Whitebark Pine Restoration in St'at'imc Territory

Project # COA-F17-W-1292

Prepared for: Fish and Wildlife Compensation Program

Prepared by: Randy Moody MSc, RPBio and Ken Wright on behalf of the Lillooet Tribal Council

Prepared with financial support of the Fish and Wildlife Compensation Program on behalf of its program partners BC Hydro, the Province of BC, Fisheries and Oceans Canada, First Nations and public stakeholders.

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Executive Summary

Whitebark pine is an endangered keystone species of high elevation ecosystems. It is an important food source of many species of wildlife, most notably the Grizzly Bear and Clark's Nutcracker (primary seed disperser). It is a blue-listed species in British Columbia and listed as endangered under the federal Species at Risk Act (SARA). It is endangered due to several agents including the introduced white pine blister rust caused by the fungus *Cronartium ribicola*, mountain pine beetle, fire, and climate change. The most effective means for whitebark pine recovery is through promoting the regeneration of blister rust resistant seedlings via planting.

This project aided in whitebark pine recovery through the following means: planting seedlings grown from potentially rust resistant parent trees, collecting additional seed, improving whitebark pine seedling production practices, identifying regional health trends, and by initiating work to determine how local Clark's Nutcrackers are utilizing whitebark pine forests and aiding in its recovery.

The most concrete action this project addressed was blister rust and fire impacts by planting putatively resistant seedlings in burned areas to expedite recovery on these sites. Putatively resistant seedlings are potentially rust resistant seedling that have not been confirmed through testing, but are suspected due to parent tree traits. It takes 40 years for a whitebark pine to produce cones, the sooner they are planted on these denuded sites the sooner they will begin functioning in the ecosystem.

This project aligns with action items in the Grizzly Bear Conservation Strategy - Implement relevant restoration activities suggested in the strategy – namely restoring compensatory habitat away from human activity to lower mortality risk; and restoring important forage such as whitebark pine. These actions also align with the provincial Grizzly Bear Conservation Strategy and the St’at’imc Resource Management Plan. Whitebak pine is an important food for grizzly bears in the region.

Michael Girard, an instructor at Vancouver Island University and a conifer growing consultant toured the Split Rock greenhouse facility on May 7, 2016. He noted that the seedlings are grown under a stressful environment and practices must be implemented to reduce stress related to: 1) high temperatures, 2) vapor pressure, 3) moisture stress, and 4) nutrient stress. Recommended practices included: 1) utilizing shade cloth, 2) misting, 3) use of an ammonium based fertilizer, and 4) extending photoperiod to 12-20 hours. A full version of the report is included in Appendix 1.

In September 2016, 2250 whitebark pine seedlings were planted in a burned area on Porcupine Ridge, in the Larochelle Drainage west of Lillooet. A total of 7.5 ha, of the originally planned 13.5 ha, was planted for a total planted density of 300 seedlings/ha (Figure 4). The entire area was not planted as the number of seedlings available for planting was lower than originally projected.

Health monitoring plots were established in six areas and complement the existing data on trends in Whitebark Pine vulnerability to the introduced pathogen White Pine Blister Rust. The Clark's nutcracker data indicate utilization in all stands (n=6) and a trend of greater nutcracker abundance where seed crops were highest. These data are being analyzed for using an occupancy modelling structure and will allow for comparisons with populations in the US.

All activities were successful and the level of community engagement in the Whitebark Pine planting effort was high. Special thanks to Vivian Birch-Jones (Lillooet Naturalist Society) and Kim North (Splitrock Nursery) for their dedication to this project. We also grateful to the Lillooet Tribal Council (Matt Manuel) many St'at'imc field technicians for their commitment to this critical restoration endeavour.

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1. Introduction

Whitebark pine (*Pinus albicaulis*) is a blue-listed species in British Columbia and listed as endangered under the Species at Risk Act (SARA) and the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (BCDC, 2002; COSEWIC, 2010). The following outlines a brief description of whitebark pine, its distribution and habitat, ecological importance, and threats.

The Clark's Nutcracker is a medium-sized member of the crow and jay family inhabiting coniferous forests of western North America. Although it is not currently listed as a species of concern, it is highly dependent on the seeds of Whitebark Pine for breeding success (Schaming 2015). Nutcrackers are also critical to the long-term survival of Whitebark Pine because they are the primary species to disperse their seeds through scatter-hoarding behaviour, ultimately leading to seedling germination. whitebark pine is very important for wildlife, particularly Clark's nutcracker, red squirrel, and grizzly and black bears. Whitebark pine seeds are highly nutritious, containing about 52% fat, 21% carbohydrates and 21% protein, which make them a prime choice to store as a winter food source for the nutcracker and red squirrel and provide a rich source of calories for bears building fat deposits for winter hibernation (Pigott, 2012).

1.1. Species Description

Whitebark pine is a long-lived species, surviving more than 500 years and occasionally greater than 1000 years (COSEWIC, 2010). Whitebark pine typically grows 5-20m tall with a rounded to irregular crown. Form is dependent on local site conditions and competition levels (COSEWIC, 2010). At treeline and on exposed sites, whitebark tends to take on a stunted and twisted form, ranging in height of 5-10m, whereas in lower elevation, closed-canopy forests, trees take on a straight form and grow up to 20m tall (COSEWIC, 2010).

Whitebark pine is one of three five-needled pines in BC, other species being western white pine (*Pinus monticola)* and limber pine (*Pinus flexilis*). Needles are 3-9cm in length and tend to clump towards the end of branches (COSEWIC, 2010; Parish, 1948). Pollen buds are visible in mid-June to mid-July and are raspberry red in colour, which is easily distinguishable from the yellow-orange pollen buds of western white pine, lodgepole pine, and limber pine (Pigott, 2012). Mature cones are egg-shaped to almost round, and are dark brown to purple in colour, ranging in size of 3-8cm in length. Cones are first produced when the tree is 30-50 years in age and a sizable crop is commonly not produced until the tree is 60-80 years in age (COSEWIC, 2010). Cone production also varies in years, experiencing no to very little production in some years and in others experiencing a mast cone production. Cones are permanently closed and require the bird, Clark's nutcracker (*Nucifraga columbiana*), to break open the cone and cache seeds for seed dispersal. The bark on young whitebark pine trees is thin, smooth, and chalky-white. As the tree ages the bark thickens and forms narrow, brown, scaly plates (COSEWIC, 2010).

The Clark's Nutcracker (Nucifraga columbiana) is a medium-sized (ca. 150 grams) member of the avian family Corvidae (Jays, Crows and Allies) that inhabits montane coniferous forests in western North America. One of three species of nutcrackers worldwide, this bird has remarkably co-evolved with a tree

- the Whitebark Pine (Pinus albicaulis), also restricted to montane regions of western North America. They have a gray body with distinctive white and black wings; sexes are similar with males averaging slightly larger than females (Figure 1). Clark's Nutcrackers have a long, straight and pointed bill—morphologically adapted for the extrication and consumption of conifer seeds (esp. Pinus sp.). The lower mandible even has an internal ridge to help crack open nuts.

Nutcrackers communicate vocally and are often heard giving their distinctive sharp "kraaa". This vocalization is used in flight and as a conspecific contact call and may be audible for > 1 km, facilitating detection during surveys.

Figure 1. Clark's nutcracker (Nucifraga columbiana) feeding on Whitebark Pine seeds, Porcupine Ridge, British Columbia. Photo courtesy of Ian Routley.

Distribution and Habitat

Whitebark pine grows on dry to moderately moist sites found in high elevation, upper subalpine habitats ranging from timberline to closed subalpine in western North America. Whitebark occurs most abundantly on drier, exposed south-facing slopes near treeline. Specifically, in Canada, whitebark pine reaches its northernmost extent at approximately 55°N in the Coast Mountains and at about 54°N in the Rocky Mountains between the British Columbia and Alberta border (Figure 2). Elevations vary in Canada, with trees commonly found at 1950m to 2250m at the Canada-USA border and from 1000m to 1600m in northcentral BC (COSEWIC, 2010).

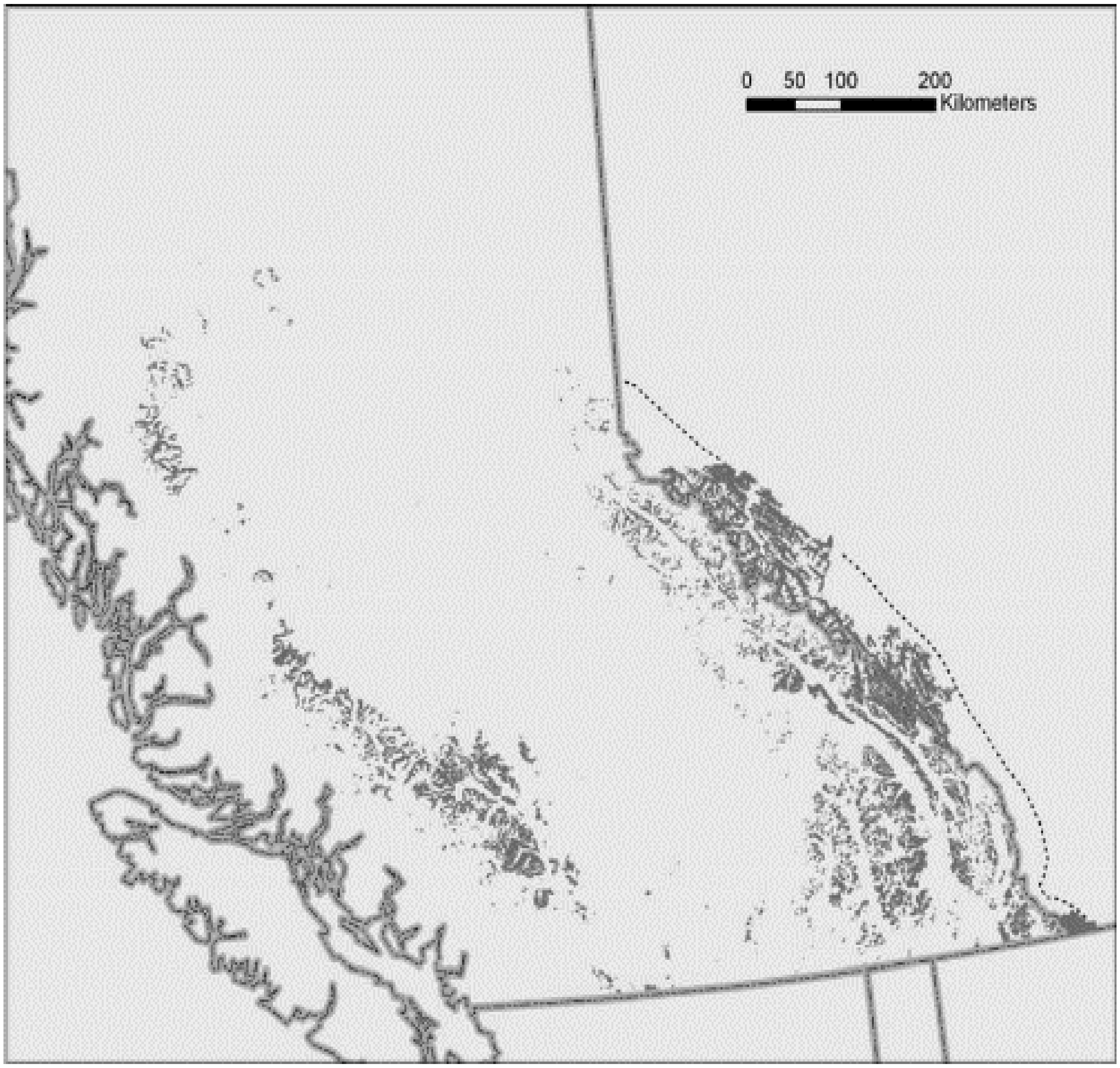

Figure 2. Canadian range of Whitebark Pine. Dotted line in Alberta indicates eastern edge of range (COSEWIC 2010).

Clark's Nutcrackers are distributed across western North America from Mexico to central British Columbia. They are primarily associated with montane coniferous forests in elevations ranging from 200 – 3500 m. Although non-migratory, nutcrackers will undertake seasonal altitudinal movements to exploit locally abundant seed crops. Figure 3 depicts the range of Clark's Nutcracker in relation to Whitebark and Ponderosa Pine.

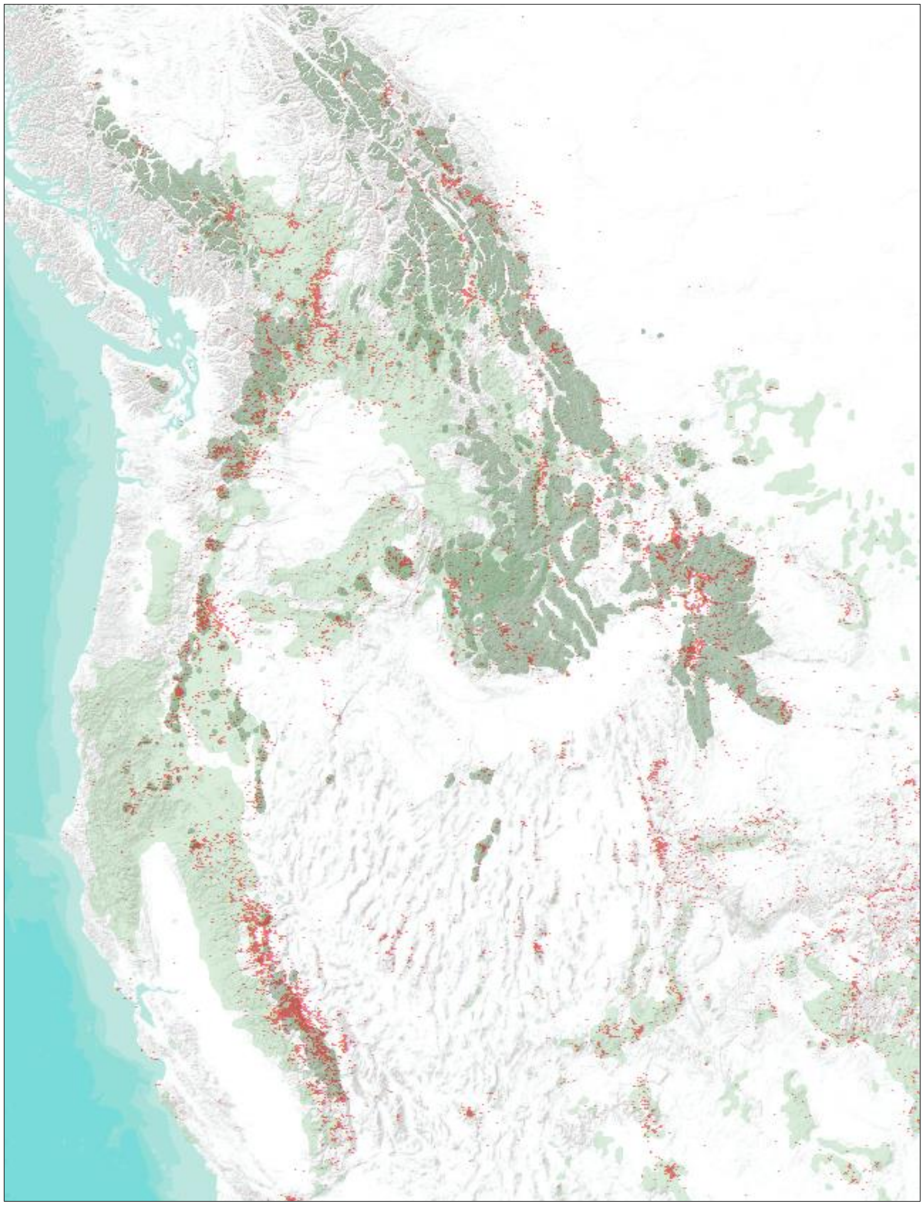

Figure 3. Clark's nutcracker range (red dots) overlayed on Whitebark Pine (dark green) and Ponderosa Pine (light green shading) in western North America. Map courtesy of Duane Griffin (Bucknell University).

Ecological Importance

Whitebark pine is classed as both a foundation and keystone species. It plays a very important ecological role, growing in some of the most inhospitable climates, tolerating high wind and snow, with relatively little soil or water (Pigott, 2012; COSEWIC, 2010). On these sites whitebark pine stabilizes soil and rock, reducing erosion; slows the progression of snowmelt, decreasing flooding at lower elevations; and facilitates the survival and growth of conifers and understory vegetation by creating favourable habitat for establishment (COSEWIC, 2010). Further, whitebark pine is very important for wildlife, particularly Clark's nutcracker, red squirrel, and grizzly and black bears. Whitebark pine seeds are highly nutritious, containing about 52% fat, 21% carbohydrates and 21% protein, which make them a prime choice to store as a winter food source for the nutcracker and red squirrel and provide a rich source of calories for bears building fat deposits for winter hibernation (Pigott, 2012).

Clark's Nutcrackers, like other members of the Corvid family are known as scatter-hoarders for their propensity to store abundant seed crops in spatially distributed cache sites across the landscape. As many of the caches are never recovered, this seed caching behaviour leads to mutualism, whereby the tree (ie, Whitebark Pine) benefits from the dispersal services provided by the nutcracker. The ecological consequences of this bird-pine mutualism are very profound indeed, setting the stage for a foundation ecosystem like no other in this part of the world.

1.2. Threats and Conservation Status

Despite its important ecological role, whitebark pine populations are rapidly declining, largely unchecked, due to four main agents:

1) **White Pine Blister Rust**
   White pine blister rust is caused by the fungus *Cronartium ribicola,* which was accidentally introduced to British Columbia in 1910 from Europe (Pigott, 2012). The fungus requires alternate hosts from the *Ribes* (currant and gooseberry), *Pedicularis* (lousewort), or *Castilleja* (Paintbrush) genera. Fungal spores are released from the alternate hosts in the spring and land on the needles of the tree (COSEWIC, 2010). The fungus enters through the stomata on the needles of the pine tree and travel down the branch to the main stem where it girdles and eventually kills the tree (Pigott, 2012).

2) **Mountain Pine Beetle**
   Mountain pine beetle (*Dendroctonus ponderosae*) can kill and reproduce in whitebark pine. Trees already weakened by white pine blister rust are more susceptible to mountain pine beetle attack (Alberta Whitebark and Limber Pine Recovery Team, 2014).

3) **Fire Suppression**
   Whitebark pine is a poor competitor. Under natural fire regimes, low intensity fires would burn through stands, removing the understory, which would allow whitebark pine to thrive (COSEWIC, 2010). As well, Clark's nutcracker uses burned sites for seed caching, allowing for rapid regeneration of whitebark pine (COSEWIC, 2010). Years of fire suppression have allowed shade tolerant species to dominate whitebark pine habitats, limiting whitebark's ability to establish and survive on sites.

4) **Climate Change**
   Increasing global temperatures will require whitebark pine to migrate to areas of suitable climate and adapt to changed climatic conditions or be extirpated (COSEWIC, 2010). Warming temperatures are expected to increase competition as lower elevation species migrate upslope which will increase tree stress, potentially making it more susceptible to blister rust and mountain pine beetle attack.

1.3. Restoration and Conservation Activities

To restore whitebark pine, a multi-pronged approach is required to address the multiple threats it faces. These approaches include: collecting seed and producing seedlings from plus trees, screening select seedlings for rust resistance, protecting against mountain pine beetle, prescribed burning for habitat creation, and experimenting with assisted migration to move whitebark to suitable habitats in response to climate change.

Confirming rust resistance in plus trees and producing and deploying seedlings to increase the frequency of these genes on the landbase is the primary route to whitebark pine recovery. Plus trees are defined as trees displaying greater fitness than their counterparts with respect to rust tolerance or resistance, in general these are the healthiest trees in highly infected stands. At present, seedlings produced from plus trees are defined as the best available stock and most likely to be rust resistant and are deployed as such. Not until long-term screening efforts confirm resistance, and seed orchards are established, will fully resistant stock be available.

Given the vastness of the range occupied by whitebark pine, delivering effective restoration will require a combination of paid work, volunteer efforts, and reliance on the Clark's Nutcracker to effectively disperse desirable genes throughout the range. This project combines direct human effort with a much-needed foray into understanding the role of the Clark's Nutcracker in whitebark pine recovery.

For this project, we initiated the following activities:

a. Plant seedlings grown from locally collected putatively resistant parent trees;
b. Hired a Nursery Consultant to train nursery staff to better undertake whitebark pine seedling production, as it is a novel species for most nurseries and growing methods are not yet well understood;
c. Collect additional seed to support future efforts; and
d. Initiate Clark's nutracker surveys to better understand its exploitation levels in a range of whitebark pine stands.

2. Goals and Objectives

This project will directly aid in recovery of whitebark pine by:

1) Planting seedlings grown from potentially rust resistant parent trees,
2) Improving capacity to locally produce whitebark pine seedlings,
3) Collecting additional seed, and by
4) Initiating work to determine how local Clark's Nutcrackers are utilizing whitebark pine forests and aiding in its recovery.

3. Study Area

The study area for 2016 work primarily included whitebark pine stands within both the Bridge and Seton watersheds; with one stand at Blustry Mountain outside of these drainages (Figure 4). For the activities described herein, cone collections and Clark's nutcracker surveys occurred at all six locations, and seedling planting only occurred at the Porcupine Ridge site.

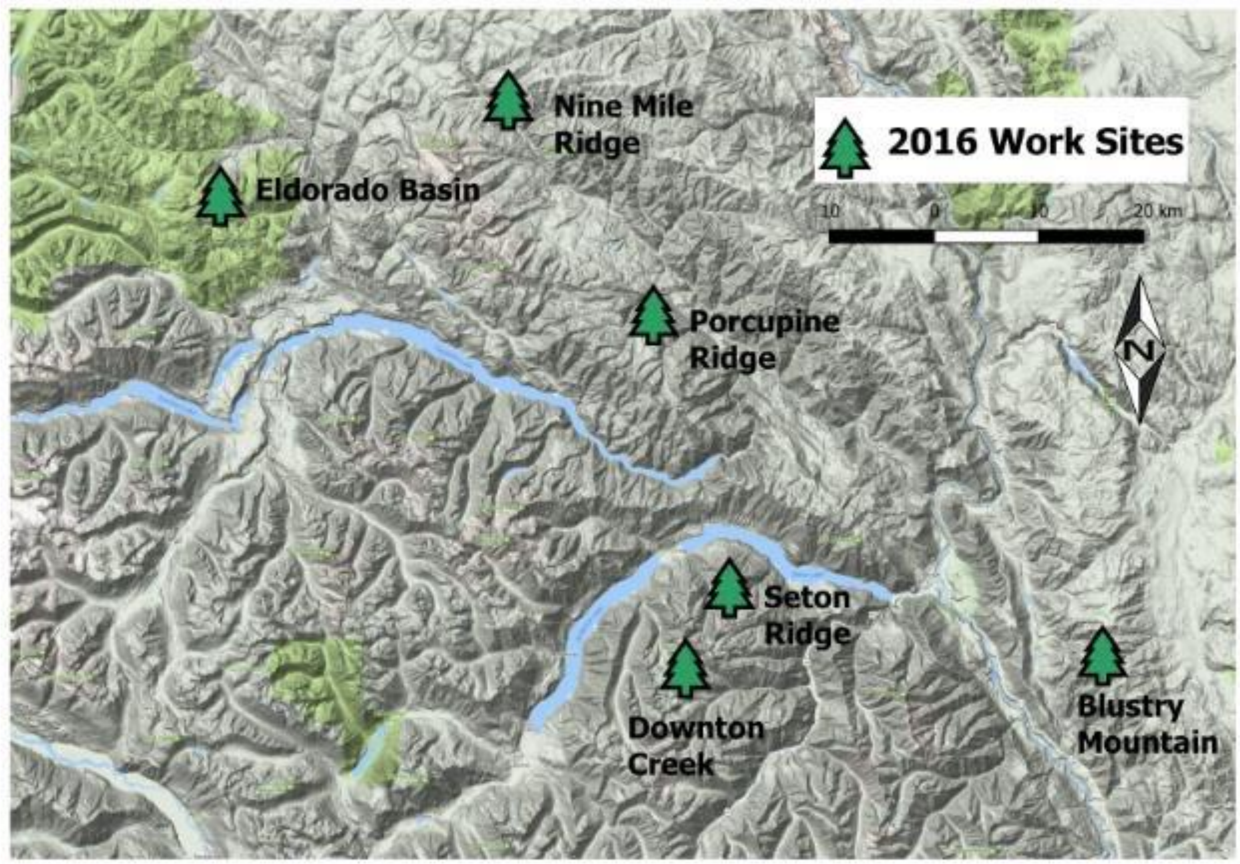

Figure 4. Locations of Whitebark Pine and Clark's Nutcracker Work in the Lillooet Region in 2016.

4. Methods

The methods and approach employed to implement this project were developed to address the main threats includes:

a) Train Nursery Staff: A conifer seedling consultant from Vancouver Island University was hired to work with Splitrock Staff on conifer production techniques to aid in producing more, and higher quality, whitebark pine seedlings.

b) Planting: Planting was implemented by first pre-surveying the proposed planting area on Porcupine Ridge in mid-summer. During this survey, features such as potential hazards, natural stocking levels, and logical planting boundaries were identified. The entire boundary of the planting unit was mapped with GPS and ribboned with flagging tape to identify the boundaries.

   Planting was conducted by a combination of paid planters and volunteers. To identify and recruit volunteer planters a public outreach event was held to educate interested individuals about whitebark pine and the Clark's nutcracker.

c) Seed Collection: Seed collections were conducted in stands not previously collected from to increase the diversity of seed collections. At each collection site cones were caged on the healthiest trees in early to mid-summer and retrieved in mid-September. This approach was required as seeds not caged would be consumed by wildlife by late summer. At each stand where a collection was conducted a rust monitoring plot was established to characterize and monitor the stand over time, monitoring methods are described in Smith et al. 2008.

d) Clark's Nutcracker Surveys: We conducted occupancy surveys using a 30-minute point count methodology at six different sites in the southern Coast Mountains, including the Cayoosh (2 sites), Clear, Chilcotin and Shulaps (2 sites) ranges. Surveys were conducted during two key phases of the Clark's Nutcracker life cycle:

    - Harvest period: when birds are actively exploiting Whitebark Pine stands to collect and cache seeds for later consumption (surveys Aug 3 - 31); and
    - Post-harvest period: this is when most of the harvesting of ripe cones has been completed and when birds may be accessing cache sites and (surveys Sep 23 - Oct 5)

    During each point count, we record every detection of a unique nutcracker in each of three 10-minute time blocks. This replicate sampling structure allows us to generate detection probability which is necessary for occupancy modelling. Point counts were located a minimum of 300 m apart and situated in Whitebark Pine habitat. We used a combination of trails, roadways/horse tracks and off-trail sites. Access to each study site required truck (Blustry Mountain, Downton, Nine Mile Ridge, Porcupine Ridge), helicopter (Seton Ridge) and horseback (Eldorado Basin). Due to logistical constraints and practicality, sites were mostly non-randomly chosen. In our study area, Whitebark Pine forests are generally confined to moderate to steep southerly aspects in a relatively narrow band (ca. 500 m) between Subalpine-fir, Engelmann Spruce and Lodgepole Pine forests below and alpine tundra above. Since we are specifically examining Clark's Nutcracker use of Whitebark Pine habitats, we believe there is minimal bias imposed by our non-randomly chosen sites.

    At each point count station we recorded the following information: start time, end time, meteorological data (temperature, wind direction/velocity, cloud cover, precipitation), elevation, latitude and longitude. For each bird detected we recorded estimated distance and azimuth from the observer, detection type (auditory, visual) and where possible, behaviour information (harvesting seeds, flyover, caching seeds, roosting, vocalizing).

    Our sampling methods conform with those used by Schaming (2016), and as such, will facilitate a large-scale comparison of nutcracker occupancy in western North America.

    In order to gain inference on the relationship between nutcracker occupancy and food availability, we also surveyed a subset of sites for cone abundance and other habitat characteristics.

3. Results

a) Nursery Consultant

Michael Girard, an instructor at Vancouver Island University and a conifer growing consultant toured the Split Rock greenhouse facility on May 7, 2016. He noted that the seedlings are grown under a stressful environment and practices must be implemented to reduce stress related to: 1) high temperatures, 2) vapor pressure, 3) moisture stress, and 4) nutrient stress. Recommended practices included: 1) utilizing shade cloth, 2) misting, 3) use of an ammonium based fertilizer, and 4) extending photoperiod to 12-20 hours. A full version of the report is included in Appendix 1.

b) Planting

In September 2016, 2250 whitebark pine seedlings were planted in a burned area on Porcupine Ridge, in the Larochelle Drainage west of Lillooet. A total of 7.5 ha, of the originally planned 13.5 ha, was planted for a total planted density of 300 seedlings/ha (Figure 5). The entire area was not planted as the number of seedlings available for planting was lower than originally projected.

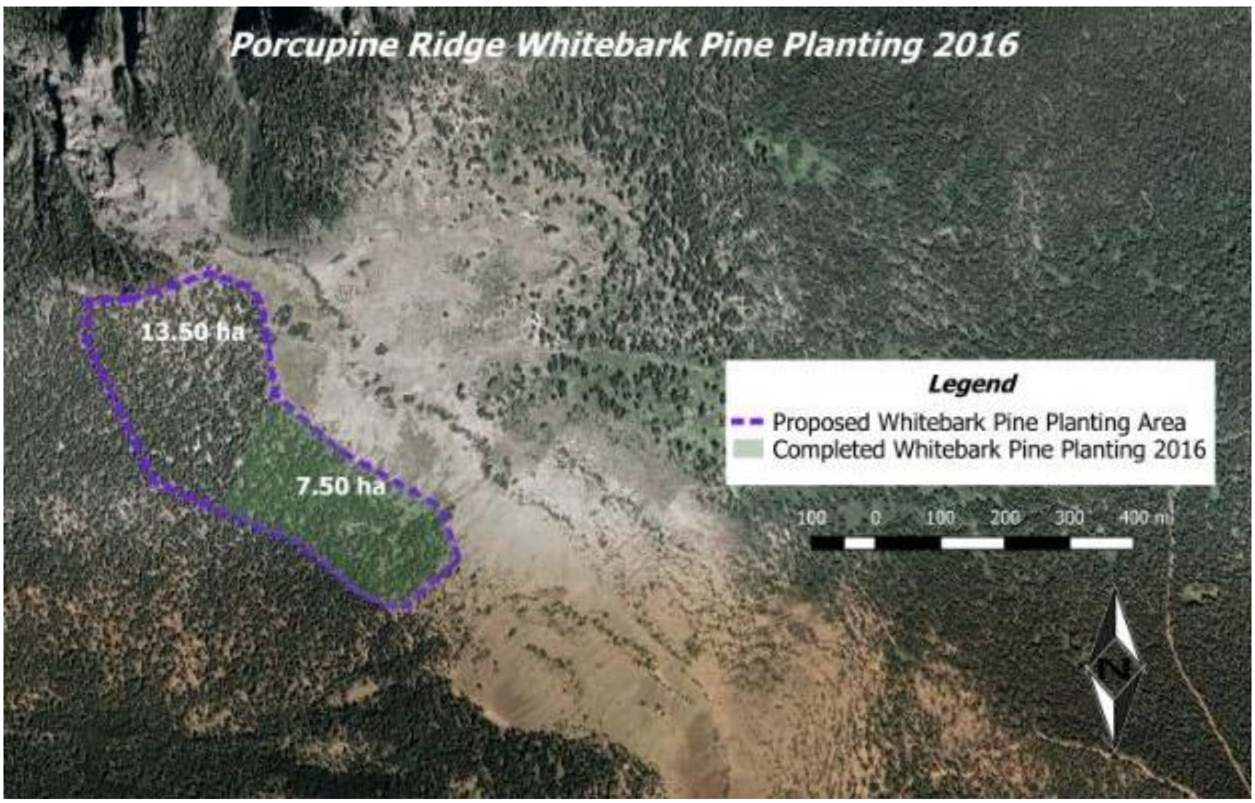

Figure 5. Map showing Porcupine Ridge planting area. Note just over half of proposed planting area was successfully planted in 2016.

A total of 25 planters assisted with the restoration planting event, most of these were volunteers (Figure 6). To encourage volunteers to participate in the planting event, a public outreach event was held the evening prior to planting, this event was attended by 35 residents of the Lillooet Region.

Figure 6. Volunteer planters preparing for planting on Porucpine Ridge; note dead whitebark pine forest in the background.

c) Seed Collections

Seed collections were conducted at six study locations (Figure 4, Table 1). Cones were caged in mid-summer and collected in early fall. Seed from each site were air dried and then extracted in November 2016. Most of these seeds are presently in storage, while seeds from Blustry, Eldorado Basin, and Nine Mile were entered into stratification for seedling production; these seedlings will be planted in 2018. The seeds in storage will be used for long-term planning of restoration activities in the region.

For cone collections in the South Chilcotin (Eldorado Basin) and Yalakom (Nine Mile Ridge) Provincial Parks, outreach signs were put on caged trees in visible locations (Figure 7). These signs were designed to educate the park visitors about the decline of whitebark pine and the recovery activities being implemented. Signs were placed on trees directly adjacent to the trail from a vantage point where the cone cages could be viewed. Signs were tied onto trees using clothesline to reduce impacts, and signs were removed when cones were collected.

Figure 7. Outreach sign on Nine Mile Ridge trail in Yalakom Provincial Park.

Table 1. Summary of seed amounts collected at each location.

Site	Tree Number	Grams of Seed
Downton Creek	1	33g
Downton Creek	2	19g
Downton Creek	3	36g
Downton Creek	5	48g
Downton Creek	6	38g
Downton Creek	7	57g
Downton Creek	8	33g
Downton Creek	9	51g
Downton Creek	10	35g
Porcupine Ridge	1	20g

Site	Tree Number	Grams of Seed
Porcupine Ridge	2	23g
Porcupine Ridge	3	29g
Porcupine Ridge	4	25g
Porcupine Ridge	5	28g
Porcupine Ridge	6	45g
Porcupine Ridge	7	24g
Porcupine Ridge	8	32g
Seton Ridge	1	24g
Seton Ridge	2	25g
Seton Ridge	3	24g
Seton Ridge	4	21g
Seton Ridge	5	14g
Seton Ridge	6	16g
Seton Ridge	7	8g
Nine Mile	1	25g
Nine Mile	2	8g
Nine Mile	3	10g
Nine Mile	4	8g
Nine Mile	5	1g
Nine Mile	6	2g
Nine Mile	7	2g
Nine Mile	8	2g
Nine Mile	9	7g
Nine Mile	10	1g
Blustry	862	12.5g
Blustry	863	20g
Blustry	864	31g
Blustry	865	6.5g
Blustry	866	10g
Blustry	867	11g
Blustry	868	19g
Blustry	869	20g

Site	Tree Number	Grams of Seed
Eldorado	1	6g
Eldorado	2	27g
Eldorado	870	16.5g
Eldorado	871	8.5g
Eldorado	872	34g
Eldorado	6	6g
Eldorado	7	17g
Eldorado	8	4g
Eldorado	9	9g
Eldorado	10	19g

At most locations where cone collections were conducted, a health plot was also established to inform seed users about the level of infection in the area and the status of the stand. These plots were permanently marked to be re-measured every 5-years to monitor changes to whitebark pine health in the region. At three locations (Blustry, Downton, and Porcupine Ridge) transects were already established in 2015, at two of the three remaining sites (Eldorado Basin, Nine Mile) new transects were established in 2016; no new transect was established at Seton Ridge due to heavy snow at the time of cone collection. At Eldorado, three transects were established, one along the Lick Trail, one directly above the basin and one just east of the basin towards the park boundary; and at Nine Mile Ridge two transects were established, one along the main trail and another in a basin to the east of the first transect.

When assessing health by percent of stems healthy, Porcupine (82%), Eldorado 2 (80%), and Downton (72%) were the three healthiest sites (Figure 8). When assessing by basal area, Porcupine remained the healthiest (73%) followed again by Eldorado 2 (68%), but Downton was replaced by Eldorado 1 (53%) as the third healthiest location by basal area analysis (Figure 8).

The unhealthiest stands by percent of stems were Lick (10%), Blustry (16%), and Nine Mile 1 (49%) (Figure 8). When assessed by Basal Area, the unhealthiest stands were Blustry (2%), Lick (12%), and Nine Mile 2 (19%) (Figure 8). When combined with plots established in 2015; the mean average for the region is 56% healthy (n=18).

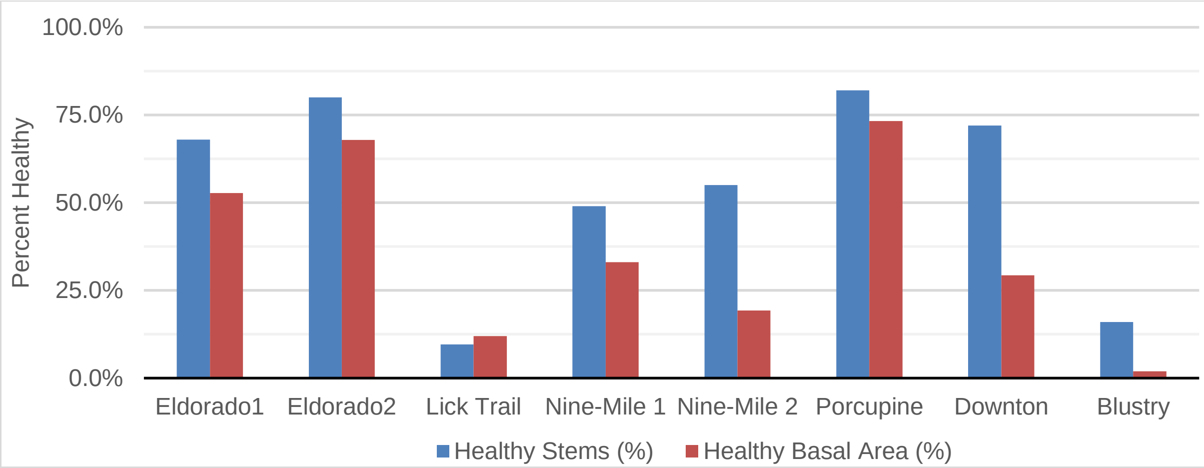

Figure 8. Summary of Whitebark Pine health at locations where cones were collected in 2016.

The future basal area on all sites is likely much lower when comparing the total basal area with the healthy basal area (Figure 9). Declines in basal area were greatest on the Lick Trail, Nine-Mile 1, and Blustry sites with healthy basal areas of 2.79 m^2/ha, 1.37m^2/ha, and 0.22m^2/ha respectively at each site.

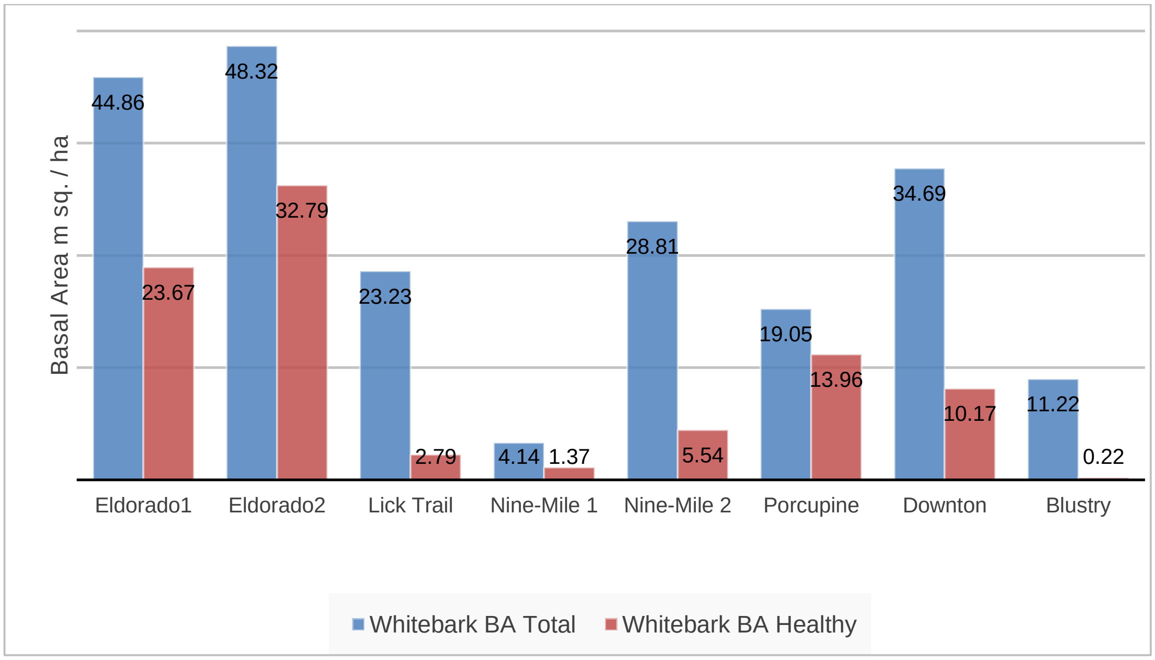

Figure 9. Summary of Basal Area totals for all Whitebark Pine trees and for healthy Whitebark Pine trees.

d) Clark's Nutcracker Surveys

We conducted a total of 65 point counts at 38 stations spread among the six study areas (**Error! Reference source not found.**, Table 2). More surveys were completed during the harvest period (n=38) than during the post-harvest period (n=27). Heavy snow showers in Downton prevented us from finishing two stations and the Seton Ridge survey (9 stations) was cancelled entirely due to an unanticipated snowfall event.

Table 2. Study sites and number of Clark's Nutcracker point count stations.

Site	# Point Count Stations
Blustry Mountain	3
Downton	8
Eldorado Basin	7
Nine Mile Ridge	5
Porcupine Ridge	6
Seton Ridge	9
Total	38

A total of 319 detections of Clark's Nutcrackers were made during our point counts. While Clark's Nutcrackers were observed at all sites, there was a significant bias in the number of detections, with 261 (82%) during the harvest period versus 58 (18%) during the post harvest period (Table 3, Figure 10, Appendix 2). Some of this can be explained by a difference in effort, but there was general decline in activity as the season progressed; further less long-distance observations were made, thus factors limiting long-distance detections may have affected results (Figure 11). Mean abundance varied among sites (Table 3), being highest on Blustry Mountain (9.33 birds/station) where the highest cone abundance was observed. Abundance was significantly higher during the harvest period (3.13 + 3.00 birds/station, n = 38) than post-harvest period (1.74 + 1.81 birds/station, n = 27), presumably because birds are more conspicuous while harvesting and hauling away seeds to cache sites. Although Blustry was the only site that appeared to be masting, other nodes of spatially-restricted (several trees) higher cone abundance (Downton, Porcupine Ridge) were evident and nutcrackers were using those sites. Nutcrackers were more scarce and variable at Eldorado Basin, Nine Mile Ridge and Seton Ridge where the cone crop was lower and more variable.

Table 3. Abundance of Clark's Nutcrackers in southern Coast Mountains; August – October, 2016.

	HARVEST[1]			POST HARVEST[2]		
Site	Mean	SD	*N*	Mean	SD	*N*
Blustry Mountain	9.33	1.15	3	1.11	1.53	3
Downton	4.38	1.17	8	0.83	0.75	6
Eldorado Basin	1.29	1.11	7	2.00	1.63	7
Nine Mile Ridge	3.60	0.89	5	4.20	2.17	5
Porcupine Ridge	1.50	0.55	6	0.50	0.84	6
Seton Ridge	2.22	1.56	9	-	-	-
All sites	3.13	3.00	38	1.74	1.81	27

[1]Aug 3-31,[2]Sep 23 - Oct 5

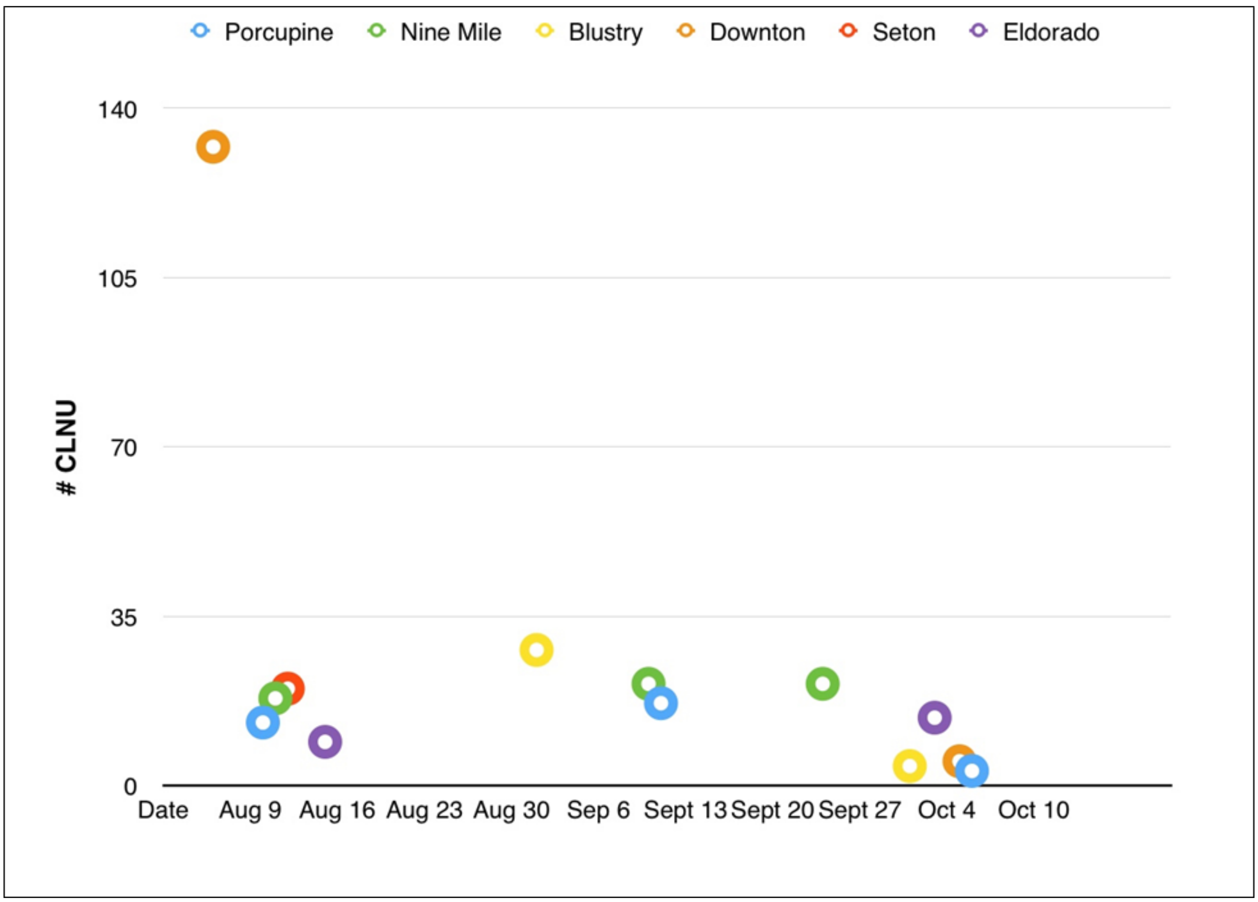

Figure 10. Seasonal pattern of Clark's Nutcracker abundance (pooled total birds observed at each survey site).

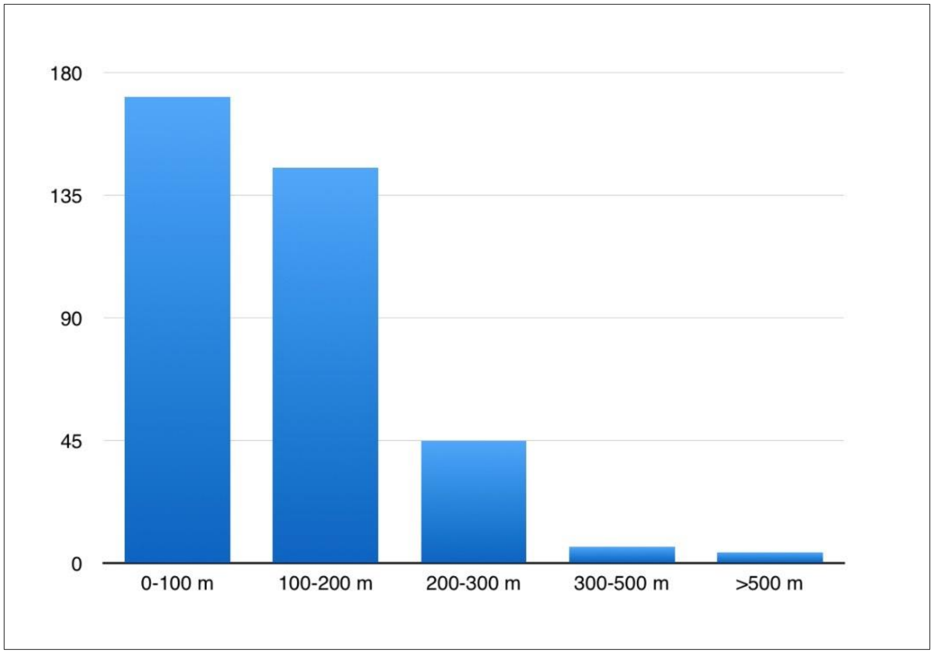

Figure 11. Detection distance of Clark's Nutcrackers with distance from observer category on the x-axis and number of observations on the y-axis.

4. Discussion

Establishing health monitoring plots, in conjunction with cone collections, is important for monitoring present day rust levels to relate to the potential rust resistance of the collected genetic material and for change monitoring over time. Rust transects provide stand level insights with minor details about each trees and cone collections provide greater details about a select few trees; by implementing both in the same stands, over-time we will have excellent documentation regarding changes to stand health and cone production.

The mean healthy level of whitebark pine in the region (56%) shows a promising trend that infection level increases may be slow; Zeglen (2002) reported an uninfected level in the region of 61%, thus there has been a net decrease in health of 5% over 14-years. This rate of infection increase (~ 0.4%/year) is lower than that reported in other regions where annual increases of 1.5-3.5 %/year have been reported (Smith et al. 2008).

Although regional trends are promising, a number of notable locations were well below the mean health levels; these areas are important for several reasons: i) these sites may serve as an indicator of future regional health trends; ii) cone collections should be preferentially conducted at these sites as it is likely there is increased selection pressure for rust-resistant seedlings; and iii) these areas may serve as ideal candidates for restoration activities given their much greater level of decline.

Although the percentage declines in number of trees and total basal area are important indicators of ecosystem decline, the change in absolute basal area is a more important indicator as it is directly linked to the ecosystem function. Barringer et al. (2012) found that the likelihood of a stand to see frequent visitation and seed dispersal by Clark's nutcracker's declined when basal area dropped below $2m^2$/ha; a level corresponding to the production of 1,000 cones/ha. It is unclear if these same thresholds apply to the Lillooet Region but are generally proposed by Environment Canada in the draft Whitebark Pine Critical Habitat criteria.

5. Recommendations

The following recommendations are suggested based on the finding of work in 2016:

- Increase nursery production of whitebark pine seedlings employing the recommendations provided by the nursery consultant;
- Monitor success of the 2016 planting to help inform future planting work;
- Continue with outreach based restoration;
- Focus restoration efforts at sites with high levels of whitebark pine decline including sites with high rust infection levels and high mortality due to wildfire, identified sites include Blustry Mountain, Big Dog Mountain, and Mount Maclean;
- Continue with cone collections, prioritizing collections from highly infected stands, submit seed to provincial blister rust screening programs; and
- Carry on with Clark's nutcracker surveys to develop local ecological thresholds for stand occupancy, to be used in management planning.

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http://www.fgcouncil.bc.ca/Factsheet1-WhiteBarkPine_2011.pdf

Appendix 1 – Conifer Consultant Report

Consultation report

SplitRock Native Plant Nursery

Lillooet, BC

Michael Girard

May 12, 2016

Introduction

I was asked to visit the nursery to offer advice in respect to the growing facilities and cultural practices used for the nurseries containerized conifer seedling production. More specifically they were having problems with the Whitebark pine container crop. I visited the nursery on May 7, 2016 and spent six hours touring the facility and meeting with Kim North, Marylyn and Felicity to discuss their facilities and cultural practices.

The following report summarized my observations and includes some general recommendations which could be used to improve their cultural practices.

The current Whitebark pine crop had been sown in May 2015 as 2+0 crop for planting in fall of 2016 or spring 2017. Container size was 412A (77 cavities per block density). I was sent a picture of the crop April 1 (Figure 1). The seedlings were observed to be very compact and with secondary needles. Color was slightly chlorotic and the cotyledons had begun to die off. Observation of the seedlings May 7 (Figure 2) showed the seedlings to average about 3-4 cm in height and with secondary needle development but no active shoot growth The cotyledons on the seedlings had continued die off but that was as expected for a one year old seedling. Root systems exhibited good branching with active root tips (Figure 3). Seedling densities in the blocks were very low (less than half density) and I was informed that there had been good initial germination.

My primary observation is that the seedlings growth hasstalled out most likely as a result of being subjected to fairly severe levels of environmental stresses from high air and grit temperatures, low relative humidity and correspondingly high vapor deficit (VPD) conditions. Nutrient stress may also be present perhaps as a result of both inadequate fertilization practices. Frequent misting to maintaining a favorable media surface temperature has also likely leached nutrients from the foliage. The seedling were initially located in the larger of the sites greenhouses but had more recently been moved outside a few weeks earlier and being placed along the sidewall areas between the greenhouses to locate them to a less stressful growing environment (Figure 4).

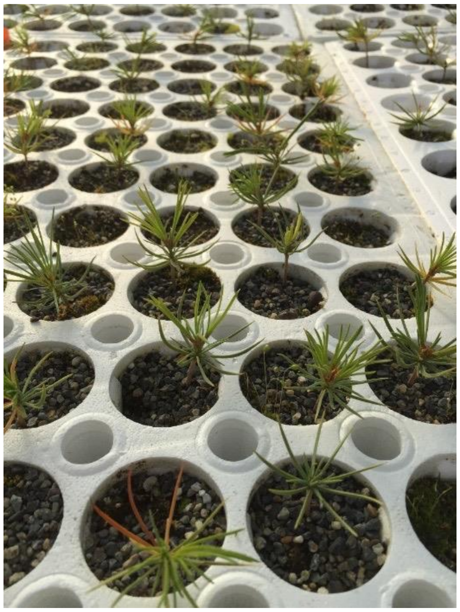


Figure 1. White bark 2+0 seedling crop as of April 1, 2016

Figure 2. White bark 2+0 seedling crop as of May 7, 2016

Figure 3   Seedling Root Health May 7, 2016

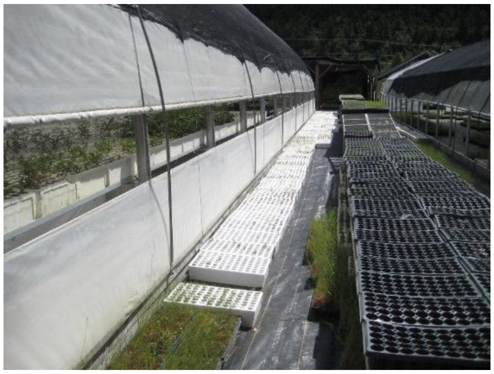


Figure 4   Location of the seedlings May 7, 2016

Observations of growing facilities and action plan

In order to have the seedlings resume their shoot growth the above stresses need to be removed and the seedlings subjected to more favorable growing conditions. The low crop density and small seedling size does not promote a favorable micro climate around the seedlings. There is little shading of the media surface by the seedlings and a very severe microclimate develops.   Media surface temperature should be kept below 35 C to provide a favorable microclimate around the seedlings.   Media surface temperature in excess of   45 C can also result in stem damage to the seedlings.

Ideal air temperatures would be 22-24 C.   Relative humidity should be kept above 60%.   Media and grit surface temperatures should be kept below 40 C. (below 30-35 C would be optimum)   Vapor pressure deficits (VPD) values should be kept below a maximum of 16-18 mb.   The geographic location and climate of the nursery along with existing greenhouse environment and cultural practices make it difficult to maintain optimal growing conditions and ultimately produce what is a montain species at this location.

Review of March and April greenhouse temperature and Relative humidity readings indicate air temperatures in excess of 30 C and relative humidities below 50 percent.   Air temperatures and relative humidity at mid-day on my visit were reaching 30 C and the RH below 40%   Those values result in extremely high vapor pressure deficits in excess of 25 mb. High VPS are very stressful and do not promote seedling bud bust.   Seedling undergoing vegetative growth subject to high VPD will typically stop vegetative growth and set bud.

The low seedling densities in existing crop result in severe microclimate around the trees due to the large area of openly expose media that heats up. The compact size of the seedlings do not create a favorable microclimate.

Photoperiod

High elevation and northern provenances species require long day lengths to promote vegetative growth and prevent budset.   Day lengths should be maintained between 18-20 hours and I would recommend 20 hours for this species.   There was no evidence of photoperiod extension being used.

Use of three 400 watt HPS lights in the larger greenhouse would be sufficient to produce sufficient light levels for maintaining vegetative growth.

<u>Nutrient and irrigation management</u>

The seedlings should be subjected to a complete nutrient program. Nitrogen levels in the fertilizer program should he between a minimum of 100-125 ppm with all the macro and micro nutrients supplied in concentrations relative to that. The ratio of nitrate (NO3) to ammonium (NH4) forms of nitrogen is important and should be around three to one. Higher or pure ammonium nitrogen form can be useful in promoting reflushing. Soluble fertilizers should be used and those are supplied via a constant fertigation program rather than intermittently at a higher level.

Incorporation of controlled release fertilizer in the media is important. Osmocote 18-6-12 in 9 month formulation is most commonly used. Nutricote may also be used. The controlled release fertilizer also provides a bit of a buffer compensate for periods when fertigation is not happening such during period of precipitation. It is estimated that the time release fertilizer supplies about 30% of the nutrient program. I would recommend that we find out from the manufacturer what amendments are used in the mixes they have supplied.

The salinity or electrical conductivity (EC) of the media while it reflects existing nutrient levels should not be allowed to build up so as to subject the seedlings to a physiological drought stress. EC values should be monitored and seedling should be watered to 20% excess to ensure that salinity and EC values are not building up.

As fertilizer release is effected by temperature and high soil temperature can result in early or flash release or the nutrients. This could be a problem owing to the warm geographic climate of the nursery.

I measured the pH and EC in the media from two cells with trees in the block that I brought back on May 7th. A two to one dilution was used to obtain the soil solution. The pH was 5.1 which is close to the optimal level of 5.5 for soil less media systems. The EC was .12 uS/cm which for a on to two media dilution indicates very low nutrient levels.

http://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/animal-and-crops/crop-production/on-site_testing_of_growing_media_and_irrigation_water_2015.pdf

Seedlings should not be subjected to any moderate moisture stress. Seedlings should be watered once the media moisture drops to 75-80% or the full recharge weight (field capacity). Light block loading densities can result in rapid dry down of the media. Application of grit to the container surfaces helps to reduce evaporation from the top of the plugs. The darker colored forestry grit commonly used however does promote warming of the plug surfaces.

The block that I had brought back had a total weight of just 3.5 kg which is quite light. Given that the majority of cells were treeless this means that that moisture levels in the cells with seedlings was probably well below the target irrigation weight. The full watering weight of the block is around 5.3 kg and water should done once the weights drop 75-80%. That would indicate a watering weight of 4 to 4.2 kg. In order to promote reflushing I would recommend water at the 80% full recharged weight.

The larger greenhouse has an overhead irritation system consisting of   micro spinners set up in four zones.   The arrangement is a bit problematic as the zones overlap.   Control of the sprinklers is manual through the use of ball valves.

The nursery had been using Direct solutions 20-8-20 forestry soluble fertilizer. The rate which was recommended was to apply the fertilizer at 100 ppm.   The nursery has been using a portable Dosmatic injector. There is no current method of connecting the injector to the overhead watering system. Fertilization of greenhouse and outside crops is done via hand watering with hose and water breaker. That method is very time consuming and probably results in uneven watering. My recommendation would be to supply a bypass quick connection at each watering location to allow the injector to be used. The injector should have been set at 1:100 but was actually set at 1:50.   That would have result in applications of fertilizer at an actual rate of 200 ppm.   The technician did notice that the applied EC was higher than recommend and used less fertilizer in the mix.

Development of a complete fertigation program needs to take into consideration the base nutrients in the water supply. The nursery water source is from a well located on the site. The nursery last had and analysis of the water supply done in April 2, 2015.   The water is basically alkaline with a pH of 7.6 which is on the high side.   Optimum recommend pH is between 5 and 7.

See attached BC Ministry of Agriculture factsheet for irrigation water guidelines:

http://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/animal-and-crops/crop-production/irrigation_water_quality_of_bc_greenhouses_2015.pdf

The water contains appreciable amounts of   Calcium (48 ppm), Magnesium (18 ppm) and Sulfate (88 ppm = 29 ppm S).   These nutrient are of benefit as they will make up a portion of the full fertilizer program.   Some Sodium was present (16 ppm).   It would be important to know that concentration of all of the nutrient in the water notable the micro elements Iron and Boron. I would recommend that another full analysis is done.   The electrical conductivity of the water was .45 us/Cm which is acceptable and reflective of some of the beneficial nutrients in the water.

Considering the background level of nutrients the basic mix can continue to Direct Solutions 20-8-20.   I have developed a couple of basic growing mixes and one that could be used to encourage the seedling to resume vegetative growth.   The 20-8-20 can be amended with some 13% chelated iron and also slobber to get a fairly completer fertigation program.   There are mixes sheet for 100 and 125 ppm. The mix sheets show the amounts to weigh out are in grams and are for the existing portable dogmatic injector system which has a stock tank size of 56 l and an injection ratio of 1:100.   The mix sheets show what the full fertilizer program taking into consideration the water analysis which is beneficial as it contains calcium, magnesium and sulfur.   Because of the calcium in your water we don’ need to use a double injector and so can stay with your existing system.   The mixes have 50% more extra iron of the general target level target. The extra iron seems to work well for conifer production.   We normally use Plant Products 20-8-20 and I do see that the direct solutions version has less zinc in it hence that is below the target amount in the mixes. That could be corrected the addition of some with chelated zinc but I wouldn't worry about that for now.

The Nitrate to Ammonium ratios of the mixes is lower (2/1) that what I would want for normally growing which is usually 3/1. The lower rate is okay for now as we really want to promote foliage growth.

I have also made up a mix that is 150 ppm ammonium N from Urea (45-0-0). The idea is to use one initial application of that as the ammonium may encourage the seedlings to get going. With that mix I would recommend doing a fresh water rinse after the fertilizer has been applied as water can bead on on the terminal ends of the seedlings and that drop can get more concentrated as it dries down and possibly result in a fertilizer burn that location. Only a quick rinse should be used though as we don't want to dilute what has been just applied. I have applied this mix to the seedling block that I brought back from the nursery on May 7th and will be monitoring for regrowth.

After the initial one application of the high ammonium mix I would recommend switching back to the the regular growing mix at 100 ppm N and up then increase the fertilization rate to 125 ppm when the growth begins to accelerate.

<u>Greenhouse structures and growing facilities.</u>

The facility has two relatively new freestanding gothic arch houses, 25x100 ft and 20 x100 ft. The larger greenhouse has an inflated double poly roof (likely four year poly) and twinwall polycarbonate end walls. The smaller greenhouse is unheated and has a single poly covering.

Both greenhouses have shading fabric pulled over the exterior of the structure.

Both greenhouses have landscape fabric floors.

The greenhouses are good quality structures well suited for conifer seedling production.

<u>Greenhouse environmental control systems.</u>

<u>Heating systems</u>

The larger greenhouse has a hotwater heating system comprising of a wood burning boiler (200,000 BTU/Hr maximum output located external to greenhouses. Heat is distributed in the greenhouse via under bench heating PEX heating pipes as well on one overhead forced air hot heat exchanger. Review of the specifications for the boiler indicates a sustained output of 110,000 BTU/hr for a 8 hour burn time and a reduced output of 72,000 BTU/hr for a 12 burn time. I assume the shorter burn time is used as I was told if was common to have someone come in to restoke the boiler in the night.

The calculated size of heating system for the greenhouse needed to maintain an inside temp of 20 C given an outside temperature of -5 C is 136,000 BTU per hour. It takes about 5400 BTU/hr of heating capacity of each 1 C temperature rise. 110,000 BTU/hr output on an 8 hour burn time can effectively give a 20 temperature rise.

The heating system is not capable of maintaining the 20 C setpoint under severe conditions. Germination temeratures of 20-24 C are required for complete and uniform germination. The bottom heat application being used does maximize the heat where the plants are located and does comensate for the undersized heating system.

There are also a couple of problems with the heating distruibution piping system used on the benches. Barrier PEX piping was used and it is evident that the plastic is being degraded by the UV light in the greenhouses. It can be expected that the plastic will become brittle. There was also some concern that the pipes are in too close a contact with the bottom of the stryroblocks. High pipe temperatures may result in heat damage to seedling roots at the bottom of the containers. The pipe temperature could be reduced by running the overhead heat exchanger during partial heating loads.

Cooling systems

Both greenhouses have manual roll up sidewalls. The rollup sidewalls in the larger house have a lower 2 two foot high skirt that is there to provide a positive seal when the sidewall is down. The height of the skirting does seem excessive and is reducing air flow across the greenhouse. I did notice that the sidewalls were not fully rolled up to provide maximum cooling.

The larger house has a small peak exhaust fan located at the south which I would estimate to be about 18 inches in diameter. That fan is there to provide winter and early spring cooling. It does help to remove some of the heat from the peak of the greenhouse.

The larger greenhouse also had four Horizontal air flow fans. The are there to provide air movement to even out the temperature throughout the house. They should be set up so that the fans on the east side of the house face north and the two fans on the west side face south. I did notice that the end fans were angled in. The fans can be angled downward slightly to promote air movement across the crop. More efficient cooling of the greenhouse by the peak fan could be achieved if all the fans direct the air towards the south end of the greenhouse.

The single peak exhaust fan is in sufficient to cool the greenhouse in summer and warm spring conditions. If forced ventilation is to be the primary cooling system it would be my recommendation that two 30 inch exhaust fans be added. Total cooling air flow in cubic feet per minute (cfm) should be 8x total greenhouse floor area (2400 ft2) = 19,200 cfm. I would estimate that the peak exhaust fan only provides less than 5000 cfm. Recommend air flow for winter cooling is 2.0 x floor area = 4800 cfm. My assumption is that the existing fan was supplied primarily for that type of cooling.

More effective cooling could be provided if the larger greenhouse was retrofitted for natural ventilation with a peak roof roll up. Small electric motors are available that can be used automate both the roll up sidewalls and the peak vent.

Shading systems

Both the greenhouse air temperature and media surface temperature can be lower but reducing the amount of solar energy entering the greenhouse. The shade fabric that is been used externally over the greenhouses is helping to lower those temperatures but with the covering in place an excessive amount of heat is still being trapped in the greenhouses. Greenhouse air temperatures are in excess of 35 C and the media surface temperatures are in excess of 40 C. It would be my recommendation that the coverings be removed from May onward. In order to reduce the yearly cost of poly replacement I would recommend use of a cheaper overwintering poly.

Evaporative cooling

Both air and media surface temperatures can be reduced though the use of evaporative cooling. The overhead irrigation system can be pulsed on to just wet the floor and surface of the media.

Best cooling of the greenhouse could be achieved through the installation of a high pressure fogging system.

I was able to determine that Arbutus Grove nursery in Victoria does have available for sale some surplus evaporative cooling equipment.

They have a number of humidifans (8) and also a complete fogging system. They are asking just $75 each for the humidifans which is a very good deal as those are probably over $1500 can each. They also have a complete high presser fogging system for $2500. The humidifans would be easy to install but are quite noisy. I would recommend two for the large house. They do create some wetness on the crop.

The high pressure fogging system would give you the ultimate control of humidity. The high calcium carbonate levels in the nursery water might be a problem those clean water to pass through the very small orifice misting nozzles. The humidifans can tolerate the high calcium water.

Temperature monitoring and controllers

The nursery is using simple thermostats to control the bench heating and overhead exhaust fan.

A simple digital weather station is being used to monitor the temperatures and relative humidity in the main greenhouse.

Ultimately if would be very beneficial if the nursery had a complete integrated computer control system such as Argus controls. That provides very good integrated control of all of the environmental control equipment as well as provide data logging and alarm functions. The system and also can do all of the irrigation management and be accessed remotely. I would estimate that it would cost over $15, 000 for the Argus system. A much cheaper fix would be to go with a modern step controller such as the Igrow 800.

http://store.link4corp.com/igrow-800-greenhouse-controller/

Media and media densities in the containers.

I was told the media used come from Sumas Grow media. Two different artificial medias are used at the nursery. The seeding mix consists of peat and soil mix perite at a ratio of 80/20%. The media appears to contain some form of coated fertilizer. This was the mix that the seedlings were in. The other mix is what was referred to as the container mix and appears to mix of peat and find wood waste 60/40 ratio and also contains some form of coated fertilizer.

I would recommend that the nursery should ask the supplier for a complete analysis and mix constituent breakdown of the two mixes.

The aeration and water holding porosity of the media is important. The mix constituents along with the soil loading density can have a large effect on the media porosities. Soilless Medias should have a high percentage of aeration (20-30 %) and a good water holding porosity yielding a total porosity of 70%. I sampled two plugs from and determined the block loading density to be .1 g/cc. That is a bit on the heavy side. Optimum loading densities are between .065 and .075 g/cc. I was told that the blocks are hand loaded and bumped as part of the block filling process. It may be that less aggressive bumping should be done.

Media covering.

It is important to cover the seeds as part of the sowing process. Forestry grit from Target products is typically used and that had been applied to the crop. The grit helps to keep the seed moist during germination but also acts as mulch to conserve moisture in the plugs and also provide a dry sterile surface the helps to inhibit algae, moss and weed growth. Target products grit is dark in color and this has both advantages and disadvantages. During germination the grit will warm up as a result of solar insolation and help to provide a warm germinating environment. During periods of high solar input the dark color allows the grit to warm up excessively with media temperatures often exceeding 45 C. For this location it might be beneficial to supply some white shade paint or just diluted white latex paiont to the grit surface at the time of seeding.

Crop monitoring.

The crops need to be regularly monitored as part of the irrigation management system. Block weights should be set up and taken daily.

Media grit temperature need to be monitored.

Soil pH and EC should be checked monthly. Catchment containers can be set up under a few blocks to collect irrigation overdrain and the pH and EC of that should be monitored.

I did notice that the nursery lacked the basic lab ware need to monitor pH and EC.

I would recommend purchasing a Hanna combination pH/EC meter, pH 4.0 and 8.0 buffers, EC standardizing and storage solutions. Some basic lab ware such as 500 ml plastic beakers, 10 ml and 100 ml graduate cylinders are essential to have.

One way of quickly measuring is through the use the plant communicator which provides and audibly indication of soil EC levels:

http://www.charleysgreenhouse.com/N3675-Plant-Communicator-Water-Fertilizer-Tester.htm.

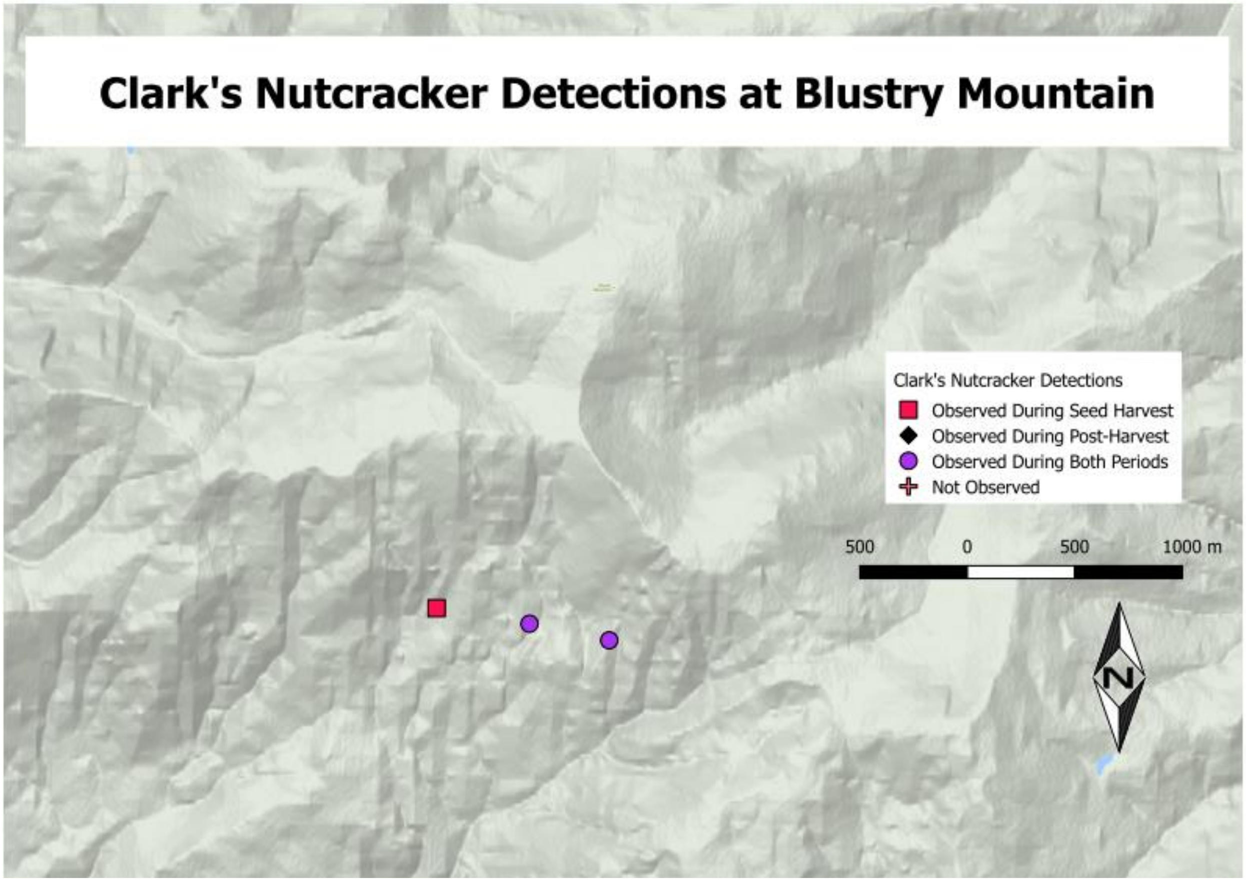
This provides a quick way of check relative EC levels in the pots and styroblock cells.

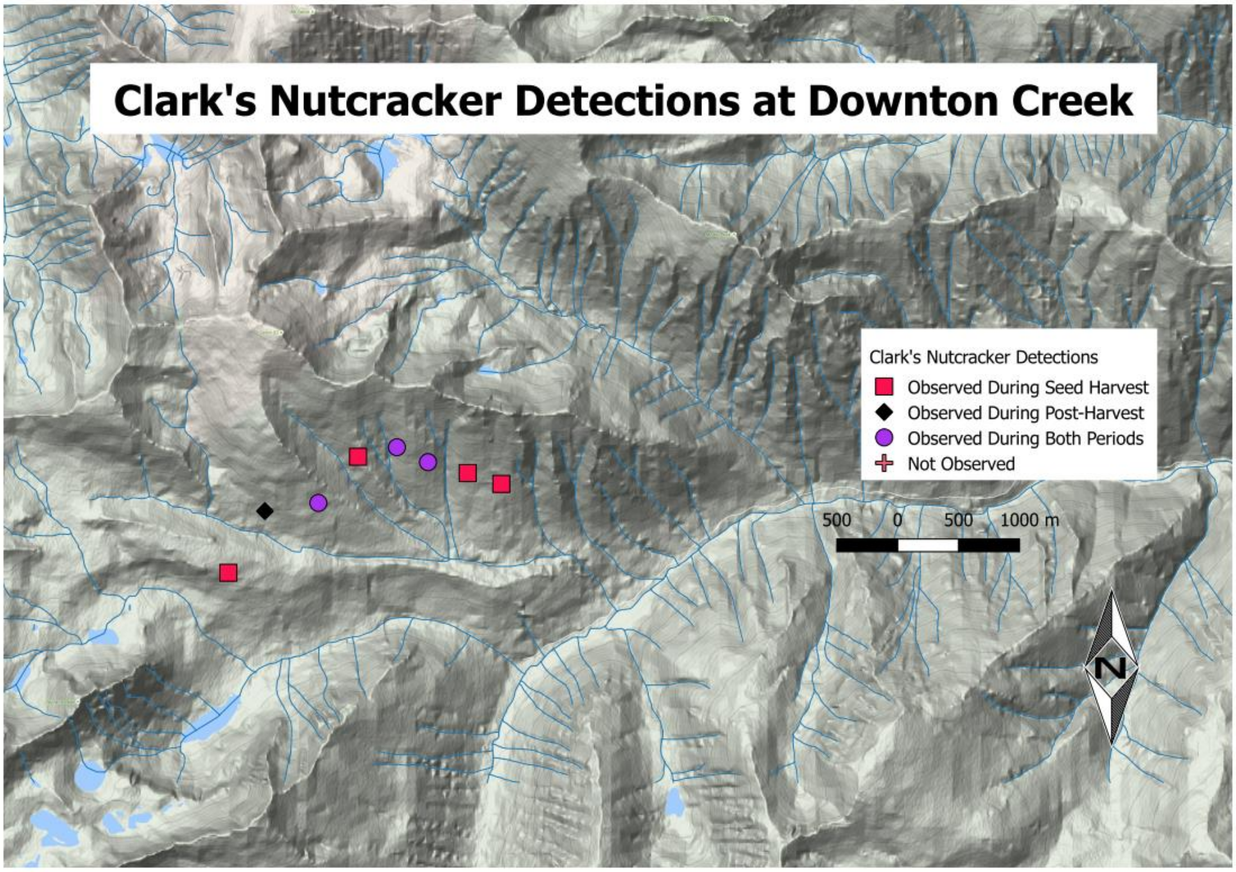
Final summary

The main thing is that we to need to reduce the stresses on the trees so that they reflush. That means keeping the grit temperature under 35 C and the vapor pressure deficit below 18-20 mb. Good irrigation good management is needed so as not to subject the seedlings to moderate to severe moisture stress. Use of a ammonium based fertilizer and maintenance or a low Nitrate to ammonium Nitrogen levels in the fertilizer program should help to get the trees to reflush and have good vegetative growth. The low density of the seedlings in the blocks will be a tough to overcome as that is going to continue to promote quite a stressful environment. That can be reduced greatly by keeping the trees under shade and misting the grit to keep the media surface temperature under control. The trees also need to have the photoperiod extended to 18-20 hours.

For future crops as thorough growing plan should be developed.

Appendix 2 – Occupancy Modelling Maps

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Clark's Nutcracker Detections
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Observed During Post-Harvest
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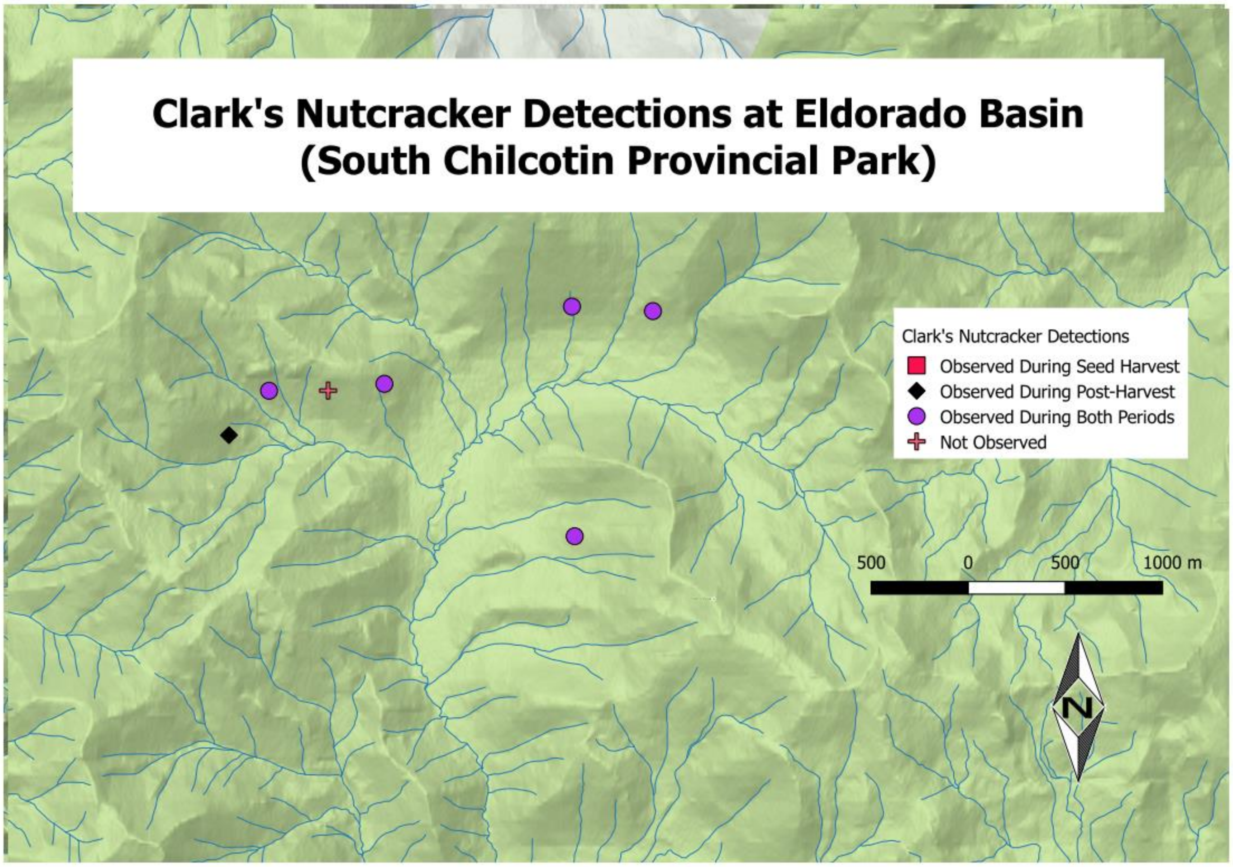
Clark's Nutcracker Detections at Eldorado Basin
(South Chilcotin Provincial Park)
Clark's Nutcracker Detections
Observed During Seed Harvest
Observed During Post-Harvest
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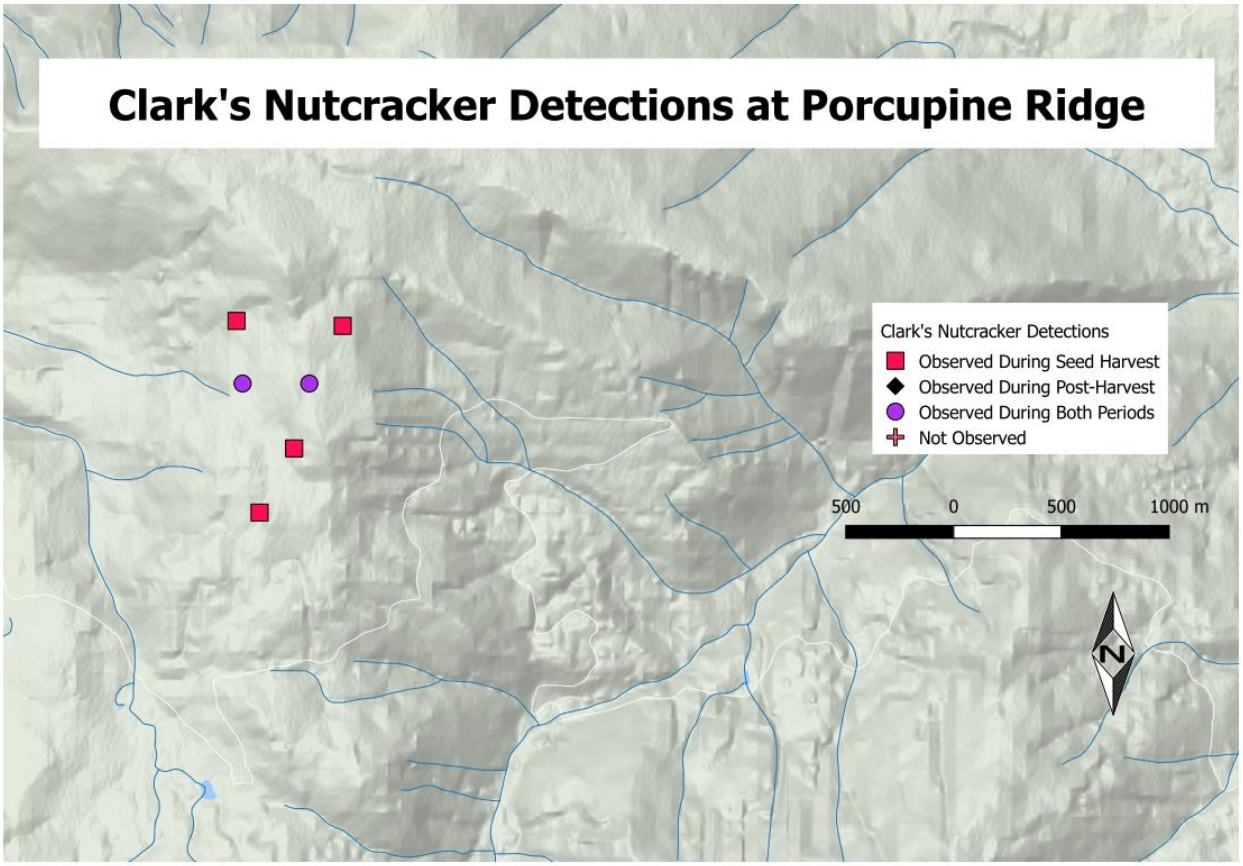
Clark's Nutcracker Detections at Porcupine Ridge
Clark's Nutcracker Detections
Observed During Seed Harvest
Observed During Post-Harvest
Observed During Both Periods
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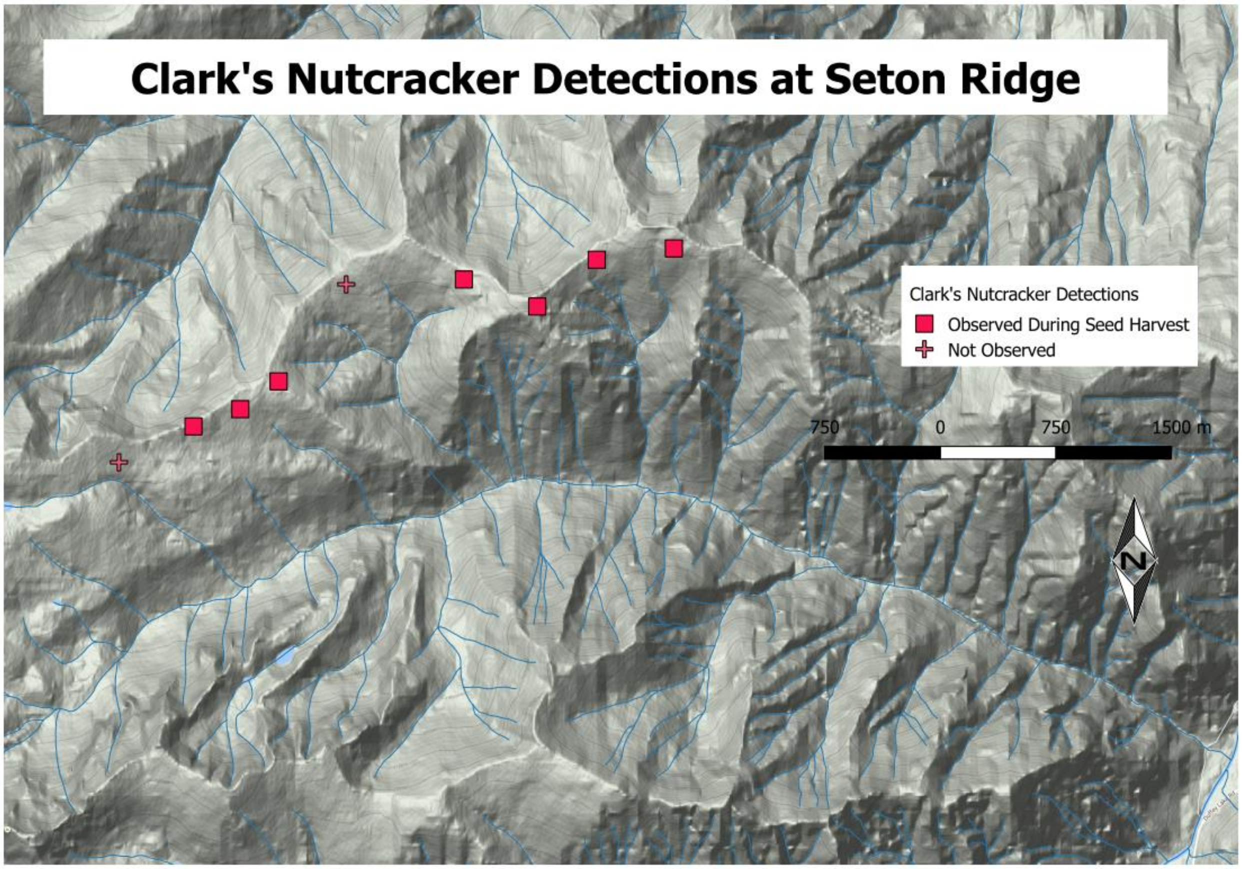
Clark's Nutcracker Detections at Seton Ridge
Clark's Nutcracker Detections
Observed During Seed Harvest
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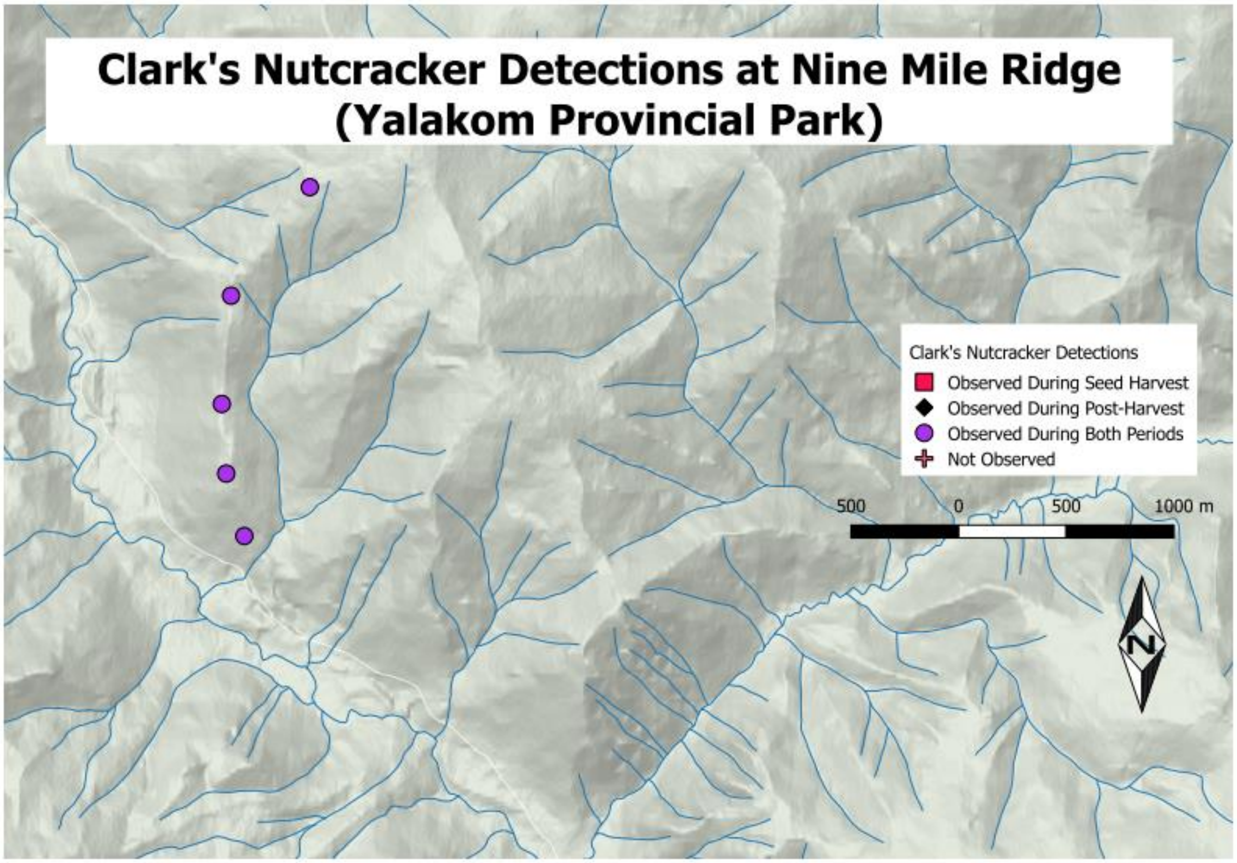
Clark's Nutcracker Detections at Nine Mile Ridge
(Yalakom Provincial Park)
Clark's Nutcracker Detections
Observed During Seed Harvest
Observed During Post-Harvest
Observed During Both Periods
Not Observed
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