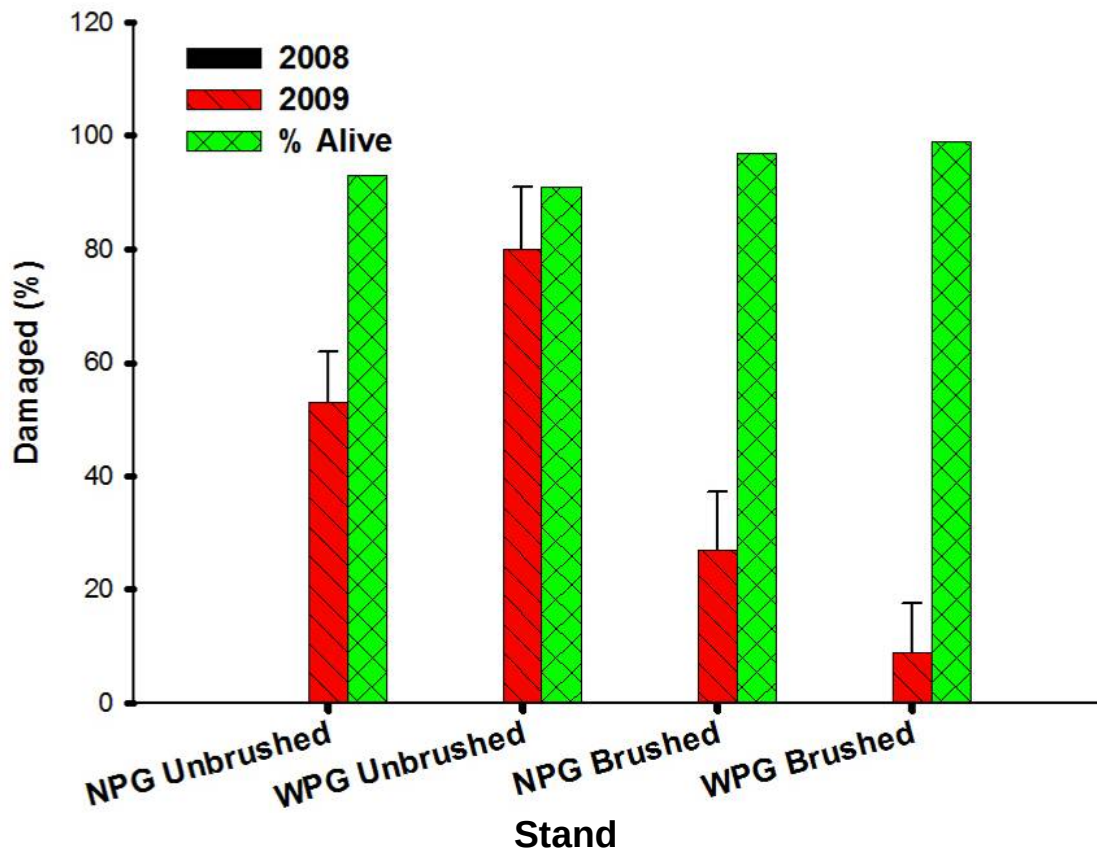
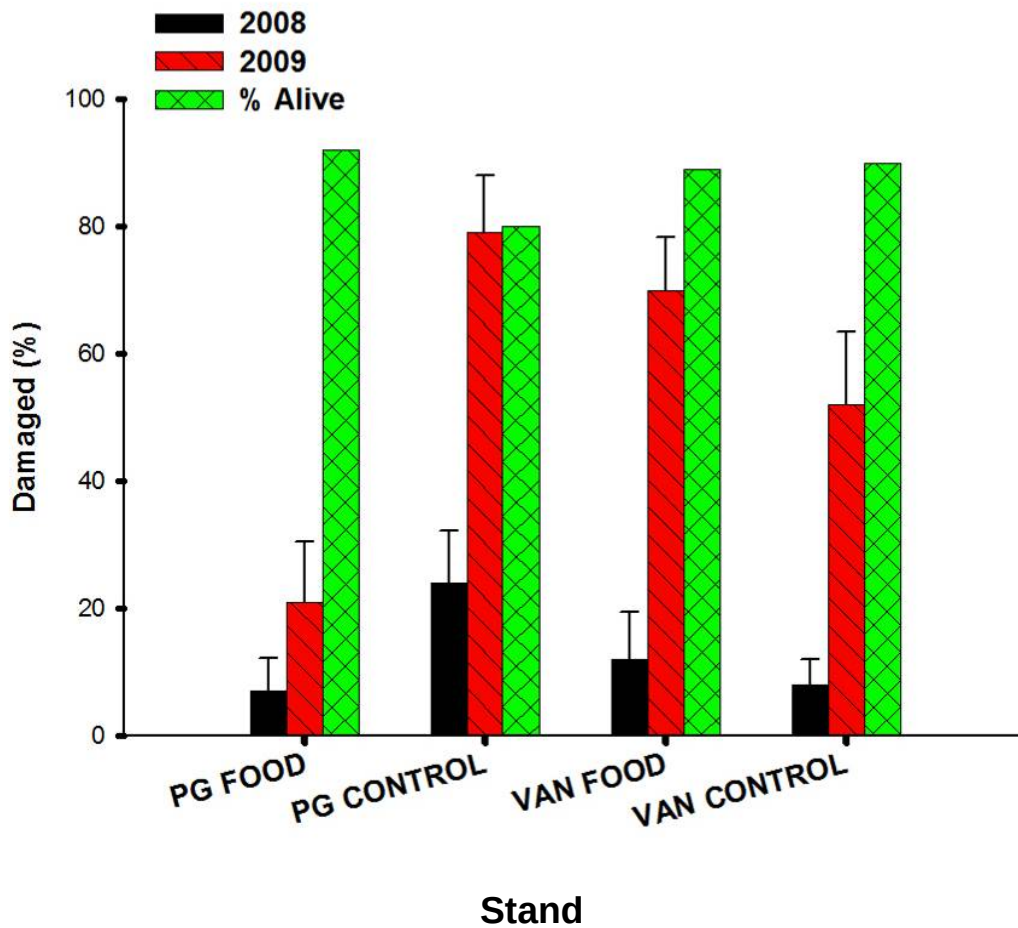


Figure 44. Mean ($\pm$ 95% CI) number of seedlings damaged in two stands with diversionary food added (FOOD) and without (CONTROL) in two regional replicates: Prince George (PG) and Vanderhoof (VAN). Green cross-hatched bars represent the percentage of live trees present (clipped and unclipped) in 2009.



8.0 TABLES

Table 1. Site descriptions and histories for the 7 project areas in the NIFR.

Location	Grid	UTM N	UTM E	Size (ha)	Age	Tree Species	Height (m)	Site Index	Activity
Vanderhoof	A	5969520	10-417239	60.9	27	65% PL; 25% SX; 10% AT	7.6	16	Pruned 1997; Spaced 1996
	B	5958696	10-410787	120.0	68	100% PL	18.6	17	Spaced 1987, 1988
	C	5956109	10-411496	95.8	140	100% PL	18.8	11	
	D	5964774	10-413218	20+	2	Planted		17	Harvested 2004
	E	5969396	10-417033	41.5	192	100% SX	25.9	10	
	UT	5965421	10-413369	50.3	15	100% PL	3	16	
Prince George	A	5962553	10-455108	26.0	32	98% PL,	9.3	16	Spaced 1986
	B	5958937	10-454564	33.6	30	80% PL, 10% AT, 10% SX	8.7	16	Spaced 1990
	C	5956472	10-451547	178.7	35	95% PL, 5% SX	14	21	Spaced 1980, Fertilized 1986
	D	5968291	10-465290	20 +	2	Planted		16	Harvested 2004
	E	5970497	10-470076	12.2	142	60% SX, 30% PL, 5% FD	28.5	15	
	UT	5967163	10-465887	64.2	16	100% PL	3	16	
Dunkley	A	5907038	10-540912	80.0	25	90% PL			Brushed 1990, Fertilized 1997
	B	5907933	10-543838	40.0	36	95% PL			Spaced 1994, Pruned 1994
	C	5907124	10-544009	106.0	35	95% PL			Brushed 1990
	D	5910526	10-549669	25.8	1	Planted			Harvested 2005
	E	5908299	10-545663	145	34	70%% SX, 10% AT			
	UT	5912697	10-547371	118	16	Dominated by SX			
Fort Fraser	A	5954210	10-370407	156	75	100% PL	14.7	12	

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	B	5954194	10-371104	62.5	135	100% PL	22.3	14	
	C	5960201	10-358189	163	151	90% PL, 10% SX	24.8	16	
	UT	5965467	10-377480	80	24	75% PL, 12 EP, 8% SW	6.6	16	Planted: 1986, 1987, 1989
Fort Saint James	A	6043069	10-412464	22	140	68% PL, 16% Sx, 12% BL	26.5	18	
	B	6041690	10-413440	73	139	76% PL, 19% FD, 5% SW	23.3	15	
	C	6040670	10-414850	60	123	85% PL, 5% SW, 5% FD	26.9	19	
	UT	6045004	10-414257	25	26	50% PL, 30% AT, 10%SW	7.3	16	Planted 1991, Brushed 1995
Quesnel	A	5872632	10-512343	29	124	80% PL, 20% S	26	18	
	B	5868576	10-511130	45	130	100% PL	26.8	18	
	C	5872533	10-488721	46	135	85% PL	20	12	
	UT	5860719	10-478685	26	17	100% PL	4	16	Spaced 1998
Kamloops	A	5592140	10-674829	20	40	100% PL	4		Nat. regen. 1960, thinned 1975 & 1989.
	B	5591744	10-675683	38	39	100% PL	4		Nat. regen. 1960, thinned 1975 & 1989.
	C	5592719	10-677382	23	43	100% PL	16		Nat. regen. 1960, thinned 1975 & 1989.
	UT	5593215	10-677477	22	43	60% PL, 40% AT	18		Nat. regen. 1960
	E	674988	5588832	72	193	50% SE 30% PL 20% BL	12	25.4	Mature

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1100 ROAD	5927415	10-454241	10.5	43	100% PL	15	19	Spaced 1981, 85, 86, 88; Fertilized 1987; Planted 2007
93G043-524	5921691	10-458885	12	52	100% PL	14.7	16	Spaced 1991; Planted 1995, 2007
93G056-030	5937964	10-503187	67.7	33	73% PL, 26% SW	9.6	16	Spaced 1983, 87; Planted 1970, 2007; Fertilized 1987
93G065-035	5939282	10-497339	47	31	70% PL, 10% S' 10% AT	9	16	Planted 1976, 2007; Spacing 1992, 1980

9.0 APPENDICES

Appendix A. Brushing Trial to Reduce Hare Damage to Seedlings

Appendix B: Tables 2 to 18 summarize the captures of all small mammals captured in three MPB-killed non-merchantable stands (A, B, and C), salvage clearcut (D), and uncut forest (E) at Dunkley, Prince George, and Vanderhoof monitoring sites in 2006 (Tables 2, 3, 4, respectively), 2007 (Tables 5, 6, 7, respectively), 2008 (Tables 8, 9, 10, respectively), and 2009 (Tables 11, 12, 13, respectively).

Appendix C: Table 19 contains the mean ($\pm$ 95% CI) number of seedlings clipped by snowshoe hares (*Lepus americanus*) and voles (*Microtus* spp. and *Myodes* spp.) in four young stands killed by MPB in the NIFR for 2007. Data contains the tree tag number for each seedling monitored and whether it was clipped terminally (TC) or laterally (LC).

Appendix D: Supplemental: Detailed maps for each grid used to monitor voles, hares, and damage were included in a supplementary document in 2008. This document is available, please contact the primary author (it is a rather large file). Additional maps for the brushing trials have been included in this report.

Appendix A

BRUSHING TRIAL TO REDUCE HARE DAMAGE TO SEEDLINGS

The following trial will be implemented in association with the current FFT project titled Managing Damaging Agents in MPB-killed Stands & Protection of New Plantations conducted by Dr. Doug Ransome and Dr. Tom Sullivan (UBC).

Rationale: Snowshoe hares are a major damaging agent to newly planted coniferous seedlings shortly after planting and to seedling and saplings during overwinter periods of peak populations in the NIFR (Northern Interior Forest Region) and SIFR (Southern Interior Forest Region) of B.C. Hares damage seedlings by clipping the leader and lateral shoots, leaving an oblique cut surface at a 45° angle. Significant damage to newly planted seedlings in MPB-killed non-merchantable stands has been recorded in the Prince George Forest District (2007 & 2008) and elsewhere throughout the NIFR and SIFR. There are several reports relating presence/absence of snowshoe hares to cover attributes in recently harvested forest sites (Ferron et al., 1998; de Bellefeuille et al., 2001). Both spring and overwinter densities were positively correlated with understory cover (Maine; Litvaitis et al., 1985). Pietz and Tester (1983) found that hares in Minnesota avoided open habitats and found a positive correlation between intensity of habitat use by hares and cover of shrubs over 1 m tall. Habitat selection was strongest for alder (*Alnus* spp.) fens and upland alder edge habitats. Similarly, Wolfe et al. (1982) found a strong correlation between habitat use by hares and density of horizontal cover at heights of 1.0 to 2.5 m above ground in Utah. Abundance of snowshoe hares, and their feeding damage to seedlings and lodgepole pine stems, tend to be greater at high than low stand densities (Sullivan and Sullivan, 1983; Koehler, 1990a, b). In B.C., heavy thinning to densities ≤ 1000 stems/ha reduced the carrying capacity of pine stands for hares (Sullivan et al. 2006). Consequently, intensive management of young stands would likely reduce understory cover for hares (Mowat and Slough, 2003). Thus, damage to young seedlings in plantations is usually most severe in or near areas having sufficient cover to provide suitable habitat for hares (often 10-25 years post-harvest; Sullivan, 1994). Removing this cover should reduce the potential for seedlings to be damaged by hares. The above studies are only a few of the many studies that have found a strong correlation between habitat use by hares and the density of understory cover.

Prediction: brushing young, mountain-pine beetle killed stands with high brush will remove security cover for snowshoe hares; thus reduce damage to under-planted seedlings.

Experimental Design and Methods: the study design will include a split-plot design with two replicates and two treatments. Each replicate will have a 10-ha area brushed (square configuration) 3 to 4 weeks prior to planting. This time period should be sufficient to result in hares leaving the treatment area to find better cover prior to planting. All shrub cover (0 - 2.5 m) will be cut down to reduce security cover for hares. The down shrubs will be further reduced in size, resulting in down material laying flat on the ground to prevent down material providing cover for hares, and to facilitate planting. Brush will not be piled to avoid creating security cover for hares. Control areas will be located in the same stand, adjacent to the brushed treatment, but sufficiently removed from the influence of the brushing (edge effect). The split-plot design will ensure similarity of habitat use by hares prior to treatment (brushing). Following completion of the planting, permanent pellet plots and survival plots will be established in both the brushed and control treatments. Permanent pellet sampling plots will be established in August 2008 to monitor habitat use by hares. We will use 1.0-m² circular plots as recommended by McKelvey et al. (2002) and Murray et al. (2002). One hundred plots will be located systematically, in 5-plot arrays installed at 20 stations located systematically every 50 m throughout each of the four sites. Pellet will be counted and removed at establishment (see progress report titled: Managing Damaging Agents in MPB-killed Stands & Protection of Newly Planted Seedlings, 2007-2008 for greater detail).

To monitor the level of damage to newly planted seedlings, 20 damage plots will be systematically established (30-m intervals) along transects in each of 4 areas. At each damage plot, the 5 closest seedlings will be marked with a pig-tail stake and individually numbered tree tag. Species and damage (vole or hare, terminally clipped, laterally clipped, debarked) will be noted for each seedling. Damage will be reassessed each year of the project.

Analysis: Comparison of pellet plots between brushed and unbrushed sites in August 2008 will evaluate the similarity of pre-treatment habitat use by hares between treatment and control areas. Comparison of pellet plots between brushed and unbrushed sites in May 2009 will determine if brushing resulted in reduced habitat use by hares. Comparing the proportion of seedlings damaged by hare between brushed and unbrushed sites will evaluate the effectiveness of brushing in reducing hare damage to newly planted seedlings.

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Appendix B

Table 2. Numbers of small mammals captured in three MPB-killed stands (A, B, and C), salvage clearcut (D), and uncut forest (E) at the Dunkley project area in 2006.

Grid and Species	Dates				
	6 June	29 June	25 July	21 Aug.	18 Sept.
GRID A					
<i>M. gapperi</i>	1	11	8	12	17
<i>M. longicaudus</i>			1		
<i>M. pennsylvanicus</i>		2	4	5	3
<i>P. intermedius</i>					
<i>P. maniculatus</i>	2	8	14	10	8
<i>T. amoenus</i>					
<i>Sorex</i> spp.	8	22	18	16	23
<i>Zapus</i> weasel			1		
<i>Lepus americanus</i>	2	5	10	9	3
TOTAL (excluding hares)	11	43	46	43	51
GRID B					
<i>M. gapperi</i>		12	14	11	10
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>		2	1		2
<i>P. intermedius</i>					
<i>P. maniculatus</i>	1	3	15	19	20
<i>T. amoenus</i>					
<i>Sorex</i> spp.	2	24	19	15	27
<i>Zapus</i> spp, weasel		1			
<i>Lepus americanus</i>	0	1	0	0	2
TOTAL (excluding hares)	3	42	49	45	59
GRID C					
<i>M. gapperi</i>		19	22	20	31
<i>M. longicaudus</i>			1		
<i>M. pennsylvanicus</i>		2		2	3
<i>P. intermedius</i>					
<i>P. maniculatus</i>	1	1			
<i>T. amoenus</i>					
<i>Sorex</i> spp.		14	20	16	14
<i>Zapus</i> spp, weasel					
<i>Lepus americanus</i>	2	1	7	4	3
TOTAL (excluding hares)	1	36	43	38	48

GRID D					
<i>M. gapperi</i>		7	11	5	4
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>		8	7	11	6
<i>P. intermedius</i>					
<i>P. maniculatus</i>		6	10	13	16
<i>T. amoenus</i>					
<i>Sorex</i> spp.		20	20	22	27
<i>Zapus</i> spp, weasel				1	
TOTAL	0	41	48	52	53
GRID E					
<i>M. gapperi</i>		9	7	12	21
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>		1			
<i>P. intermedius</i>					
<i>P. maniculatus</i>		12	12	12	12
<i>T. amoenus</i>					
<i>Sorex</i> spp.		18	25	16	16
<i>Zapus</i> spp, weasel					
TOTAL	0	40	44	40	49

Table 3. Numbers of small mammals captured in three MPB-killed stands (A, B, and C), salvage clearcut (D), and uncut forest (E) at the Prince George project area in 2006.

Grid and Species	Dates				
	7 June	1 July	6 Aug.	23 Aug.	22 Sept.
GRID A					
<i>M. gapperi</i>			4	13	26
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>			2	12	22
<i>P. intermedius</i>					
<i>P. maniculatus</i>					
<i>T. amoenus</i>					
<i>Sorex</i> spp.			4	6	10
<i>Zapus</i> spp, weasel					
<i>Lepus americanus</i>					
TOTAL (excluding hares)	0	0	10	31	58
GRID B					

<i>M. gapperi</i>	2		4	20	26
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>			2		
<i>P. intermedius</i>					
<i>P. maniculatus</i>					
<i>T. amoenus</i>					
<i>Sorex</i> spp.				6	11
<i>Zapus</i> spp, weasel					
<i>Lepus americanus</i>				2	3
TOTAL (excluding hares)	2	0	6	20	37
GRID C					
<i>M. gapperi</i>			1	20	26
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>				1	
<i>T. amoenus</i>					
<i>Sorex</i> spp.			1	8	2
<i>Zapus</i> spp, weasel					
<i>Lepus americanus</i>					
TOTAL (excluding hares)	0	0	2	29	28
GRID D					
<i>M. gapperi</i>		3	16	13	8
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>			1	7	16
<i>P. intermedius</i>		1	1		
<i>P. maniculatus</i>		3	1	6	7
<i>T. amoenus</i>		1	7	5	5
<i>Sorex</i> spp.			3	3	5
<i>Zapus</i> spp, weasel					
TOTAL	0	8	29	34	41
GRID E					
<i>M. gapperi</i>		13	30	36	49
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>				2	
<i>T. amoenus</i>					
<i>Sorex</i> spp.		2	8	5	8
<i>Zapus</i> spp, weasel					

TOTAL	0	31	38	43	57
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Table 4. Numbers of small mammals captured in the three MPB-killed stands (A, B, and C), salvage clearcut (D), and uncut forest (E) at the Vanderhoof project area in 2006.

Grids and Species	Dates				
	8 June	29 June	1 Aug.	25 Aug.	20 Sept.
GRID A					
<i>M. gapperi</i>	3	15	7	10	20
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>			1	4	6
<i>P. intermedius</i>					1
<i>P. maniculatus</i>	3	10	22	14	13
<i>T. amoenus</i>					
<i>Sorex</i> spp.			1	4	4
<i>Zapus</i> spp, weasel					
<i>Lepus americanus</i>					2
TOTAL (excluding hares)	6	25	31	32	44
GRID B					
<i>M. gapperi</i>		6	17	17	21
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>				1	
<i>P. intermedius</i>			1	1	4
<i>P. maniculatus</i>		1	7	9	8
<i>T. amoenus</i>	1	7	6	4	3
<i>Sorex</i> spp.			1	2	6
<i>Zapus</i> spp, weasel					
<i>Lepus americanus</i>					
TOTAL (excluding hares)	1	14	32	34	42
GRID C					
<i>M. gapperi</i>	1	16	17	11	16
<i>M. longicaudus</i>			1		
<i>M. pennsylvanicus</i>					4
<i>P. intermedius</i>			1		
<i>P. maniculatus</i>					
<i>T. amoenus</i>				1	1
<i>Sorex</i> spp.			2	6	4
<i>Zapus</i> spp, weasel					

<i>Lepus americanus</i>			1		1
TOTAL (excluding hares)	1	16	21	18	25
GRID D					
<i>M. gapperi</i>		3	3	4	4
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>		11	7	2	2
<i>P. intermedius</i>		1			1
<i>P. maniculatus</i>			9	8	18
<i>T. amoenus</i>		1		1	1
<i>Sorex</i> spp.			2	3	8
<i>Zapus</i> spp, weasel				1	
TOTAL	0	16	21	19	34
GRID E					
<i>M. gapperi</i>		8	18	16	27
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>		14	15	13	14
<i>T. amoenus</i>					
<i>Sorex</i> spp.			2	3	1
<i>Zapus</i> spp, weasel					
TOTAL	0	22	35	32	42

Table 5. Numbers of small mammals captured in three MPB-killed stands (A, B, and C), salvage clearcut (D), and uncut forest (E) at the Dunkley project area in 2007.

Grids and Species	Dates				
	18 May	18 June	21 July	13 August	22 Sept.
GRID A					
<i>M. gapperi</i>	2	4	2	1	2
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>				2	1
<i>P. intermedius</i>		1			
<i>P. maniculatus</i>	5	6	7	11	11
<i>T. amoenus</i>					
<i>Sorex</i> spp.		7	12	9	6
<i>Zapus</i> spp, Weasel family				1 ST Weasel	
<i>Lepus americanus</i>	8	10	4	7	5
TOTAL (excluding hares)	7	18	21	19	20

GRID B

<i>M. gapperi</i>	1	5	1	2	3
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>				10	8
<i>P. intermedius</i>					
<i>P. maniculatus</i>	7	5	4	3	8
<i>T. amoenus</i>					
<i>Sorex</i> spp.		2	12	9	7
<i>Zapus</i> spp,		4			
Weasel family				1	
<i>Lepus americanus</i>	3	1			
TOTAL (excluding hares)	8	16	17	24	26

GRID C

<i>M. gapperi</i>	2	5	7	3	
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>		3	2	12	6
<i>P. intermedius</i>					
<i>P. maniculatus</i>		1			
<i>T. amoenus</i>					
<i>Sorex</i> spp.			4	4	4
<i>Zapus</i> spp,		1			
Weasel family					
<i>Lepus americanus</i>	1	9	2	1	3
TOTAL (excluding hares)	2	10	13	19	10

GRID D

<i>M. gapperi</i>					
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>		6	12	11	15
<i>P. intermedius</i>					
<i>P. maniculatus</i>	2	1	3	2	10
<i>T. amoenus</i>					
<i>Sorex</i> spp.		6	9	4	2
<i>Zapus</i> spp,					
Weasel family				1	1
TOTAL	2	13	24	18	28

GRID E

<i>M. gapperi</i>	1	5	2	4	6
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>	11	8	7	9	10
<i>T. amoenus</i>					
<i>Sorex</i> spp.	1	1	1	1	1
<i>Zapus</i> spp,					

Weasel family					
TOTAL	13	14	10	14	17

Table 6. Numbers of small mammals captured in three MPB-killed stands (A, B, and C), salvage clearcut (D), and uncut forest (E) at the Prince George project area in 2007.

Grids and Species	Dates				
	20 May	16 June	17 July	8 Aug.	17 Sept.
GRID A					
<i>M. gapperi</i>	5	14	8	16	4
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>	1	12	14	21	4
<i>P. intermedius</i>					
<i>P. maniculatus</i>	2				
<i>T. amoenus</i>					
<i>Sorex</i> spp.		4	8	4	2
<i>Zapus</i> spp,					
Weasel family					2 marten
<i>Lepus americanus</i>					
TOTAL (excluding hares)	8	30	30	41	12
GRID B					
<i>M. gapperi</i>	4	11	11	7	11
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>		6	9	8	5
<i>P. intermedius</i>	1	1			
<i>P. maniculatus</i>	1	4		1	
<i>T. amoenus</i>					
<i>Sorex</i> spp.		1	3	2	1
<i>Zapus</i> spp,		1			
Weasel family	1 Fisher				
<i>Lepus americanus</i>	3	7	3	6	5
TOTAL (excluding hares)	7	24	23	18	17
GRID C					
<i>M. gapperi</i>	5	6	6	5	8
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>		1		3	4
<i>P. intermedius</i>					
<i>P. maniculatus</i>		3	2	5	
<i>T. amoenus</i>					
<i>Sorex</i> spp.		6	4	6	1
<i>Zapus</i> spp,		1			

Weasel family					
<i>Lepus americanus</i>	1				1
TOTAL (excluding hares)	5	17	12	19	13
GRID D					
<i>M. gapperi</i>	3		4	3	12
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>	6	3	12	12	1
<i>P. intermedius</i>		1			
<i>P. maniculatus</i>	2	3	4	6	4
<i>T. amoenus</i>	7	2	4	10	2
<i>Sorex</i> spp.	1	1	7	10	3
<i>Zapus</i> spp,					
Weasel family					
TOTAL	19	10	31	41	22
GRID E					
<i>M. gapperi</i>	13	18	36	44	31
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>					
<i>T. amoenus</i>					
<i>Sorex</i> spp.				2	
<i>Zapus</i> spp,					
Weasel family					
TOTAL	13	18	36	46	31

Table 7. Numbers of small mammals captured in three MPB-killed stands (A, B, and C), salvage clearcut (D), and uncut forest (E) at the Vanderhoof project area in 2007.

Grid and Species	Dates				
	22 May	13 June	13 July	10 Aug.	19 Sept.
GRID A					
<i>M. gapperi</i>	2	4	8	11	20
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>			1	7	6
<i>P. intermedius</i>					
<i>P. maniculatus</i>	4	17	11	18	11
<i>T. amoenus</i>					
<i>Sorex</i> spp.				1	2
<i>Zapus</i> spp,		1			
Weasel family					
<i>Lepus americanus</i>	1			4	2

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TOTAL (excluding hares)	6	21	20	37	39
GRID B					
<i>M. gapperi</i>	9	10	15	13	23
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>		3	8	5	4
<i>P. intermedius</i>			1		1
<i>P. maniculatus</i>		2	5	4	
<i>T. amoenus</i>	2	4	1	5	
<i>Sorex</i> spp.		1	2	3	2
<i>Zapus</i> spp,					
Weasel family				ST Weasel	
<i>Lepus americanus</i>		3	3		
TOTAL (excluding hares)	11	20	32	31	30
GRID C					
<i>M. gapperi</i>	4	6	9	12	10
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					1
<i>P. intermedius</i>	1		1		
<i>P. maniculatus</i>				1	
<i>T. amoenus</i>					
<i>Sorex</i> spp.			1	2	2
<i>Zapus</i> spp,					
Weasel family					
<i>Lepus americanus</i>		1	3	1	
TOTAL (excluding hares)	5	6	11	15	13
GRID D					
<i>M. gapperi</i>					1
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>	1	6	2	6	1
<i>P. intermedius</i>					
<i>P. maniculatus</i>	6	9	9	14	21
<i>T. amoenus</i>					
<i>Sorex</i> spp.		2	1	4	
<i>Zapus</i> spp,					
Weasel family					
TOTAL	7	17	12	24	22
GRID E					
<i>M. gapperi</i>	13	17	22	39	56
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>	3	8	8	11	6
<i>T. amoenus</i>				1	
<i>Sorex</i> spp.					

<i>Zapus</i> spp,					
Weasel family					
TOTAL	16	25	30	41	62

Table 8. Numbers of small mammals captured in three MPB-killed stands (A, B, and C), salvage clearcut (D), and uncut forest (E) at the Dunkley project area in 2008.

Grids and Species	Dates				
	25 May	20 June	27 July	15 August	15 Sept.
GRID A					
<i>M. gapperi</i>	2	3		1	
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					1
<i>P. intermedius</i>					
<i>P. maniculatus</i>	7	6	14	17	15
<i>T. amoenus</i>	1				
<i>Sorex</i> spp.		2	8	11	8
<i>Zapus</i> spp,		2	1		
Weasel family					1
<i>Lepus americanus</i>	13	10	5	8	8
TOTAL (excluding hares)	10	13	23	29	25
GRID B					
<i>M. gapperi</i>					1
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>		2	1	2	4
<i>P. intermedius</i>		1			
<i>P. maniculatus</i>	3	4		5	9
<i>T. amoenus</i>					
<i>Sorex</i> spp.	1		9	15	7
<i>Zapus</i> spp,	1	13	1		
Weasel family					
<i>Lepus americanus</i>	6	1	0	3	1
TOTAL (excluding hares)	5	20	11	22	21
GRID C					
<i>M. gapperi</i>		2	2	1	2
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>	1	2	1		2
<i>T. amoenus</i>					
<i>Sorex</i> spp.		4	8		4
<i>Zapus</i> spp,		3			

Weasel family				1	
<i>Lepus americanus</i>	3	4	2		1
TOTAL (excluding hares)	1	11	11	2	8
GRID D					
<i>M. gapperi</i>					
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>	1	1	1		
<i>P. intermedius</i>					
<i>P. maniculatus</i>	1	2	1	1	1
<i>T. amoenus</i>					
<i>Sorex</i> spp.		13	15	6	7
<i>Zapus</i> spp,					
Weasel family			2		
TOTAL	2	16	19	7	8
GRID E					
<i>M. gapperi</i>	3	3	5	3	0
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>	9	10	8	7	14
<i>T. amoenus</i>					
<i>Sorex</i> spp.			12	8	12
<i>Zapus</i> spp,					
Weasel family				2	
TOTAL	12	13	25	20	26

Table 9. Numbers of small mammals captured in three MPB-killed stands (A, B, and C), salvage clearcut (D), and uncut forest (E) at the Prince George project area in 2008.

Grids and Species	Dates				
	20 May	16 June	17 July	8 Aug.	17 Sept.
GRID A					
<i>M. gapperi</i>			6	9	7
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>		1	1	1	5
<i>P. intermedius</i>					
<i>P. maniculatus</i>					
<i>T. amoenus</i>					
<i>Sorex</i> spp.		3	8	8	13
<i>Zapus</i> spp,					
Weasel family					

<i>Lepus americanus</i>				1	2
TOTAL (excluding hares)	0	4	15	18	25
GRID B					
<i>M. gapperi</i>			2	3	2
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>			6	4	5
<i>P. intermedius</i>			1		2
<i>P. maniculatus</i>					
<i>T. amoenus</i>			3	1	
<i>Sorex</i> spp.	2	6	3	4	6
<i>Zapus</i> spp,					
Weasel family					
<i>Lepus americanus</i>	2	3	6	5	3
TOTAL (excluding hares)	2	6	15	12	14
GRID C					
<i>M. gapperi</i>	1	4	2	3	6
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>			6	4	5
<i>P. intermedius</i>			1		
<i>P. maniculatus</i>		1			1
<i>T. amoenus</i>	1	2	3	1	3
<i>Sorex</i> spp.		4	5	3	5
<i>Zapus</i> spp,					
Weasel family					
<i>Lepus americanus</i>	2	2	1		1
TOTAL (excluding hares)	2	11	17	11	20
GRID D					
<i>M. gapperi</i>				1	3
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>			2	1	4
<i>T. amoenus</i>	6	5	7	6	2
<i>Sorex</i> spp.	1	4	7	7	8
<i>Zapus</i> spp,					
Weasel family					
TOTAL	7	9	16	14	17
GRID E					
<i>M. gapperi</i>	5	7	8	8	12
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>					
<i>T. amoenus</i>					

<i>Sorex</i> spp.			2	3	4
<i>Zapus</i> spp,					
Weasel family					
TOTAL	5	7	10	11	16

Table 10. Numbers of small mammals captured in three MPB-killed stands (A, B, and C), salvage clearcut (D), and uncut forest (E) at the Vanderhoof project area in 2008.

Grid and Species	Dates				
	22 May	13 June	13 July	10 Aug.	19 Sept.
GRID A					
<i>M. gapperi</i>				3	1
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>		1	2	2	8
<i>P. intermedius</i>					
<i>P. maniculatus</i>	2	4	1	2	2
<i>T. amoenus</i>					
<i>Sorex</i> spp.			2	6	4
<i>Zapus</i> spp,					
Weasel family					
<i>Lepus americanus</i>	1				1
TOTAL (excluding hares)	2	4	4	13	15
GRID B					
<i>M. gapperi</i>	2	1		3	3
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>			2		
<i>P. intermedius</i>		1	1		
<i>P. maniculatus</i>					
<i>T. amoenus</i>	5	4	6	4	4
<i>Sorex</i> spp.		3	6	8	3
<i>Zapus</i> spp,					
Weasel family					
<i>Lepus americanus</i>	2	3	3	7	5
TOTAL (excluding hares)	7	9	15	15	10
GRID C					
<i>M. gapperi</i>	2	5	8	8	3
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>					
<i>T. amoenus</i>					

<i>Sorex</i> spp.			4	9	4
<i>Zapus</i> spp,					
Weasel family					
<i>Lepus americanus</i>		2	4	4	2
TOTAL (excluding hares)	2	5	12	17	7
GRID D					
<i>M. gapperi</i>					
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>			1	4	
<i>P. intermedius</i>			1	1	1
<i>P. maniculatus</i>	8	8	16	17	28
<i>T. amoenus</i>			1		
<i>Sorex</i> spp.		6	8	6	4
<i>Zapus</i> spp,					
Weasel family					
TOTAL	8	14	27	28	33
GRID E					
<i>M. gapperi</i>	2	5	1		1
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					1
<i>P. intermedius</i>					
<i>P. maniculatus</i>		9	4	6	9
<i>T. amoenus</i>					
<i>Sorex</i> spp.				6	2
<i>Zapus</i> spp,					
Weasel family				2	
TOTAL	2	14	5	14	13

Table 11. Numbers of small mammals captured in three MPB-killed stands (A, B, and C), salvage clearcut (D), and uncut forest (E) at the Dunkley project area in 2009.

Grid and Species	Dates				
	21 May	23 June	17 July	13 Aug.	09 Sept.
GRID A					
<i>M. gapperi</i>		1			
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>	7	22	24		
<i>T. amoenus</i>					
<i>Sorex</i> spp.	3	9	21		
<i>Zapus</i>		1			

weasel			
<i>Lepus americanus</i>	3	4	
TOTAL (excluding hares)	10	33	45
GRID B			
<i>M. gapperi</i>	1	5	5
<i>M. longicaudus</i>			
<i>M. pennsylvanicus</i>			
<i>P. intermedius</i>			
<i>P. maniculatus</i>		1	2
<i>T. amoenus</i>			
<i>Sorex</i> spp.		4	20
<i>Zapus</i> spp,		13	
weasel			
<i>Lepus americanus</i>	6	1	
TOTAL (excluding hares)	1	13	27
GRID C			
<i>M. gapperi</i>		6	5
<i>M. longicaudus</i>			
<i>M. pennsylvanicus</i>			1
<i>P. intermedius</i>			
<i>P. maniculatus</i>			
<i>T. amoenus</i>			
<i>Sorex</i> spp.	3	1	10
<i>Zapus</i> spp,			
weasel			
<i>Lepus americanus</i>	2		1
TOTAL (excluding hares)	3	7	16
GRID D			
<i>M. gapperi</i>			
<i>M. longicaudus</i>			
<i>M. pennsylvanicus</i>		6	3
<i>P. intermedius</i>			1
<i>P. maniculatus</i>			2
<i>T. amoenus</i>			
<i>Sorex</i> spp.	1	16	13
<i>Zapus</i> spp,			
weasel			
TOTAL	1	22	19
GRID E			
<i>M. gapperi</i>			
<i>M. longicaudus</i>			
<i>M. pennsylvanicus</i>			
<i>P. intermedius</i>			
<i>P. maniculatus</i>		13	11

<i>T. amoenus</i>			
<i>Sorex</i> spp.	2	1	26
<i>Zapus</i> spp, weasel			
TOTAL	2	14	37

Table 12. Numbers of small mammals captured in three MPB-killed stands (A, B, and C), salvage clearcut (D), and uncut forest (E) at the Prince George project area in 2009.

Grid and Species	Dates				
	23 May	21 June	13 July	15 Aug.	11 Sept.
GRID A					
<i>M. gapperi</i>	2	9	10		
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>			1		
<i>P. intermedius</i>					
<i>P. maniculatus</i>	2	1			
<i>T. amoenus</i>					
<i>Sorex</i> spp.		8	3		
<i>Zapus</i> spp, weasel					
<i>Lepus americanus</i>					
TOTAL (excluding hares)	4	18	14		
GRID B					
<i>M. gapperi</i>		3	12		
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>			6		
<i>P. intermedius</i>					
<i>P. maniculatus</i>		1			
<i>T. amoenus</i>					
<i>Sorex</i> spp.	1	1	7		
<i>Zapus</i> spp, weasel					
<i>Lepus americanus</i>	3				
TOTAL (excluding hares)	1	5	25		
GRID C					
<i>M. gapperi</i>	3	7	10		
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					

<i>P. maniculatus</i>	2	3	
<i>T. amoenus</i>	2		2
<i>Sorex</i> spp.		1	6
<i>Zapus</i> spp, weasel			
<i>Lepus americanus</i>	2	1	1
TOTAL (excluding hares)	7	11	18
GRID D			
<i>M. gapperi</i>		2	4
<i>M. longicaudus</i>			
<i>M. pennsylvanicus</i>		1	1
<i>P. intermedius</i>			
<i>P. maniculatus</i>	3	3	8
<i>T. amoenus</i>	4	1	6
<i>Sorex</i> spp.	2	1	4
<i>Zapus</i> spp, weasel			
TOTAL	9	8	23
GRID E			
<i>M. gapperi</i>	6	13	8
<i>M. longicaudus</i>			
<i>M. pennsylvanicus</i>			
<i>P. intermedius</i>			
<i>P. maniculatus</i>			
<i>T. amoenus</i>			
<i>Sorex</i> spp.			1
<i>Zapus</i> spp, weasel			
TOTAL	6	13	9

Table 13. Numbers of small mammals captured in the three MPB-killed stands (A, B, and C), salvage clearcut (D), and uncut forest (E) at the Vanderhoof project area in 2009.

Grids and Species	Dates				
	25 May	19 June	11 July	17 Aug.	13 Sept.
GRID A					
<i>M. gapperi</i>	2	5	10		
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>			3		
<i>P. intermedius</i>					

<i>P. maniculatus</i>	1	5	5
<i>T. amoenus</i>			
<i>Sorex</i> spp.			
<i>Zapus</i> spp,			
weasel			
<i>Lepus americanus</i>			1
TOTAL (excluding hares)	3	10	18
GRID B			
<i>M. gapperi</i>	6	5	11
<i>M. longicaudus</i>			
<i>M. pennsylvanicus</i>			
<i>P. intermedius</i>			
<i>P. maniculatus</i>			1
<i>T. amoenus</i>	2	3	14
<i>Sorex</i> spp.			7
<i>Zapus</i> spp,			
weasel			
<i>Lepus americanus</i>	3	3	5
TOTAL (excluding hares)	8	8	33
GRID C			
<i>M. gapperi</i>	5	4	7
<i>M. longicaudus</i>			
<i>M. pennsylvanicus</i>			
<i>P. intermedius</i>			
<i>P. maniculatus</i>			
<i>T. amoenus</i>			
<i>Sorex</i> spp.			
<i>Zapus</i> spp,			
weasel			
<i>Lepus americanus</i>	2	1	
TOTAL (excluding hares)	5	4	7
GRID D			
<i>M. gapperi</i>			1
<i>M. longicaudus</i>			
<i>M. pennsylvanicus</i>		1	
<i>P. intermedius</i>			1
<i>P. maniculatus</i>	16	14	18
<i>T. amoenus</i>			
<i>Sorex</i> spp.		1	8
<i>Zapus</i> spp,			
weasel			
TOTAL	16	16	28
GRID E			
<i>M. gapperi</i>	4	12	11

<i>M. longicaudus</i>			
<i>M. pennsylvanicus</i>			
<i>P. intermedius</i>			
<i>P. maniculatus</i>	4	9	5
<i>T. amoenus</i>			
<i>Sorex</i> spp.		1	
<i>Zapus</i> spp,			
weasel	1		
TOTAL	8	22	16

Table 14. Numbers of small mammals captured in three MPB-killed stands (A, B, and C), unspaced live stand (D), and uncut forest (E) at the Kamloops project area in 2008.

Grid and Species	Dates				
	21 May	17 June	15 July	9 Aug.	11 Sept.
GRID A					
<i>M. gapperi</i>		2	4	3	8
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>					
<i>T. amoenus</i>		2	4	2	6
<i>Sorex</i> spp.				5	5
<i>Zapus</i> spp,					
Weasel family					1
TOTAL	0	4	8	10	20
GRID B					
<i>M. gapperi</i>		5	8	4	7
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>				2	3
<i>P. intermedius</i>					
<i>P. maniculatus</i>					
<i>T. amoenus</i>				1	2
<i>Sorex</i> spp.					3
<i>Zapus</i> spp,					
Weasel family					
TOTAL	0				
GRID C					
<i>M. gapperi</i>		4	8	5	8
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					

<i>P. intermedius</i>					
<i>P. maniculatus</i>					
<i>T. amoenus</i>		3	2	1	4
<i>Sorex</i> spp.				2	1
<i>Zapus</i> spp,					
Weasel family					
TOTAL	0	7	10	8	13
GRID D					
<i>M. gapperi</i>		5	7	7	10
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>					
<i>T. amoenus</i>		1	3		1
<i>Sorex</i> spp.					2
<i>Zapus</i> spp,					
Weasel family					
TOTAL	0	6	10	7	13
GRID E					
<i>M. gapperi</i>	1	15	6	9	19
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>					
<i>T. amoenus</i>			6	2	1
<i>Sorex</i> spp.					6
<i>Zapus</i> spp,					
Weasel family					
TOTAL	1	15	9	11	26

Table 15. Numbers of small mammals captured in three MPB-killed stands (A, B, and C), unspaced live stand (D), and uncut forest (E) at the Penticton project area in 2008.

Grid and Species	Dates				
	22 May	19 June	17 July	14 Aug.	12 Sept.
GRID A					
<i>M. gapperi</i>	1				
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>		3	4	1	2
<i>T. amoenus</i>	1	4	2	4	3
<i>Sorex</i> spp.				3	1
<i>Zapus</i> spp,					
Weasel family					
TOTAL	2	7	6	8	6
GRID B					
<i>M. gapperi</i>					
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>	1	1	1	2	2
<i>T. amoenus</i>	1	4	1	6	5
<i>Sorex</i> spp.					2
<i>Zapus</i> spp,					
Weasel family					
TOTAL	2	5	2	8	9
GRID C					
<i>M. gapperi</i>		2	1		
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>	1	2	2	1	3
<i>T. amoenus</i>		7	5	5	9
<i>Sorex</i> spp.					1
<i>Zapus</i> spp,					
Weasel family					
TOTAL		11	8	6	13
GRID D					
<i>M. gapperi</i>	1	2		2	
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					

<i>P. intermedius</i>					
<i>P. maniculatus</i>	2	3	1	5	6
<i>T. amoenus</i>	2	6	5	5	6
<i>Sorex</i> spp.					
<i>Zapus</i> spp.					
Weasel family					
TOTAL	5	11	6	12	12
GRID E					
<i>M. gapperi</i>	4	6	1	2	3
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>				1	
<i>T. amoenus</i>		5	5	4	3
<i>Sorex</i> spp.			1		3
<i>Zapus</i> spp.					
Weasel family					
TOTAL	4	11	7	7	9

Table 16. Numbers of small mammals captured in three MPB-killed stands (A, B, and C), salvage clearcut (D), and uncut forest (E) at the Dunkley project area in 2009.

Grid and Species	Dates				
	21 May	23 June	17 July	13 Aug.	09 Sept.
GRID A					
<i>M. gapperi</i>		1			1
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>	7	22	24	24	20
<i>T. amoenus</i>					
<i>Sorex</i> spp.	3	9	21	14	14
<i>Zapus</i>		1			
weasel					1
<i>Lepus americanus</i>	3	4		6	7
TOTAL (excluding hares)	10	33	45	38	36
GRID B					
<i>M. gapperi</i>	1	5	5	15	14
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>				1	3
<i>P. intermedius</i>					
<i>P. maniculatus</i>		1	2	7	8

<i>T. amoenus</i>				
<i>Sorex</i> spp.		4	20	14
<i>Zapus</i> spp, weasel		13		3
<i>Lepus americanus</i>	6	1		1
TOTAL (excluding hares)	1	13	27	28

GRID C

<i>M. gapperi</i>		6	5	12	11
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>			1	3	7
<i>P. intermedius</i>					
<i>P. maniculatus</i>					
<i>T. amoenus</i>					
<i>Sorex</i> spp.	3	1	10	6	7
<i>Zapus</i> spp, weasel					
<i>Lepus americanus</i>	2		1	1	
TOTAL (excluding hares)	3	7	16	21	25

Dates

Grid and Species	21 May	23 June	17 July	13 Aug.	09 Sept.
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GRID D

<i>M. gapperi</i>					
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>		6	3	1	1
<i>P. intermedius</i>			1		
<i>P. maniculatus</i>			2		4
<i>T. amoenus</i>					3
<i>Sorex</i> spp.	1	16	13	19	10
<i>Zapus</i> spp, weasel					1
TOTAL	1	22	19	20	19

GRID E

<i>M. gapperi</i>				3	4
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>				1	1
<i>P. intermedius</i>					
<i>P. maniculatus</i>		13	11	9	13
<i>T. amoenus</i>					
<i>Sorex</i> spp.	2	1	26	18	11
<i>Zapus</i> spp, weasel					
TOTAL	2	14	37	31	29

Table 17. Numbers of small mammals captured in three MPB-killed stands (A, B, and C), salvage clearcut (D), and uncut forest (E) at the Prince George project area in 2009.

Grid and Species	Dates				
	23 May	21 June	13 July	15 Aug.	11 Sept.
GRID A					
<i>M. gapperi</i>	2	9	10	11	25
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>			1	5	8
<i>P. intermedius</i>					
<i>P. maniculatus</i>	2	1			
<i>T. amoenus</i>					
<i>Sorex</i> spp.		8	3	8	4
<i>Zapus</i> spp, weasel					
<i>Lepus americanus</i>				1	
TOTAL (excluding hares)	4	18	14	24	37
GRID B					
<i>M. gapperi</i>		3	12	19	28
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>			6	15	13
<i>P. intermedius</i>					
<i>P. maniculatus</i>		1		1	1
<i>T. amoenus</i>					
<i>Sorex</i> spp.	1	1	7	5	5
<i>Zapus</i> spp, weasel					
<i>Lepus americanus</i>	3			6	2
TOTAL (excluding hares)	1	5	25	40	47
GRID C					
<i>M. gapperi</i>	3	7	10	14	28
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>				8	5
<i>P. intermedius</i>					
<i>P. maniculatus</i>	2	3		5	2
<i>T. amoenus</i>	2		2	1	3
<i>Sorex</i> spp.		1	6	2	3
<i>Zapus</i> spp, weasel					1
<i>Lepus americanus</i>	2	1	1	3	5
TOTAL (excluding hares)	7	11	18	30	42

Grid and Species	Dates				
	23 May	21 June	13 July	15 Aug.	11 Sept.
GRID D					
<i>M. gapperi</i>		2	4	5	1
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>		1	1	4	1
<i>P. intermedius</i>				2	
<i>P. maniculatus</i>	3	3	8	5	
<i>T. amoenus</i>	4	1	6	4	
<i>Sorex</i> spp.	2	1	4	7	
<i>Zapus</i> spp, weasel					
TOTAL	9	8	23	27	2
GRID E					
<i>M. gapperi</i>	6	13	8	14	26
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					1
<i>P. intermedius</i>					
<i>P. maniculatus</i>					
<i>T. amoenus</i>					
<i>Sorex</i> spp.			1	8	1
<i>Zapus</i> spp, weasel					
TOTAL	6	13	9	22	28

Table 18. Numbers of small mammals captured in the three MPB-killed stands (A, B, and C), salvage clearcut (D), and uncut forest (E) at the Vanderhoof project area in 2009.

Grids and Species	Dates				
	25 May	19 June	11 July	17 Aug.	13 Sept.
GRID A					
<i>M. gapperi</i>	2	5	10	9	22
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>			3		2
<i>P. intermedius</i>					
<i>P. maniculatus</i>	1	5	5	2	10
<i>T. amoenus</i>					
<i>Sorex</i> spp.				1	1
<i>Zapus</i> spp, weasel					

<i>Lepus americanus</i>			1		1
TOTAL (excluding hares)	3	10	18	12	35
GRID B					
<i>M. gapperi</i>	6	5	11	12	24
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>				3	4
<i>P. intermedius</i>				1	
<i>P. maniculatus</i>			1		1
<i>T. amoenus</i>	2	3	14	7	2
<i>Sorex</i> spp.			7	3	4
<i>Zapus</i> spp, weasel					
<i>Lepus americanus</i>	3	3	5	5	4
TOTAL (excluding hares)	8	8	33	26	35
GRID C					
<i>M. gapperi</i>	5	4	7	15	15
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>					
<i>T. amoenus</i>					
<i>Sorex</i> spp.				1	1
<i>Zapus</i> spp, weasel					
<i>Lepus americanus</i>	2	1			2
TOTAL (excluding hares)	5	4	7	16	16

Grids and Species	Dates				
	25 May	19 June	11 July	17 Aug.	13 Sept.
GRID D					
<i>M. gapperi</i>			1	2	2
<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>		1		3	2
<i>P. intermedius</i>			1		
<i>P. maniculatus</i>	16	14	18	26	35
<i>T. amoenus</i>					
<i>Sorex</i> spp.		1	8	3	8
<i>Zapus</i> spp, weasel					
TOTAL	16	16	28	34	47
GRID E					
<i>M. gapperi</i>	4	12	11	8	37

<i>M. longicaudus</i>					
<i>M. pennsylvanicus</i>					
<i>P. intermedius</i>					
<i>P. maniculatus</i>	4	9	5	4	9
<i>T. amoenus</i>					1
<i>Sorex</i> spp.		1		1	1
<i>Zapus</i> spp,					
weasel	1				
TOTAL	8	22	16	13	48

Appendix C

Table 19. Mean ($\pm$ 95% CI) number of seedlings clipped (TC = terminally clipped; LC = laterally clipped) by snowshoe hares (*Lepus americanus*) and voles (*Microtus* spp. and *Clethrionomys* spp.) in four young stands killed by MPB in the NIFR for 2007.

Study Site	Plot	Tree Tag #	Species	Damage 2006	Damage 2007
93G043-524	1	1	Sx	no	Hare TC
	1	2	Sx	Hare TC	Hare TC/LC
	1	3	Sx	Hare TC	Hare TC
	1	4	Sx	Hare TC	Hare TC
	2	5	Sx	no	no
	2	6	Sx	no	Hare TC
	2	7	Sx	no	Hare TC
	2	8	Fd	no	Hare TC
	3	9	Sx	no	Hare TC
	3	10	Fd	no	no
	3	11	Sx	no	Hare TC
	3	12	Sx	Hare TC	Hare TC
	4	13	Sx	no	Hare TC
	4	14	Sx	no	no
	4	15	Sx	no	no
	4	16	Sx	no	Hare TC
	5	17	Fd	no	Hare TC
	5	18	Fd	no	no
	5	19	Fd	no	Hare TC
	5	20	Fd	no	no
	6	21	Sx	no	Hare TC/LC
	6	22	Sx	no	Hare TC/LC
	6	23	Sx	no	Hare TC
	6	24	Sx	no	no
	7	25	Sx	no	no
	7	26	Sx	no	no
	7	27	Sx	no	Hare TC
	7	28	Sx	no	no
	8	29	Sx	no	no
	8	30	Sx	no	Hare TC
	8	31	Sx	no	no
	8	32	Sx	no	no
	9	33	Sx	no	no
	9	34	Sx	no	no
	9	35	Sx	no	no
	9	36	Sx	no	no
	10	37	Sx	no	no
	10	38	Sx	no	Hare TC/LC
	10	39	Sx	no	Hare TC
	10	40	Sx	no	Hare TC

11	41	Sx	no	Hare TC
11	42	Sx	no	Hare TC
11	43	Sx	no	no
11	44	Sx	no	Hare TC/LC
12	45	Sx	no	no
12	46	Sx	no	Hare TC/LC
12	47	Sx	no	no
12	48	Sx	no	no
13	49	Fd	no	no
13	50	Sx	no	no
13	51	Sx	no	no
13	52	Sx	no	no
14	53	Sx	no	Hare TC
14	54	Sx	Hare TC	Hare TC
14	55	Sx	no	Hare TC
14	56	Sx	Hare TC	Hare TC
15	57	Sx	no	no
15	58	Sx	no	no
15	59	Sx	no	no
15	60	Sx	no	Hare TC/LC
16	61	Sx	no	Hare TC
16	62	Sx	no	Hare TC
16	63	Sx	no	no
16	64	Sx	no	Hare TC
17	65	Fd	no	Hare TC
17	66	Sx	no	no
17	67	Sx	no	no
17	68	Fd	no	Hare TC
18	69	Fd	no	Hare TC
18	70	Sx	no	Hare TC
18	71	Fd	no	no
18	72	Sx	no	no
19	73	Sx	no	Hare TC
19	74	Sx	no	no
19	75	Fd	no	no
19	76	Sx	no	Hare TC
20	77	Sx	no	Hare TC
20	78	Fd	no	no
20	79	Sx	no	Hare TC
20	80	Sx	no	no
21	81	Sx	no	no
21	82	Sx	no	Hare TC
21	83	Sx	no	no
21	84	Sx	no	no
22	85	Sx	no	Hare TC
22	86	Sx	no	Hare TC
22	87	Sx	no	Hare TC
22	88	Sx	no	Hare TC
23	89	Sx	no	Hare TC

	23	90	Sx	no	Hare TC
	23	91	Fd	no	no
	23	92	Sx	no	Hare TC
	24	93	Fd	no	Hare TC
	24	94	Sx	no	Hare TC
	24	95	Sx	no	no
	24	96	Sx	no	no
	25	97	Sx	no	Hare TC
	25	98	Sx	no	no
	25	99	Sx	no	Hare TC
	25	100	Sx	no	no
93G056-030	1	1	Sx	Hare TC	Hare TC
	1	2	Fd	no	no
	1	3	Fd	Vole TC	Vole TC
	1	4	Sx	no	Hare TC/LC
	2	5	Sx	Hare TC	Hare TC
	2	6	Sx	no	Hare TC
	2	7	Sx	no	Hare TC/LC
	2	8	Sx	no	Hare TC
	3	9	Sx	Hare TC	Hare TC
	3	10	Sx	Hare TC	Hare TC
	3	11	Sx	no	Hare TC
	3	12	Sx	Hare TC	Hare TC
	4	13	Sx	no	Hare TC
	4	14	Sx	no	Hare TC
	4	15	Sx	Hare TC	Hare TC
	4	16	Sx	no	Hare TC
	5	17	Sx	no	Hare TC
	5	18	Sx	no	Hare TC
	5	19	Sx	Hare TC	Hare TC
	5	20	Sx	Hare TC	Hare TC
	6	21	Sx	Hare TC	Hare TC
	6	22	Sx	Hare TC	Hare TC
	6	23	Sx	Hare TC	Hare TC
	6	24	Sx	no	Hare TC
	7	25	Sx	no	Hare TC
	7	26	Sx	no	Hare TC
	7	27	Sx	no	Hare TC
	7	28	Sx	no	Hare TC
	8	29	Sx	no	Hare TC
	8	30	Sx	no	Hare TC
	8	31	Fd	no	Hare TC
	8	32	Sx	no	Hare TC
	9	33	Sx	no	Hare TC/LC
	9	34	Sx	no	Hare TC
	9	35	Sx	no	Hare TC
	9	36	Sx	no	Hare TC
	10	37	Sx	no	Hare TC

10	38	Sx	no	Hare TC
10	39	Sx	no	Hare TC
10	40	Sx	no	Hare TC
11	41	Sx	no	Hare TC
11	42	Sx	no	Hare TC
11	43	Sx	no	Hare TC
11	44	Sx	Hare TC	Hare TC
12	45	Sx	no	Hare TC
12	46	Sx	Hare TC	Hare TC
12	47	Sx	no	Hare TC
12	48	Fd	Hare TC	Hare TC
13	49	Sx	Hare TC	Hare TC
13	50	Sx	Hare TC	Hare TC
13	51	Sx	Hare TC	Hare TC
13	52	Sx	Hare TC	Hare TC
14	53	Sx	no	Hare TC
14	54	Sx	no	Hare TC
14	55	Sx	no	Hare TC/LC
14	56	Sx	no	Hare TC
15	57	Sx	no	Hare TC
15	58	Sx	Hare TC	Hare TC
15	59	Sx	Hare TC	Hare TC
15	60	Sx	Hare TC	Hare TC
16	61	Sx	no	Hare TC
16	62	Sx	Hare TC	Hare TC
16	63	Sx	Hare TC	Hare TC
16	64	Sx	no	Hare TC
17	65	Sx	Hare TC	Hare TC
17	66	Fd	no	Hare TC
17	67	Sx	Hare TC	Hare TC
17	68	Sx	Hare TC	Hare TC
18	69	Sx	no	Hare TC
18	70	Fd	no	Hare TC
18	71	Sx	no	Hare TC
18	72	Fd	no	Hare TC
19	73	Sx	Hare TC	Hare TC
19	74	Fd	Hare TC	Hare TC
19	75	Sx	Hare TC	Hare TC
19	76	Sx	Hare TC	Hare TC
20	77	Sx	Vole TC	Vole TC
20	78	Sx	Hare TC	Hare TC
20	79	Fd	no	Hare TC
20	80	Sx	no	Hare TC
21	81	Sx	no	Hare TC
21	82	Sx	no	Hare TC
21	83	Sx	no	Hare TC
21	84	Sx	no	Hare TC
22	85	Sx	Hare TC	Hare TC/LC
22	86	Sx	no	Hare TC

	22	87	Sx	no	Hare TC
	22	88	Sx	no	Hare TC
	23	97	Sx	no	Hare TC
	23	98	Sx	Hare TC	Hare TC
	23	99	Fd	no	Hare TC
	23	100	Sx	no	Hare TC
				Hare TC +	
	24	93	Sx	LC	Hare TC
	24	94	Sx	Hare TC	Hare TC
	24	95	Sx	Hare TC	Hare TC
				Hare TC +	
	24	96	Sx	LC	Hare TC
	25	89	Sx	no	Hare TC
	25	90	Sx	no	Hare TC
	25	91	Sx	no	Hare TC
	25	92	Sx	Hare TC	Hare TC
93G065-035	1	1	PI	no	Hare TC
	1	2	Sx	no	Hare TC
	1	3	Sx	no	Hare TC
	1	4	PI	no	Hare TC
	2	5	Sx	no	Hare TC
	2	6	Sx	no	Hare TC
	2	7	Sx	no	Hare TC
	2	8	Sx	no	Hare TC
	3	9	PI	no	Hare TC
	3	10	PI	no	Hare TC
	3	11	PI	no	Hare TC
	3	12	Sx	no	Hare TC
	4	13	Sx	no	Hare TC
	4	14	PI	no	Hare TC
	4	15	Sx	no	no
	4	16	Sx	no	no
	5	17	Sx	no	no
	5	18	Sx	no	Hare TC
	5	19	Sx	no	no
	5	20	Sx	no	no
	6	21	Sx	no	Hare TC
	6	22	Sx	no	Hare TC
	6	23	Sx	no	Hare TC
	6	24	Sx	no	Hare TC/LC
	7	25	Sx	no	Hare TC
	7	26	Sx	no	Hare TC
	7	27	PI	no	Hare TC
	7	28	PI	no	no
	8	29	Sx	no	Hare TC
	8	30	Sx	no	Hare TC
	8	31	Sx	no	Hare TC
	8	32	Sx	no	no
	9	33	Sx	no	Hare TC

9	34	Sx	no	no
9	35	PI	no	Hare TC
9	36	Sx	no	no
10	37	Sx	no	Hare TC
10	38	Sx	no	Hare TC
10	39	Sx	no	Hare TC
10	40	PI	no	Hare TC
11	41	Sx	no	Hare TC/LC
11	42	Sx	no	Hare TC
11	43	Sx	no	Hare TC
11	44	Sx	no	Hare TC
12	45	Fd	no	no
12	46	Sx	no	Hare TC
12	47	Sx	no	no
12	48	Sx	no	Hare TC/LC
13	49	Sx	no	Hare TC
13	50	Sx	no	Hare TC
13	51	Sx	no	no
13	52	Sx	no	Hare TC
14	53	PI	no	Hare TC/LC
14	54	Sx	no	no
14	55	Sx	no	Hare TC/LC
14	56	Sx	no	Hare TC
15	57	Sx	no	no
15	58	Sx	no	Hare TC
15	59	Sx	no	Hare TC
15	60	Sx	no	Hare TC
16	61	Sx	no	no
16	62	Sx	no	Hare TC
16	63	Sx	no	Hare TC
16	64	Sx	no	no
17	65	Sx	no	Hare TC/LC
17	66	Sx	no	no
17	67	Sx	no	Hare TC
17	68	Sx	no	Hare TC
18	69	PI	no	Hare TC
18	70	PI	no	Hare TC
18	71	PI	no	Hare TC
18	72	Sx	no	Hare TC
19	73	PI	no	Hare TC
19	74	PI	no	Hare TC
19	75	Sx	no	no
19	76	PI	no	Hare TC
20	77	PI	no	no
20	78	Sx	no	no
20	79	PI	no	no
20	80	Sx	no	no
21	81	Sx	no	Hare TC
21	82	Sx	no	Hare TC

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	21	83	Sx	no	Hare TC
	21	84	Sx	no	Hare TC
	22	85	Sx	no	Hare TC/LC
	22	86	PI	no	Hare TC
	22	87	PI	no	Hare TC
	22	88	Sx	no	Hare TC
	23	89	PI	Hare TC	Hare TC
	23	90	Sx	no	Hare TC
	23	91	Sx	no	Hare TC
	23	92	PI	no	Hare TC
	24	93	Sx	no	Hare TC
	24	94	Sx	no	Hare TC
	24	95	Sx	no	Hare TC
	24	96	Sx	no	Hare TC
	25	97	Sx	no	Hare TC
	25	98	Sx	no	no
	25	99	Sx	no	Hare TC
	25	100	PI	no	Hare TC
92G042	1	1	Sx	no	no
	1	2	Sx	no	no
	1	3	Sx	no	no
	1	4	Sx	no	no
	2	5	PI	no	no
	2	6	Sx	no	no
	2	7	Sx	no	Hare TC/LC
	2	8	PI	no	Hare TC
	3	9	Sx	no	no
	3	10	PI	no	no
	3	11	PI	no	no
	3	12	Sx	no	no
	4	13	Sx	no	no
	4	14	PI	no	no
	4	15	PI	no	no
	4	16	PI	no	Hare LC
	5	17	Sx	no	no
	5	18	PI	no	no
	5	19	Sx	no	no
	5	20	Sx	no	no
	6	21	PI	no	no
	6	22	PI	no	no
	6	23	Sx	no	no
	6	24	PI	no	no
	7	25	Sx	no	no
	7	26	Sx	no	no
	7	27	PI	no	no
	7	28	PI	no	no
	8	29	Sx	no	Hare TC
	8	30	Sx	no	no

8	31	Sx	no	no
8	32	PI	no	no
9	33	Sx	no	no
9	34	PI	no	no
9	35	Sx	no	no
9	36	Sx	no	Hare TC
10	37	Sx	no	no
10	38	Sx	no	no
10	39	PI	no	Hare TC
10	40	PI	no	no
11	41	PI	no	no
11	42	PI	no	Hare TC
11	43	Sx	no	no
11	44	PI	no	no
12	45	Sx	no	no
12	46	PI	no	no
12	47	PI	no	Hare TC
12	48	Sx	no	Hare TC
13	49	PI	no	Hare TC
13	50	Sx	no	no
13	51	PI	no	Hare TC
13	52	PI	no	Hare TC
14	53	PI	no	Hare TC
14	54	PI	no	no
14	55	PI	no	no
14	56	Sx	no	no
15	57	PI	no	no
15	58	PI	no	no
15	59	Sx	no	no
15	60	Sx	no	no
16	61	Sx	no	no
16	62	Sx	no	no
16	63	Sx	no	no
16	64	Sx	no	no
17	65	PI	no	no
17	66	PI	no	no
17	67	PI	no	no
17	68	PI	no	no
18	69	PI	no	Hare TC
18	70	PI	no	Hare TC
18	71	PI	no	no
18	72	PI	no	no
19	73	Sx	no	Hare TC
19	74	Sx	no	no
19	75	PI	no	Hare LC
19	76	PI	no	no
20	77	Sx	no	no
20	78	PI	no	no
20	79	PI	no	no

20	80	Sx	no	no
21	81	PI	no	no
21	82	PI	no	no
21	83	Sx	no	no
21	84	PI	no	no
22	85	PI	no	Hare TC
22	86	PI	no	Hare TC
22	87	PI	no	no
22	88	PI	no	no
23	89	PI	no	no
23	90	PI	no	Hare LC
23	91	PI	no	no
23	92	PI	no	no
24	93	Sx	no	no
24	94	Sx	no	no
24	95	Sx	no	no
24	96	PI	no	Hare TC
25	97	PI	no	Hare LC
25	98	PI	no	no
25	99	PI	no	Hare TC
25	100	PI	no	Hare TC
