

FII Research Project

ANNUAL PROGRESS REPORT
(April 1 2003-March 31 2004)

The ecology and management of dry Douglas-fir forests: The Opax Mountain Silvicultural Systems Study

By
André Arsenault
Silviculture Systems Researcher
Southern Interior Forest Region

Submitted on April 9th 2004

To
Cheryl Smyth
Manager, Research Program
Forestry Innovation Investment Ltd.
1200-1130 West Pender Street
Vancouver, BC
V6E 4A4
Phone: 604-601-5304
Fax: 604-685-5373



Abstract

The Opax Mountain Silvicultural Systems project was set up to assess how silvicultural systems affect many variables that are of concern to managers of complex dry IDF forests. The project includes 2 study areas, one in the IDFxh2 variant and one in the IDFdk2, with 6 operational-scale harvest treatments at each: uncut control, 20% removal individual tree selection (ITS), 50% ITS, 50% ITS with uncut reserves, 20% removal with a mixture of patch cuts of 0.1, 0.4 and 1.6 ha, and 50% removal with patch cuts. The project includes studies of: fire history and other natural disturbance agents; operational regeneration in openings and under partial canopy; edge effects on microclimate, snow melt and soils; effects of canopy density, gap sizes, site preparation and edges on planted seedlings, natural regeneration and vegetation (including cover layers, individual species and groups such as forage plants, weeds, forest associates and ectomycorrhizal hosts); and, harvest treatment effects and habitat relationships of wildlife groups ranging from terrestrial invertebrates and arboreal beetles to small mammals and songbirds to woodpeckers and ungulates. Natural disturbances at the site cover a wide spectrum of sizes, frequencies, severities and effects on stand structure. Responses of the many study variables show that no one management treatment will maintain all valued components in the IDF forest. Together, these results recommend a range of management practices broader than the restricted uneven-aged management widely practiced throughout the dry IDF. In particular, patch cut systems with openings >0.1 ha, and management that responds to local stand characteristics are needed complements for individual tree selection systems. A summary of the key results, extension activities and deliverables is presented.



The Opax Mountain Team

Opax Mt. was designed as an interdisciplinary project from the start. Since no single research agency in B.C. had people with the training, skills and talent to design and implement the project of this magnitude at the time (and this situation is still true today), we deliberately set out to create a project that was open to collaborators in both research and extension. The scientific partners meet once a year at a minimum to discuss progress and approve future plans. Operational partners are kept up to date with progress on a regular basis. They are also invited to participate in any extension events, whether on site or at meetings around the province. The site was chosen by the research team in co-operation with members of the Small Business Forest Enterprise Program (now BC Timber Sales) in the Kamloops Forest District, and with the approval of the Local Land-use Planning Team. This team has numerous public representatives.

This project is supported by key industry and agency partners and clients involved in the development and implementation of forest policy and regulations, as well as in planning and management of dry-Douglas-fir forests in the Southern Interior Forest Region of British Columbia. Craig Sutherland is a regional staff manager for the Southern Interior Forest Region in charge of Compliance and Enforcement and Stewardship. Craig is also closely involved with the development of the Forest Practices Code. Steve Carr is the regional director for the Southern Interior Region with the Ministry of Sustainable Resource Management, Phil Belliveau is a senior biologist with the Ministry of Water, Land, and Air Protection involved with the stewardship of dry forests in the Thompson Region. Lennart Holme is a forestry supervisor for the Chasm Sawmills, division of West Fraser Sawmills. He is responsible for operations in many dry forest types. Bob Beck is manager for the Kamloops Fire Zone. Tom Lewis is Operations Manager with BC Timber Sales in the Kamloops Business area. Tom has been involved with the Opax project at many levels since its inception. Dry forest types similar to the ones studied at Opax are an important part of the landbase managed by BC Timber Sales.

The following is the list of current project team members involved in the Opax Mountain silvicultural systems study.

The Opax Mountain Research Team

<u>Project Leaders</u>	<u>Field of expertise</u>	<u>Affiliation</u>
André Arsenault	Ecology & silv. Systems	BCFS, Southern Interior Forest Region
Catherine Bealle-Statland	Growth and Yield	BCFS, Research Branch
Garry Bradfield	Ecology	UBC
Tom Dickinson	Avian Ecology	UCC
Dan Durrall	Mycology	OUC
Graeme Hope	Soil Science	BCFS, Southern Interior Forest Region
David Huggard	Wildlife Ecology	UBC
Walt Klenner	Wildlife Ecology	BCFS, Southern Interior Forest Region
Dennis Lloyd	Vegetation Ecology	BCFS, Southern Interior Forest Region
Lorraine Maclauchlan	Forest Entomology	BCFS, Southern Interior Forest Region
Hadrian Merler	Forest Pathology	BCFS, Southern Interior Forest Region
Cindy Prescott	Nutrient Cycling	UBC
Pasi Puttonen	Silviculture	Helsinki University

Dan Smith	Dendrochronology	Uvic
Alan Vyse	Silviculture	UCC

Graduate students	Topic	Status
Kaeli Stark	soil vegetation seedbank dynamics	M.Sc. @ UBC ongoing
Rochelle Campbell	Historical reconstruction of defoliator outbreaks	M.Sc. @ UVIC 2003
Vanessa Craig	Small mammals and coarse woody debris.	Ph.D. @ UBC 2002
Christine Ferguson	Ecology of long-toed salamanders	M.Sc. @ UBC 2001
Jim Herbers	Population ecology of red squirrels	M.Sc. @ UBC 2002
D.M. Rowell	Soil nitrogen mineralization	M.Sc. @ UBC 1999

Undergraduate Students	Topic	Status
Vanessa Larson	Tree regeneration in the IDFxh2	B.Sc. @UCC 1999
L. Peterson	Soil Moisture	B.Sc. @UBC 1997

Collaborators	Role
Murray Allison	Site maintenance, monitoring, publications
Michael Blackstock	Advisor, First Nations language and culture
Leandra Blevins	Soil nitrogen studies
Nicole Brand	Biomass production manuscript preparation
Ian Cameron	Stand modelling
Wayne Deptuck	Education package
Emilee Fanjoy	Site maintenance, monitoring, publications
Christine Ferguson	Seedling measurements
Reuben Irvine	Site maintenance, monitoring, publications
Mona Jules	Secwepecm translation
Jean Mather	Seedfall monitoring
David Miège	Vegetation
Alberto Orchansky	Microclimate monitoring
Russ Walton	GIS, data management & stand modelling

Introduction

The dry Douglas-fir forests of British Columbia's south-central Interior have been managed by stand-level partial cutting for almost a century. However, the management of these stands continues to be an issue. It is widely believed that these stands of Douglas-fir should be managed on an uneven aged basis with a balanced distribution of age classes represented at a scale of 0.1 ha. (Vyse et al. 1991, Day 1996). However the extensive application of this common prescription is still widely disputed and alternatives need to be tested. For example, the assumption that a balanced age structure will meet wildlife habitat needs does not consider that it is likely to eliminate large snags in the stand (Klenner and Vyse 1998)

The Opax Mountain silviculture systems study is an interdisciplinary approach to collect and synthesize information on forest ecosystem responses to harvesting and site preparation disturbances. The study addresses key management issues at the Opax Mt. site: soil nitrogen, responses by vascular and non-vascular plants, conifer regeneration, conifer growth and yield, fauna including forest floor arthropods, amphibians, shrews, small mammals, cavity nesting birds, passerine birds, and small carnivores and ungulates in winter, natural disturbances and fire history, insect defoliators, site microclimate, snow accumulation and melt and windthrow. Coordinated activities at one site allow for interactions between research team members, they facilitate the exchange of data and diminish costly measurements by multiple investigators, and they facilitate field extension activities by providing comparative examples in a compact area. The Opax Mt. silvicultural systems site is a key facility in the Southern Interior, providing an extensive set of treatments for long-term research and an established interpretive trail for field extension tours.

Operational-scale comparisons of management alternatives is essential for adaptive management, which is much discussed but little practised. Replication in a randomised experimental design gives adaptive management comparisons the ability to relate observed effects to the management treatment that caused them. Opax Mountain is one of only a few examples of well-designed, replicated adaptive management trials addressing direct management issues at an operational scale. The interdisciplinary nature of the project is rare. In a literature review Klenner and Vyse (1999) found that of 1303 articles published in prominent ecology journals between 1996 and 1998, only 165 were field studies. Of these, only two were interdisciplinary with 3 or more disciplines represented. And yet, the whole challenge of sustainable forest management is that multiple values must be accommodated. The value of long-term ecological research is well-recognized in ecology (Franklin et al. 1990), and is especially important in applied forestry work.

The work proposed for "Phase 2" of the Opax Mt. project focuses on 4 general areas:

1. Re-measurements of variables where longer-term trends are most meaningful, where succession is occurring, and where annual variability is high or rare events are important
2. Collating and synthesizing results, collaborating with researchers at other sites, and producing summaries for scientific, technical, management and public audiences.
3. Filling of knowledge gaps identified during informal meetings of the project team, namely disturbance history from fire and insect attacks.
4. Expanding extension efforts to include a wider range of users and products.

General Approach

The approach to the design of the project was based on the following propositions:

- a) Stand level experiment: an experiment that deliberately manipulates stand structure patch size and soil disturbance has more chance of meeting diverse and changing management needs than one based on the application of some widely recognized "off the shelf" silvicultural system (see Bradshaw 1992, Smith 1986 p.331, and Smith 1993).
- b) Team approach: no single agency in B.C. has the resources or staff to carry out such an ambitious ecosystem based silvicultural systems project and the only possible route to success is to encourage the development of a co-operative network of researchers from various agencies
- c) Extension: the best way to ensure management support of a research venture is to provide information to the forestry community and interested public on project findings in a readily accessible form and on a regular basis, preferably in the field.
- d) Long term: The project cannot meet its declared goals in a short period of time. Project plans call for the site to be maintained for at least 30 years and all the co-operators have agreed to this condition. No formal agreements exist.

Phase 1 project Objectives

The main objective of this study is to evaluate the effects of six forest management treatments on a range of forest resources in Interior Douglas-fir forests. Stand regeneration is a fundamental requirement of a successful silvicultural system. The treatments have been therefore been designed to create a range of residual stem densities (% basal area removed: <20%, 35% and 50+%) and spatial characteristics (uniform removal vs. patchy). Consequently there is a range of canopy gaps (0.01 – 0.05 ha) in the partial-cut units and 1 – 4 tree heights wide (0.09, 0.36, and 1.6 ha) in the patch-cut units. These treatments, plus a control area of similar size, were applied in two different areas in a randomized complete-block design. One area has an elevation range of 950 – 1100 m in the IDFxh subzone, and the other, in the IDFdK subzone, has a range of 1200 – 1370 m. A range of site preparation methods were also applied at a small scale (in limited areas of each unit). The treatments and research focus on evaluating the costs and benefits of each treatment within an integrated resource management context.

Summary of Phase 1

The Opax Mountain Project was initiated in 1992. The site was chosen by the research team in co-operation with members of the Small Business Forest Enterprise Program in the Kamloops Forest District, and with the approval of the Local Land-use Planning Team. This team has numerous public representatives. The nucleus of the project team was established in 1992, and consisted of government and university researchers with a range of expertise covering the resource values and ecosystem components that are now of concern in forest management. Some studies began pre-treatment measurements in 1992 and 1993. The treatments were designed to focus on creating or removing specific stand structures, and creating a range of canopy gaps. The harvest treatments were implemented under the Small Business Program in the winter of 1993-94. The larger openings were site prepared and planted with a mix of four species in the following year.

Effects of silvicultural systems treatments

The following variables have been measured at the Opax Mountain site: microclimate (Orchansky); snow depth and duration (Klenner, Huggard); nitrogen mineralization, organic

decomposition, soil chemistry, (Hope, Prescott); shrubs as refuge plants for ectomycorrhizal fungi (Durall); seedfall (Vyse); seed fall, natural seedling ingress, planted seedling growth (Vyse); natural seedling substrates and growth (Lloyd); advanced regeneration survival and growth (Puttonnen and Vyse); stand structure and growth (Bealle Statland); windthrow and snow breakage (Huggard, Vyse, Klenner); western spruce budworm, Douglas-fir beetle and other flying insects (MacLauchlan); fire history (Arsenault); CWD mass, volume, decay composition (Feller, Klenner, Huggard); snag abundance (Huggard, Klenner); herbaceous cover, composition and succession, lichens, terrestrial and epiphytic bryophytes, shrub cover, composition and growth (Lloyd, Arsenault, Miede); shrews, small rodents, squirrels and chipmunks, woodpeckers, ground-dwelling arthropods identified to order, beetles to family (Klenner, Huggard); long-toed salamander (Ferguson); song birds (Dickinson, Leupin).

Synthesis and extension

Project synthesis began with a workshop in 1997 at which researchers from around the province presenting findings in research in dry Douglas-fir ecosystems. The results of this workshop were published in 1998. Further synthesis of the effects of the silvicultural systems, edge effects and site preparation effects and natural disturbance history at Opax Mountain were presented at Sisco and at the IUFRO conference at SilverStar. The Opax Mountain site is used regularly as an operational scale demonstration of alternative silvicultural systems for IDF forests. With the co-operation of the Kamloops Forest District Recreation section, we built a trail through the lower part of the project area. The trail is designed to demonstrate the natural features of the site and the effects of stand management alternatives. A booklet describing various points along the trail is available in English and Secwepemc and soon in French. The study site has been visited by over 1000 people from various backgrounds.

Phase 2 (2001-2006) Project objectives

Our strategy for the second phase of this project builds on the strengths of the first phase: a long time horizon, a common site and an interdisciplinary focus. It is essentially the same approach that was already approved by Science Council, FRBC and the Ministry of Forests in 2001. The overall objective is to monitor the response of a number of ecological variables over a long time period, after the application of a range of canopy disturbances within several silviculture systems in a dry Douglas-fir forest, and to quantify historical pattern of natural disturbances. These results will enable us to reduce uncertainty and build predictive relationships between response variables that can be used in strategic stand and landscape modelling to improve stewardship decision making. The combination of a well replicated experiment, detailed monitoring, retrospective studies, and modelling makes this project very strong.

Methods

Project co-ordination

The co-ordination of the Opax Mt. Silviculture systems study was be carried out by the project leader. An effort to synthesize results to date was initiated in collaboration with Dr. Huggard and the Opax research team. We plan to publish the results of this synthesis and make it available on our web site with the assistance of FORREX.

Study 1. Recovery of nitrogen cycling processes after harvesting at Opax. G. Hope and C. Prescott.

Early post-disturbance measures of soil nitrogen dynamics at Opax Mountain have determined that all openings, including single tree selection, have elevated soil nitrate levels and possibly reduced ammonium levels, for up to 8 growing seasons after harvest. There are no data on the duration of the opening effect (commonly termed the “assart flush”) in IDF forests. The objective of the present study is to continue monitoring rates of net N mineralization to establish the duration of the opening effect. These data will be combined with other data from Opax to summarize medium term responses to cutting, and also combined with 10-year nitrogen data from other silvicultural trials, as they are collected over the next two years, in an analysis of medium-term soil nitrogen responses to harvesting.

Study 2 . Vegetation response to different silviculture systems at Opax Mt. D. Lloyd, A. Arsenault, G. Bradfield & D. Miège.

Over 1900 permanent vegetation plots have been established in a range of edge positions, and site preparation treatments and across a light gradient. Data have been collected for this project in 1997, 1998, 2000, and 2002. The data are archived and summary tables and results have been produced. The presence, abundance, and mean height of vascular and non-vascular plants will continue to be tracked over time. The response of 13,500 planted Douglas-fir seedlings and 270 permanent natural regeneration plots have also been nested within the above noted vegetation plots to track regeneration success. This year we intend to complete three manuscripts that summarize the light environment investigated and how it relates to seedling performance and biomass production, and one manuscript on the effect of forest edges on understory plant communities. We will also examine the role of seedbanks in shaping plant communities under different silviculture systems with an M.Sc. candidate at UBC.

Study 3. Regeneration studies A. Vyse P. Puttonen, C. Ferguson & A. Arsenault.

Several studies examining both natural and planted regeneration have been established across the range of treatments. Sampling of seedfall will be continued on an annual basis to gain further insight into year to year variation and to establish a long term record. Natural regeneration plots will be expanded and re-measured to meet regulatory standards. A more extensive assessment of the age structure of natural regeneration will be made at the study site and in other areas of the IDF in the Kamloops Forest District. This effort is to investigate how regular and extensive pulses of regeneration have been historically and to examine how closely they are correlated with climatic trends. In addition a manuscript on seedling performance in a partial cut will be prepared for publication.

Study 4. Maintenance and re-measurement of stand development and growth and yield plots. C. Bealle-Statland. No remeasurements planned this year.

The ultimate goals of continuing work on this project are 1) to report on the stand development and growth of the treatment areas within the Trial for the information of other scientists and forest practitioners, and 2) to obtain data sets suitable for testing a variety of growth and yield models designed to simulate the results of partial cutting. Catherine will summarize results to date and assist the group with project synthesis.

Study 5. The ten-year post treatment response of wildlife indicators to harvesting and site preparation treatments at the Opax Mountain Silvicultural Systems site. W. Klenner & D. Huggard. No remeasurements planned this year.

Following the harvesting (1994) and subsequent site preparation treatments at the Opax Mt. site (1996), several key taxonomic groups of invertebrates and vertebrates were monitored to assess their response to the harvesting, site preparation and planting treatments. The acute, short-term response (abundance and habitat association) of six taxonomic groups (forest-floor arthropods, amphibians, shrews, small mammals, sciurids, and cavity-nesting birds) was documented at permanent sample plots from 1993 (one year of pre-treatment) to 1997. A manuscript will be prepared for submission to peer-reviewed journals.

Study 6 Fire history study. A. Arsenault

The purpose of this study is to reconstruct the spatial and temporal patterns of fire events at the Opax study area. Approximately 400 tree cores and 400 scar samples have been collected. During this period a manuscript summarizing the fire history and its management implications will be prepared for publication in a peer reviewed journal. In addition further analysis examining the relationship between fire, spruce budworm and climate will be initiated.

Study 7. The influence of insect defoliators and other disturbances on radial tree growth at Opax Mt. Area. Dan Smith and A. Arsenault

This project is near completion. Rochelle Campbell is expected to complete her M.Sc. Thesis this year. We will also prepare two manuscripts for publication in a peer-reviewed journal.

Study 8. Pest response and forest disease dynamics. H. Merler

Initial pest surveys were done at the Opax installation in 1995 and 1996. Pest response to treatment and forest disease dynamics should be remeasured to correlate damage with incidence. Better understanding of pest behaviour will aid in dry belt Douglas-fir management. Three fifty meter long and two meter wide strip plots were established within each of the replicated treatments at the Opax Site. A total of 3.4 km of survey line has been installed and will need to be remeasured.

Study 9. Microclimate measurement. A. Orchansky

In this phase of the project we will continue the monitoring of the microclimate of two large openings at the Opax and Mud Lake. The overall objective will be to characterize the microclimate of the two blocks located in different IDF subzones.

Study 10. Predicting the long-term stand structure consequences of managed and natural disturbances in an IDFxh2 forest at Opax Mt. W. Klenner, I. Cameron, R. Walton and D. Huggard.

To gain a broader appreciation for the consequences of forest harvesting and natural disturbances on the abundance and distribution of important stand structure features (e.g. large live trees, snags, tree growth, gaps and understory, etc.), we propose to model stand structure changes in relation to a range of managed (harvesting) and natural (windthrow, spruce beetle, balsam bark beetle) disturbances. Data on regeneration and mortality factors gathered at the Opax site and elsewhere in similar IDF forests will be used to calibrate the Tree And Stand Structure model (TASS, K. Mitchell, MoF Research Branch, Victoria) to conditions in the IDFxh2.

Tree regeneration and stand growth, the periodicity and consequences of insect attack, and interactions with other disturbance agents such as windthrow will be simulated by using local measurements collected at Opax Mt. and observations in the Southern Interior. This project is linked with many of the studies within Opax that use structure as a common denominator as well as with Dr. Klenner's project entitled "Integrating timber, visual, hydrological and habitat management objectives through landscape planning".

Results and Discussion

Study 1. Recovery of nitrogen cycling processes after harvesting at Opax. G. Hope and C. Prescott

The most consistent trend during the tenth growing season after harvest was that nitrate-N in the forest floor was higher in large openings compared to the uncut forest, with partial cuts intermediate in value (Table 1). This trend was observed for both post-incubation concentrations and net concentration (or nitrification). For mineral soil, post-incubation NO₃-N was consistently, though not statistically, higher in the large openings than the other two treatments. The same effect was not shown for net nitrification in the mineral soil. The effects of any cutting on NH₄-N and total N were variable, with no consistent trends.

The increase in the proportion of post-incubation NO₃ in the large opening compared to the uncut forest continued the trend of earlier sampling times (Figure 1). Similarly, the trend of NO₃-N in the single tree selection harvest being intermediate, especially in the forest floor, between the large opening and the uncut forest was also observed in 1997, 40 months after harvest (Figure 2). These strong trends indicate that the so-called opening effect of increased nitrification continues in openings and single tree selection cuts 10 growing seasons after harvest.

The results continue to confirm that a range of harvest options in these dry forests will not have a negative impact on N availability and capital. The large increase in grass biomass that occurs after any harvesting, and the relatively dry soil moisture conditions that occur through most of the growing season, will ensure that the increased available nitrate is retained on site.

Table 1. Concentrations of NH_4 , NO_3 , and total N, and proportion of NO_3 at the end of the 2003 incubations, and net changes in concentration, in openings of each size

Treatment	Forest Floor				Mineral Soil			
	$\text{NH}_4\text{-N}$	$\text{NO}_3\text{-N}$	N	NO_3/N	$\text{NH}_4\text{-N}$	$\text{NO}_3\text{-N}$	N	NO_3/N
Post- incubation concentration								
Control	87.0	8.9b	95.9	0.10c	7.2	0.6	7.8	0.07b
Large	89.4	53.2a	142.6	0.47a	10.6	2.0	12.6	0.29a
Partial	72.0	24.8b	96.8	0.23b	3.3	1.0	4.3	0.16ab
Pr>F	0.90	0.003	0.41	0.001	0.19	0.16	0.13	0.033
Net change in concentration								
Control	47.8	7.6b	164.3	0.05b	1.3	0.5	1.7b	0.29
Large	72.1	50.7a	195.7	0.26a	8.2	1.8	10.1a	0.18
Partial	43.5	24.3b	311.2	0.08ab	0.9	1.0	1.9b	0.52
Pr>F	0.75	0.003	0.16	0.022	0.16	0.15	0.016	0.70

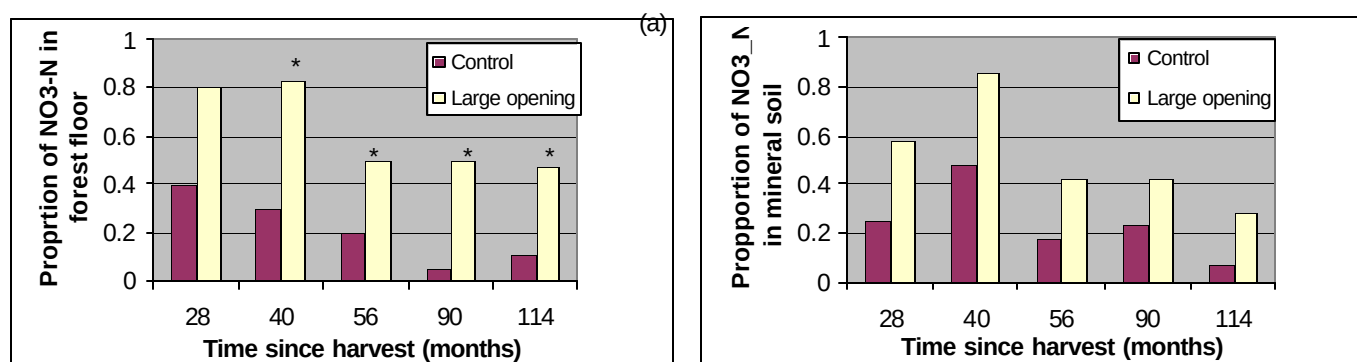


Figure 1. The proportion of inorganic N as NO_3 in forest floor (a) and mineral soil (b) following incubation in uncut forest and large (1.7 ha) openings. Significant differences ($p < 0.1$) are indicated with an asterisk.

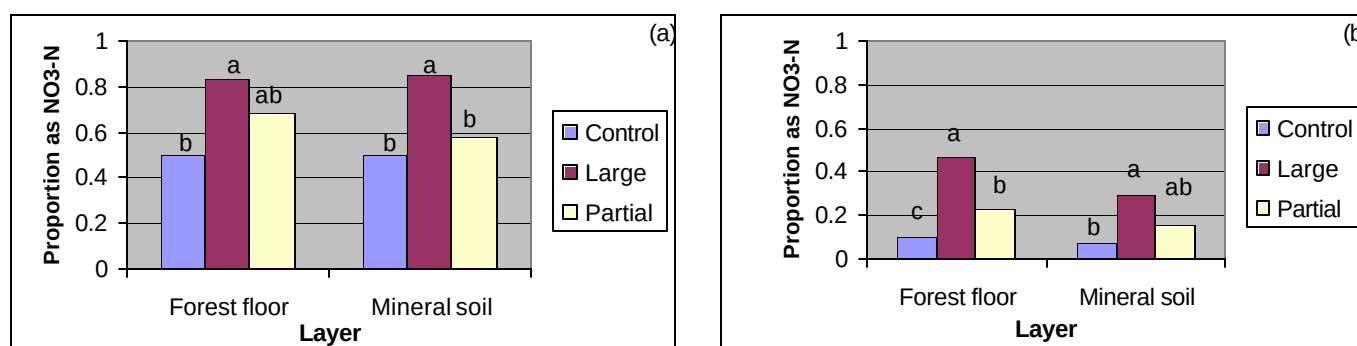


Figure 2. The proportion of inorganic N as NO_3 in forest floor and mineral soil following incubation during 1997 (a) and 2003 (b) in uncut forest (control), partial cut, and large (1.7 ha) openings. Means with different letters are significantly different ($p < 0.10$) within a year and layer.

Study 2 . Vegetation response to different silviculture systems at Opax Mt. D. Lloyd, A. Arsenault, G. Bradfield & D. Miège, & K. Stark. Four manuscripts were prepared (See appendix 1 for abstracts). New data collected on soil seedbanks is ummarized by Kaeli Stark below.

At the time of writing this report, 2064 seeds had germinated from the seed bank. While germination has slowed considerably from when the soil was first placed in the glasshouse, seeds continue to germinate from many of the samples. Any sort of statistical analysis or interpretation of results at this time would therefore be premature. The remainder of this discussion will focus on some preliminary trends in the data.

Almost half of the seed bank is dominated by three species: *Epilobium angustifolium*, *Epilobium ciliatum*, and *Plantago major*. The seeds of the *Epilobium* species were found on most sites within all treatment classes, whereas the seeds of *Plantago major* were largely concentrated in one sample (Figure 3). *Epilobium* species produce seed that is readily dispersed by wind and air currents, thus their widespread presence in the samples is neither surprising, nor is it an indication of dominance in the vegetation in the immediate sampling vicinity. Given its intolerance to shade, and its preference for the mineral soil beds that succeed severe fires, *Epilobium angustifolium* is most likely to be common in the vegetation on the sites that burned five years ago, present on the logged sites, and absent from the control sites, even though its seeds were widely dispersed. In contrast, the cluster of seeds of *Plantago major* that was concentrated in one sample from Mud Lake was likely the result of one or two particularly prolific plants in the immediate vicinity of the sample.

Preliminary analysis indicated that differences in seed density between the ten-year-old patchcuts and controls at Opax and Mud Lake might not be significant (Figure 4), thus any differences initially present between the seed density of harvested areas and adjacent undisturbed areas might not persist through time. Multivariate analyses of seed bank species structure and density have not been performed on the preliminary data, so spatial heterogeneity among samples within sites, and among disturbance classes cannot be evaluated at this time.

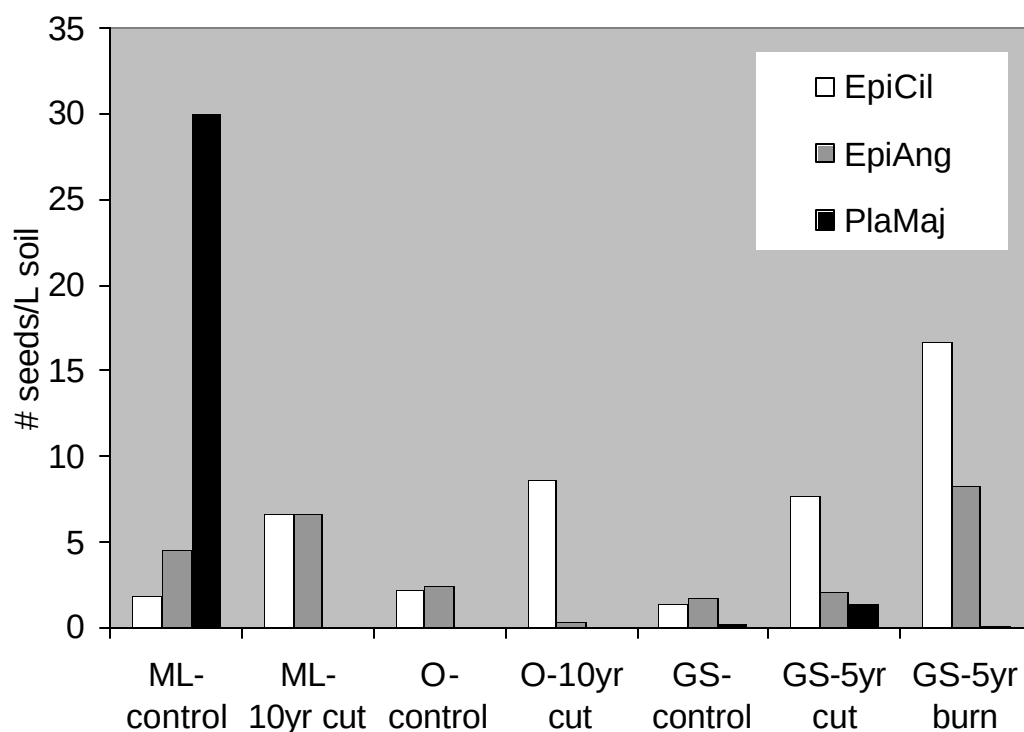


Figure 3. Preliminary seed densities (# seeds per total volume soil collected on each site) for three dominant seed bank species – *Epilobium ciliatum* (EpiCil), *Epilobium angustifolium* (EpiAng), and *Plantago major* (PlaMaj). Site abbreviations: Opax Mountain = O, Mud Lake = ML, and Greenstone = GS.

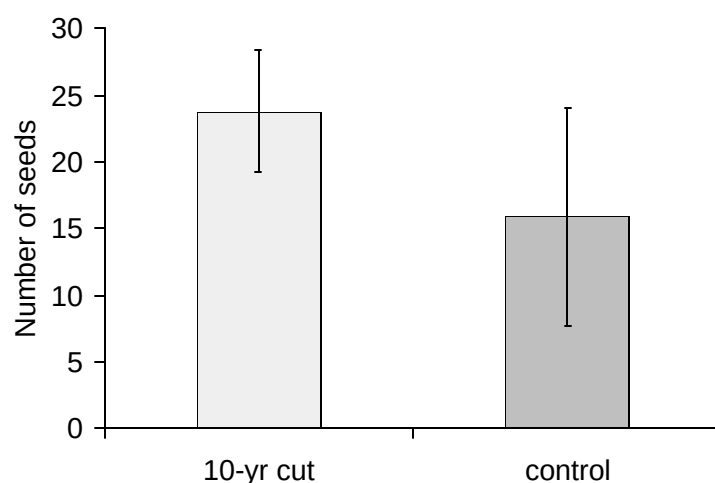


Figure 4. Mean number of seeds in each sample $\pm$ standard error for samples taken at Opax Mountain and Mud Lake (pooled). The mean number of seeds did not differ between samples taken in the ten-year-old patch cuts and samples taken in adjacent undisturbed forest controls (ANOVA: $P > 0.05$).

Study 3. Regeneration studies A. Vyse P. Puttonen, C. Ferguson & A. Arsenault.

Seedfall was monitored and viability analysis has recently been completed. Data will be incorporated in our metatdabase later this year. New data the seedling age bank structure is summarized below by André Arsenault.

343 seedlings were measured along 12 transects located at Mud Lake and Opax Mt. Seedling age varied bewteen 4 years and 81 years (Table 2). Seedling distribution appears both patchy in time and space. The age distribution for all transects examined illustrates a clear pattern of pulse regeneration (Figure 5). The sites we investigated at Opax Mt. had fairly severe mortality associated with summer drought showing that pulse mortality will also have an important role in shaping the demographic structure. This has important implications about understanding pattern of increased tree density perceived to be happening in dry forests.

Table 2. Age structure statistics for 12 transects established at Mud Lake and Opax Mt.

Site	Transect	N	Mean	Max	Min.	SD
MUD	T1	28	8.3	22	4	5.8
MUD	T2	19	20.9	41	3	10.4
MUD	T3	23	7	4	18	3.9
MUD	B1	15	26.2	43	12	8.8
MUD	B2	9	24.7	40	17	8.4
MUD	B3	90	14.7	81	3	14
MUD	C1	36	22.9	48	2	12.6
MUD	C2	22	14.8	40	2	13.1
OPAX	OT1	39	25.6	34	13	4.9
OPAX	OT2	6	25.8	30	31	3.5
OPAX	OT3	38	24	33	11	5
OPAX	OT4	20	26.4	46	14	6.6

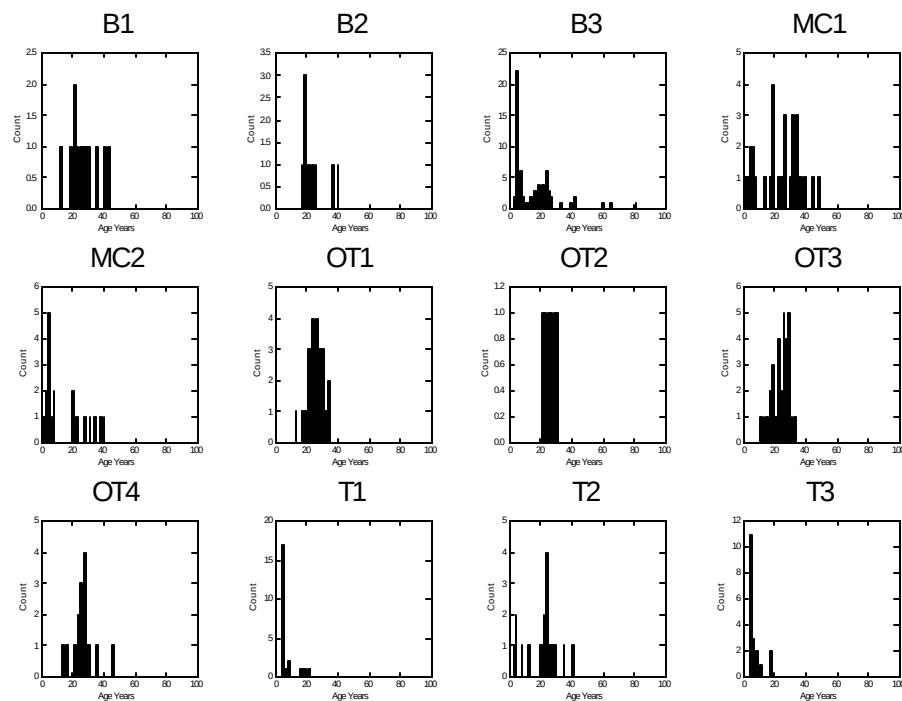


Figure 5. Histogram of tree age distribution of seedling bank for 12 transects examined at Opax Mt.

Study 4. Maintenance and re-measurement of stand development and growth and yield plots. C. Bealle-Statland. No data collected this year.

Study 5. The ten-year post treatment response of wildlife indicators to harvesting and site preparation treatments at the Opax Mountain Silvicultural Systems site. W. Klenner & D. Huggard. No new data collected this year. A manuscript was prepared on the Effects of logging pattern and intensity on squirrel demography by Jim Herbers and Walt Klenner. Some of the key management implications from this paper are summarized below.

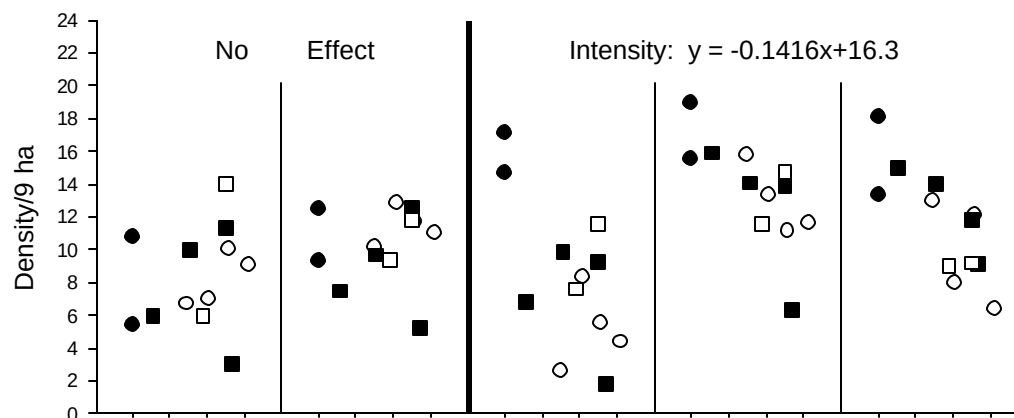
Summary from Herbers and Klenner. Effects of logging pattern and intensity on squirrel demography: Management implications.

Maintaining mature forest attributes in harvested stands is one tool for enhancing biological diversity and ecosystem function in the managed landbase. There are several reasons why forest managers might retain structure in a harvested stand: to “lifeboat” biological components into mature second-growth stands, to simply increase complexity over clearcutting, to enhance landscape connectivity (Franklin et al. 1997), to accelerate stand development toward “old-growth” conditions, to mimic natural patterns of disturbance (Zenner 2000), and to meet the needs of specific species or suites of species (Lehmkuhl et al. 1999). Our study provides information for 3 forest-dwelling species that require forest attributes. It is clear from our results that retaining >35% of a harvested stand will provide habitat for red squirrels and flying squirrels, albeit at lower densities. It is also clear that increasing residual structure in a stand will increase the number of red squirrels and flying squirrels that occupy the harvested stands. We also found significant differences between stands harvested using different patterns of tree removal. During the first 4 years after logging, the density of flying squirrels is higher in uniform removal than patch cut treatments while the density of chipmunks is higher in patch cut than uniform treatments (Figure 6). Ultimately, choices about how much structure to retain in a block and in what pattern will depend on the planning objectives for a particular management unit. Our research was conducted from 1 to 4 years after harvesting and the long term effects of uniform and patch cut harvesting are less clear. Over longer time periods, uniform harvesting methods might have significant advantages over patch cut harvesting. Foresters have long realized the benefits of “releasing” individual conifer trees on seed production (Bilan 1960). “Open grown” trees, a common result of uniform harvesting, can produce between 2 and 12 times more conifer cones compared to trees growing in dense stand conditions (Issac 1943, Garman 1955, Bilan 1960, Allen and Trousdell 1961, Owens and Blake 1985, Karlsson 2000). For species that depend on conifer seed, such as the red squirrel, the quality of the habitat might be higher in uniform than in patch-cut stands once residual trees have physiologically adjusted to post-harvesting stand conditions. Understanding the long-term response of retaining stand-level structure should be a priority for future research.

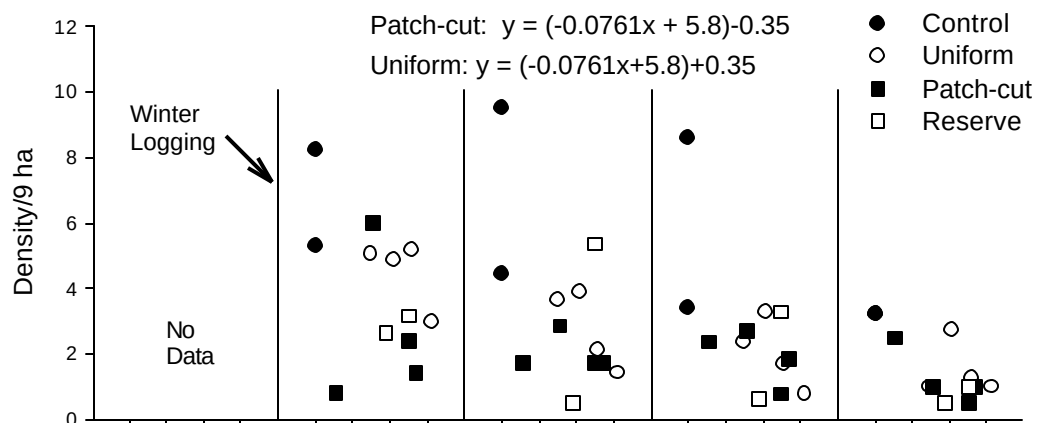
Our results apply only to managed stands where ~65% of the timber is removed. When greater than about 65% of timber is removed the disparity between uniform and patch-cut logging methods are likely to further increase. For example, as critical resources become increasingly diluted in intensively logged stands, silvicultural strategies such as uniform removal will likely result in the dilution of habitat for many small mammals that depend on mature forest attributes (Huggard 1994 in Ehrlich 1996, Ganzhorn et al. 1997). The abundance of species that depend on mature forests for food and cover will likely decline rapidly in uniform stands with >65% harvesting. For example, flying squirrels are likely to avoid habitat with few residual trees because they feed largely on the sporocarps of hypogeous fungi and require trees to facilitate movement (Mowrey and Zasada 1984, Maser et al. 1985).

It is clear that uniform and patch-cut harvesting can be used as tools to enhance long-term structural complexity in a landbase. However, if residual structure is harvested from these stands using multiple partial cut entries, then their contribution toward maintaining biological diversity and ecological function will be diminished. When multiple passes are used, delayed merely by green-up, then the net effect is a staggered clearcut and the long-term recruitment of attributes like dead wood will largely be absent.

a) Red Squirrel



b) Flying squirrel



c) Northwestern chipmunk

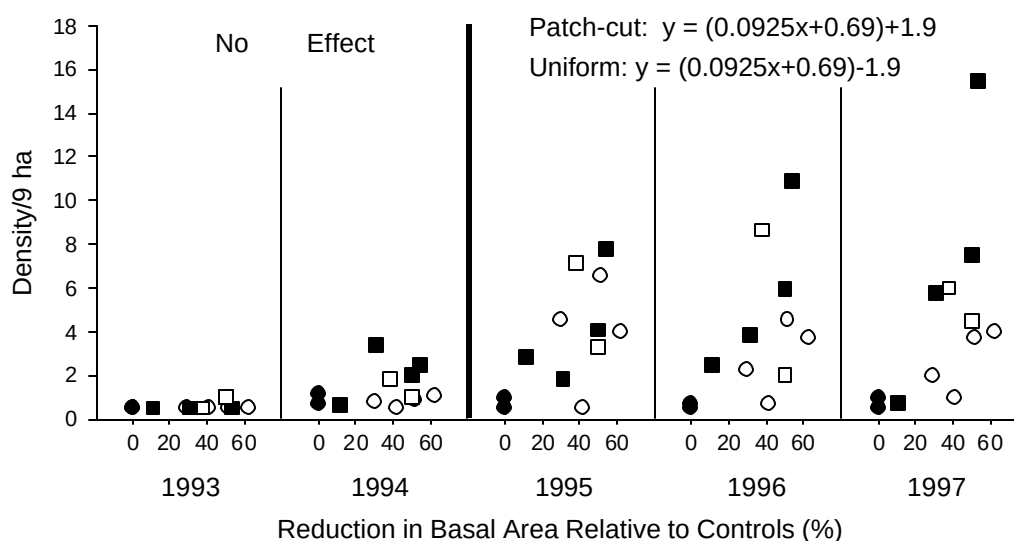


Figure 6. Mean Jolly-Seber density for a) red squirrels, b) flying squirrels, and c) chipmunks at the Opax Mountain Silvicultural Systems Site near Kamloops, B.C.

Study 6 Fire history study. A. Arsenault. No new data collected this year. A manuscript is currently under preparation.

Study 7. The influence of insect defoliators and other disturbances on radial tree growth at Opax Mt. Area. Rochelle Campbell, Dan Smith and A. Arsenault. No new data collected this year.

Summary from Campbell et al. Multicentury historical patterns of western spruce budworm outbreaks in Interior Douglas-fir forests near Kamloops, British Columbia.

This research demonstrates that western spruce budworm outbreaks in this portion of the Kamloops Forest Region have occurred periodically over the last 300 years. This long-term perspective was provided by examination of insect signatures within the tree rings of long-lived stands of Douglas-fir that sustained approximately 7 regional outbreaks over a period of three centuries (Figure 7). The existence of this historical record indicates that some overstorey trees can coexist with budworms for long periods of time. This behaviour is similar to that found by previous researchers (Swetnam and Lynch 1993; Swetnam et al. 1995; Alfaro et al. 2001; Ryerson et al. 2003) and appears to occur even when western spruce budworm populations do not reach the same level of defoliation in all trees (Myers 1993; Bjørnstad 2000). It is suspected that forest characteristics, such as the nutritive value of foliage, may be a factor preconditioning western spruce budworm populations success and that the regional climate has a synchronizing influence (Royama 1984; Shepherd 1985; Williams and Liebhold 1995, 2000; Myers 1998). This study suggests that an early spring season characterized by low precipitation during winter months and normal spring air temperature increase the success of budworm emergence and reduce the Douglas-fir trees ability to defend against western spruce budworm foraging. Research conducted by Kemp (1986) reported that, during an infestation period of western spruce budworm, defoliation following an early spring was severe, whereas that following a late spring was only light to moderate. Myers (1981) has indicated that warm dry weather, which is characteristic of early springs, would promote caterpillar feeding and reduce the incidence of disease. Evidently spring climate can effect changes in both the host plants and the phytophagous species, which synergistically affect growth and survival of the phytophagous population; for example, early spring climates that promote budworm feeding and reduce disease and late spring climates suppressing the growth of the insect population (Myers 1981). This indicates that with higher over wintering survival, increased population growth rates, and a longer growing season, outbreak areas of some species are likely to shift in latitudinal range and may increase in size. Changes in geographical ranges and spatial extent of outbreaks of western spruce budworm are likely consequences of climatic change.

“Natural trajectory experiments”, such as those of tree-ring reconstructions, can encompass large spatial scales (Diamond 1986). Thus, the strength of this historical-regional approach is that observations match the temporal and spatial scales of important processes influencing the system (Ricklefs 1987). Limitations of this approach include the lack of control of some of the interacting variables (ie. biotic, abiotic factors, other trophic levels). The tree-ring record is also inherently “noisy”, and diminishing sample sizes with increasing time before present lowers the reliability of estimates in earlier periods. These problems prevent precise identification of the specific manner in which climatic variations influence budworm populations. Future research involving simultaneous observations of insect numbers, defoliation amounts and tree-ring growth parameters to test the fidelity of the host-nonhost correction approach in reconstruction of past outbreaks to test the importance of climate variations on western spruce budworms and host trees.

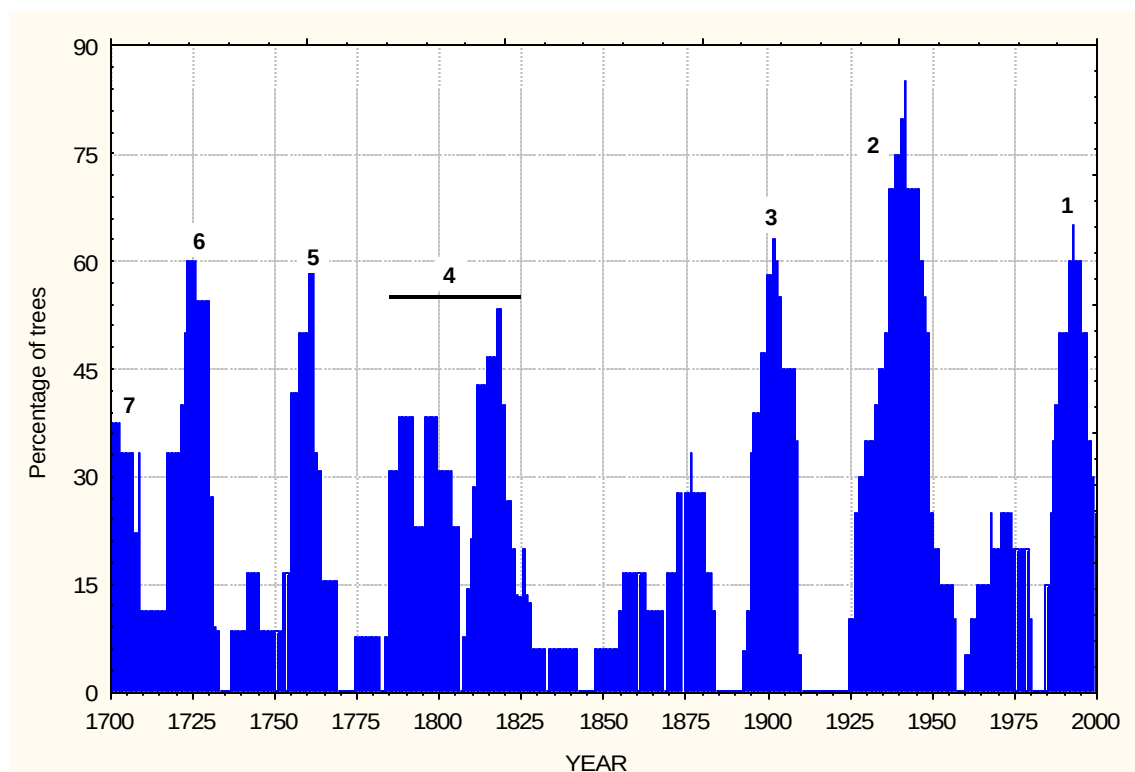


Figure 7. Percentage of Douglas-fir trees with reduced growth relative to ponderosa pine. A minimum of 30% of trees in a given year must demonstrate reduced growth to be classified as having had a western spruce budworm outbreak. Seven outbreaks were identified in the study area.

Study 8. Pest response and forest disease dynamics. H. Merler

Re-measurments have been completed. Data will be incorporated in our metatdabase later this year.

Study 9. Microclimate measurement. A. Orchansky

Climate was monitored and viability analysis has recently been completed. Data will be incorporated in our metatdabase later this year.

Study 10. Predicting the long-term stand structure consequences of managed and natural disturbances in an IDFxh2 forest at Opax Mt. W. Klenner, I. Cameron, R. Walton and D. Huggard.

Summary from Klenner, W. , I. Cameron, and R. Walton. Assessing the likely consequences of stand density on forage and timber production in dry-belt IDF stands.

The following figures and tables illustrate the likely understory grass, forb and shrub and timber consequences of managing for different stand densities in ungulate winter range areas. The results are the outcome of TASS (Tree And Stand Structure) simulations using two site index values that represent responses that would likely occur on “poor” and “good” growing sites. This approach was used to illustrate the different consequences of site condition since the IDF is a complex mosaic of site conditions where tree growth is limited by numerous factors including moisture, soils, etc. We modelled the likely response by both poor and good site index stands to facilitate extrapolating the results to a range of conditions. The overall conclusion is

that it is unlikely that treatments that will produce forage reflecting 50% of site potential will also produce 50% of the timber potential of that site. Lower stand densities may also lead to undesirable tree form (very deep crowns) that affect timber quality. A balance of timber and understory forage values would likely be more successful if a suitable landscape (multi-stand) context for balancing timber and forage values were pursued.

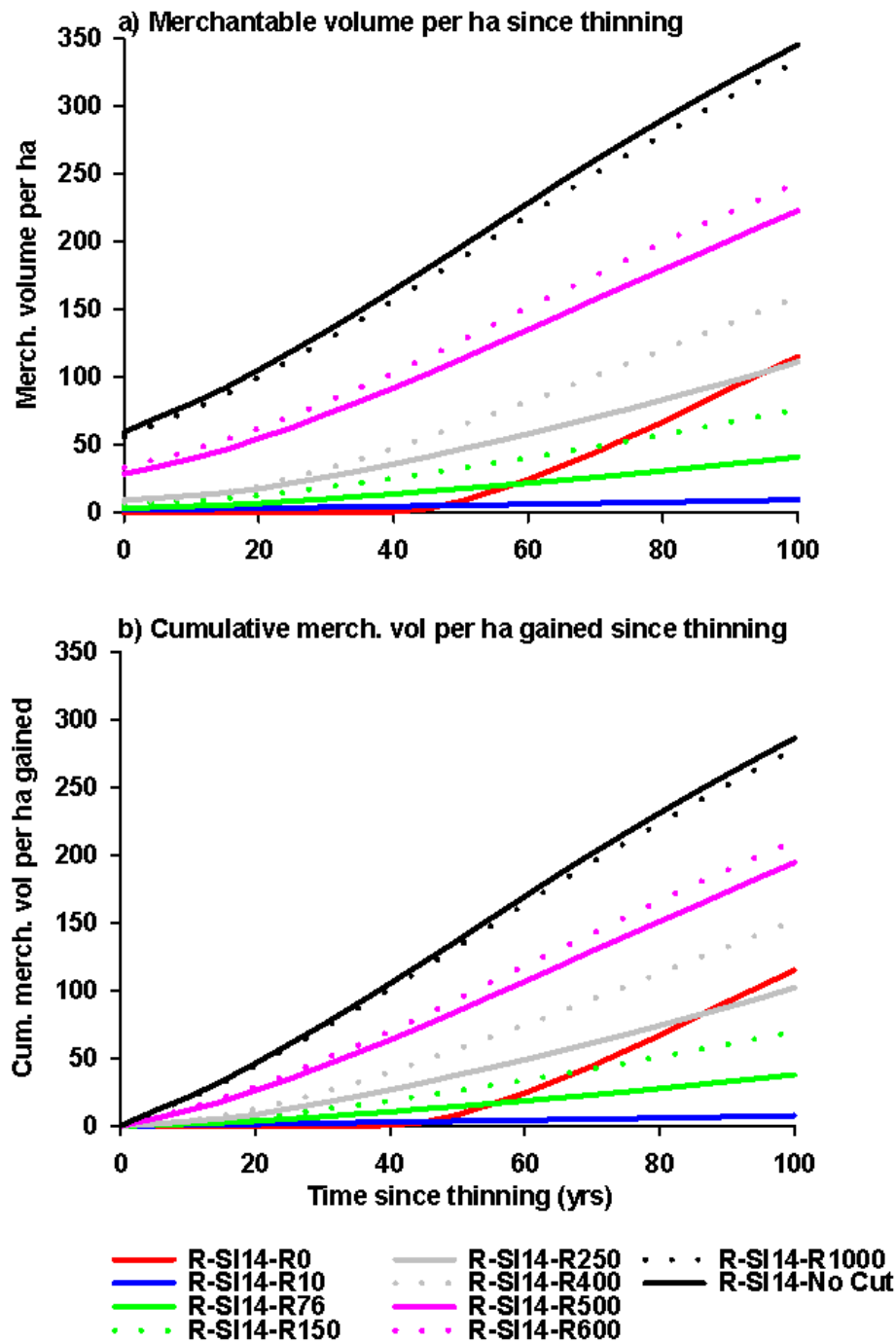


Figure 8. The merchantable volume per hectare (a) and the volume gained per ha (b) since thinning for 10 stand treatment options. The R0, R10, R76, etc. in the legend indicate the number of retention stems left after thinning. R0 indicates the clear-cut and plant with 1000 seedlings treatment, the No Cut treatment represents a stand allowed to continue to grow for an additional 100 years without thinning.

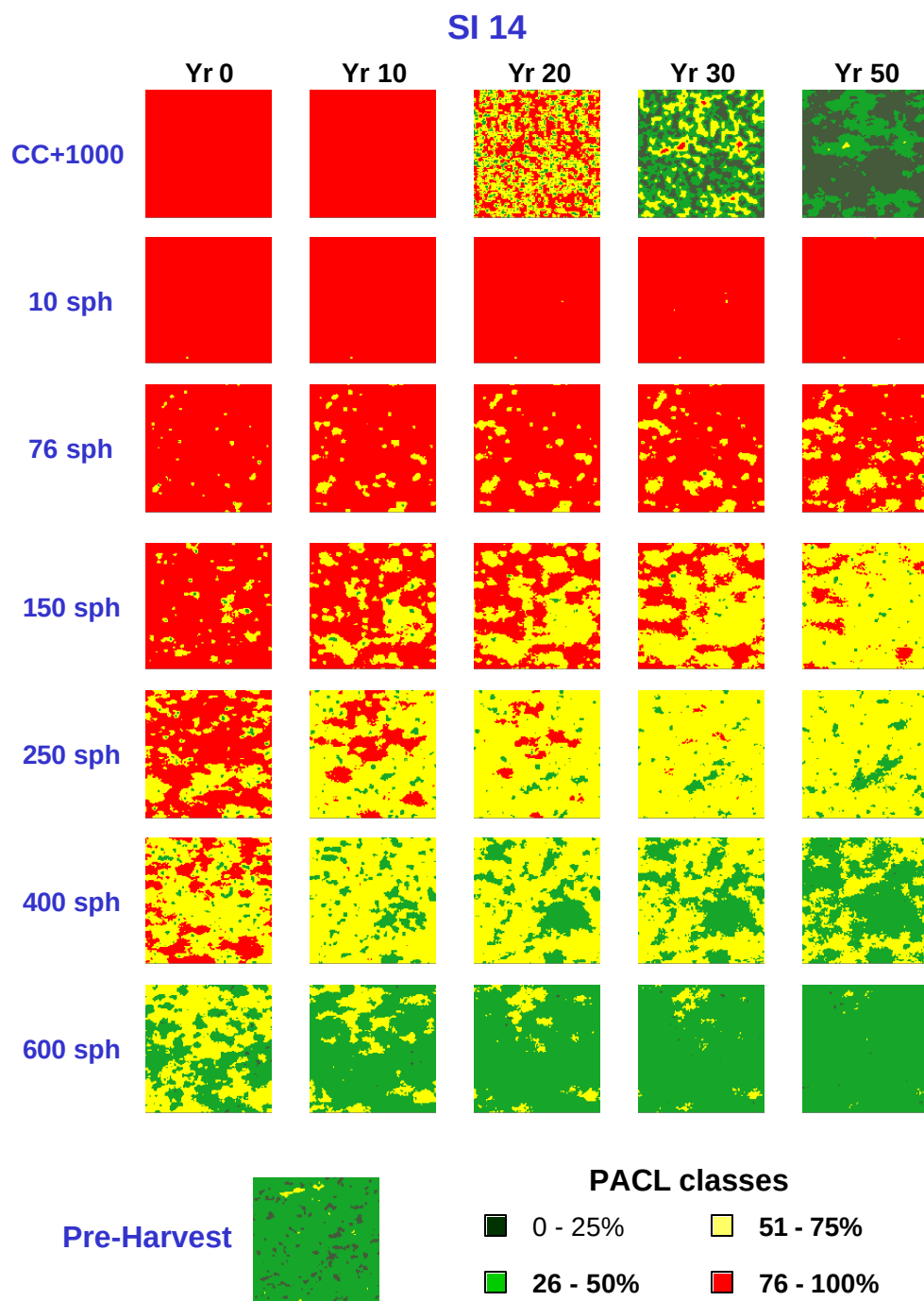


Figure 9. The effect of stand density on PACL (Percent Above Canopy Light) values. Red and yellow represent a high and moderate likelihood (respectively) of maintaining understory forage at greater than 50% of site potential.

Project coordination and Conclusion

The Opax Mountain Silviculture System project was successful in meeting key objectives. We were successful in providing forest science extension in over 20 events and have made considerable progress in producing peer reviewed journal papers. Three papers and one abstract were published this year and eight manuscripts were prepared for peer-reviewed journals. We are well on our way of completing a synthesis of project results thus far and expect to have a comprehensive extension note published this year. We end this report with 4 important conclusions that should provide insight into managing complex Interior Douglas-fir forest ecosystems:

- 1) No single management option works for everything.** This is especially true in the highly-variable IDF. Standard inverse-J selection cannot meet all objectives.
- 2) Wide range of disturbance types, frequency and intensity.** Therefore attempts to “mimic” idealized historical conditions dubious.
- 3) Different responses between openings of <0.1ha and >0.1ha.** Both of these size thresholds have positive and negative characteristics for sustainable forest management depending on which value is examined. Patch cuts >0.1ha are useful and under-utilized management tool for IDF forests.
- 4) Need patch-cuts where partial cutting has dominated.** This will provide variation for a variable ecosystem and an edge against uncertainty.

References

- Alfaro, R.I., Taylor, S., Brown, R.G. and Clowater. 2001. Susceptibility of northern British Columbia forests to spruce budworm defoliation. *For. Ecol. Manage.* 145: 181-190.
- Allen, P. H., and Trousdell, K. B. 1961. Loblolly pine seed production in the Virginia-North Carolina coastal plain. *Journal of Forestry* 59:187-190.
- Bradshaw, F.J. 1992. Quantifying edge effect and patch size for multiple use silviculture - a discussion paper. *For.Ecol. Manag.*48:249-264
- Day, K. 1996. Interior Douglas-fir and selection management. Faculty of Forestry, Dept. of Forest Sciences, UBC. Directed Study Report.
- Bilan, M. V. 1960. Stimulation of cone and seed production in pole-size loblolly pine. *Forest Science* 6:207-220.
- Day, K. 1996. Interior Douglas-fir and selection management. Faculty of Forestry, Dept. of Forest Sciences, UBC. Directed Study Report.
- Diamond, J. 1986. Overview: laboratory experiments, field experiments and natural experiments. In *Community Ecology*. Edited by J. Diamond and T.J. Case. Harper & Row, New York, USA. pp. 3-22.
- Ehrlich, P. R., 1996. Conservation in temperate forests: what do we need to know and do? *Forest Ecology and Management* 85:9-19.

Franklin, J.R., C.S. Bledsoe and J.T. Callahan. 1990. Contributions of the long-term ecological research program. *BioScience* 40:509-523.

Franklin, J. F., D. R. Berg, D. A. Thornburgh, and J. C. Tappeiner. 1997. Alternative silvicultural approaches to timber harvesting: variable retention harvest systems. Page 111-139 in Kohm K. A., Franklin J. F., editors. *Creating a forestry for the 21st century*. Island Press, Washington, D.C., USA.

Garman, E. H. 1955. Regeneration problems and their silvicultural significance in the coastal forests of British Columbia. Department of Lands and Forests, British Columbia Forest Service, Victoria, British Columbia, Canada.

Ganzhorn, J. U., S. Malcomber, O. Andrianantoanina, and S. M. Goodman. 1997. Habitat characteristics and lemur species richness in Madagascar. *Biotropica* 29:331-343.

Karlsson, C. 2000. Seed production of *Pinus sylvestris* after release cutting. *Canadian Journal of Forest Research* 30:982-989.

Kemp, W.P., Everson, D.O. and Wellington, W.G. 1985. Regional Climatic Patterns and Western Spruce Budworm Outbreaks. USDA For. Serv., Agric. Tech. Bull. No. 1693.

Klenner, W. and A. Vyse. 1998. The Opax Mountain silvicultural systems project evaluating alternative approaches to managing dry Douglas-fir forests In *Managing the dry Douglas-fir forests of the southern Interior: workshop proceedings*. Pp 128-134.

Klenner, W. and A. Vyse. 1999. Interdisciplinary research approaches to address complex forest management issues. *Forestry Chronicles* 75:473-476.

Lehmkuhl, J. F., S. D. West, C. L. Chambers, W. C. McComb, D. A. Manuwal, K. B. Aubry, J. L. Erickson, R. A. Gitzen, and M. Leu. 1999. An experiment for assessing vertebrate response to varying levels and patterns of green-tree retention. *Northwest Science* 73(Special Issue):45-63.

Maser, Z., C. Maser, and J. M. Trappe. 1985. Food habits of the northern flying squirrel (*Glaucomys sabrinus*) in Oregon. *Canadian Journal of Zoology* 63:1084-1088.

Myers, J.M. 1981. Interactions between western tent caterpillars and wild rose: a test of some plant herbivore hypothesis. *J. Animal Ecol.* 50: 11-25.

Myers, J.H. 1998. Synchrony of outbreaks of forest Lepidoptera: a possible example of the Moran effect. *Ecology* 79: 1111-1117.

Mowrey, R. A., and J. C. Zasada. 1984. Den tree use and movements of northern flying squirrels in interior Alaska and implications for forest management. Pages 351-356 in W. R. Meehan, T. R. Merrell, Jr., and T. A. Hanley, editors. *Fish and wildlife relationships in old-growth forests: proceedings of a symposium*. American Institute of Fishery Research Biologists, Morehead City, North Carolina, USA.

Owens, J. N., and Blake, M. D. 1985. Forest tree seed production: A review of literature and recommendations for future research. *Canadian Forest Service Information Report P1-X-53*.

- Ricklefs, R.E. 1987. Community diversity: relative roles of local and regional processes. *Science* 235: 167-171.
- Royama, T. 1984. Population dynamics of the spruce budworm *Choristoneura fumiferana*. *Ecol. Monogr.* 54: 429-462.
- Ryerson, D.E., Swetnam, T.W. 2003. A tree-ring reconstruction of western spruce budworm outbreaks in the San Juan Mountains, Colorado, U.S.A. *Can. J. For. Res.* 33:1010-1028.
- Smith, D.M. 1986. The practice of silviculture. John Wiley and Sons. New York
- Swetnam, T.W. and Lynch, A.M. 1993. Multicentury, regional-scale patterns of western spruce budworm outbreaks. *Ecol. Monogr.* 63: 399-424.
- Swetnam, T.W., Wickman B. E., Paul H. G. and Baisan, C. H. 1995. Historical patterns of Western Spruce budworm and Douglas-fir tussock moth outbreaks in the Northern Blue Mountains, Oregon, since A.D. 1700. USDA Forest Service Research Paper PNW. 484.
- Vyse, A., R.A. Smith, and B.G. Bondar. 1991. Management of Interior Douglas-fir stands in British Columbia: past, present and future. in D. M. Baumgartner. ed. Interior Douglas-fir: the species and its management. Symposium proceedings. Pullman, Washington State University, Dept. of Natural Resource Sciences.
- Williams, D. W. and Liebhold, A. 1995. Detection of delayed density dependence: effects of autocorrelation in an exogenous factor. *Ecol.* 76: 1005-1008.
- Williams, D. W. and Liebhold, A. 2000. Spatial synchrony of spruce budworm outbreaks in eastern North America. *Ecol.* 81: 2753-2766.
- Zenner, E. K. 2000. Do residual trees increase structural complexity in Pacific Northwest coniferous forests? *Ecological Applications* 10(3):800-810.

Appendix 1. Extension Activities and deliverables

Extension activities

Campbell, R., D. Smith, and A. Arsenault. 2004. Multicentury historical patterns of western spruce budworm outbreaks in Interior Douglas-fir forests near Kamloops, British Columbia. Presented at winter Sisco in Penticton.

Huggard, D. and A. Arsenault. 2004. Opax Mountain Silvicultural Systems Project: Results for Managing Complex IDF Forests. Presented at winter Sisco in Penticton.

Arsenault, A. 2003. Poster on the Opax Mountain Research project delivered during the "Dry forest ecosystems symposium" held in Kamloops in May 2003.

Arsenault A. and W. Klenner. 2003. Disturbance Ecology of Dry-belt forests of the Southern Interior of BC: perspectives on historic disturbances and implications for management. Oral presentation delivered during the "Dry forest ecosystems symposium" held in Kamloops in May 2003.

Klenner, W.. and A. Arsenault. 2003. The challenge to produce landscape level patterns over time. Oral presentation delivered during the "Dry forest ecosystems symposium" held in Kamloops in May 2003.

Arsenault, A. 2003. From the virtual to the operational: applying ecological information into forest management. Seminar given to UCC students.

Arsenault, A. 2003. Silviculture Systems research program. Oral presentation to staff of the Okanagan-Shuswap Forest District

La journée de l'arbre/Arbour day 2003. 4 Oral presentations to grade 1 students.

Arsenault, A. 2003. Fire ecology and management of dry forest ecosystems if the southern Interior of British Columbia. Field tour organized for SFU School of Resource and Environmental Management.

Arsenault, A. 2003. Applying dynamic ecology information into forest management in British Columbia. Seminar presented to the fire ecology and management class at UCC.

Arsenault, A. and W. Klenner. 2003. Disturbance ecology of dry-belt forests in the Southern Interior of British Columbia: Perspectives on historic disturbances and implications for management. Presented at the Wildfire and Fire Management in the Okanagan Similkameen workshop held in Penticton, BC and hosted by South Okanagan Similkameen Conservation Program.

Arsenault, A. 2003. Fire ecology in British Columbia's interior watersheds. Presented at the BCWWA/CWRA Post-Wildfire held in Kamloops.

Televised interview with French CBC on the ecological perspective of the 2003 fire season. It was aired on RDI.

Print Media interview with UCC journalism student on fire history research at Opax. Published in Nature West.

Site visit and training for BCIT

Site visit and training for NVIT

Update of Mountain Forest Webs-site

Completion of virtual trail by Wayne Deptuck, School District 73.

Published manuscripts (Available upon request)

Arsenault, A. 2003. A note on the ecology and management of old-growth forests in the Montane Cordillera. *Forestry Chronicle* 79(3): 441-454.

Arsenault, A. 2004. Fire ecology of dry forests in the Southern Interior Region. *Streamline Watershed Management Bulletin* 7(4):17

Hope, G.D., C. E. Prescott, and L. L. Blevins. 2003. Responses of available soil nitrogen and litter decomposition to openings of different sizes in dry interior Douglas-fir forests in British Columbia. *Forest Ecology and Management*. 186: 33-46

Huggard, D.J., and W. Klenner. 2003. Grylloblattids in managed forests of south-central British Columbia. *Northwest Science* 77: 12-18.

Draft Manuscripts (currently under review and not available until published).

Campbell, R., D. Smith, and A. Arsenault. (in review). Multicentury historical patterns of western spruce budworm outbreaks in Interior Douglas-fir forests near Kamloops, British Columbia. Target Journal: *Canadian Journal of Forest Research*.

Herbers, J., and W. Klenner. (in review). Effects of logging pattern and intensity on small mammal demography. Target Journal: *Canadian Forest Ecology and Management*.

Huggard, D. and A. Arsenault. (In review). Opax Mountain Silvicultural Systems Project: Results for Managing Complex IDF Forests. Target publication: . British Columbia Ministry of Forests Research Program Extension Note

Lloyd, D. and N. Brand, A. Arsenault and D. Huggard. (in review). Edge effects on understory plant communities of dry Douglas-fir forests at Opax Mountain, British Columbia. Target Journal: *Canadian Journal of Botany*

Lloyd, D., N. Brand, and A. Arsenault. (in review). Forage biomass response to canopy gaps, silviculture treatment and light in an Interior Douglas-fir forest. Target Journal: *Journal of Range Management*

Miège, D., D. Lloyd, M. Doney, and A. Arsenault. (in review). Canopy Gap Distribution and Light Regime of Partially Cut, Dry Douglas-fir Forests. Target Journal JEMS ONLINE.

D. Miège, M. Doney, A. Arsenault, D. Lloyd. Germination and Early Survival and Growth of Douglas-fir Following Site-preparation Treatments Across a Light Gradient at Opax Mountain, British Columbia. (In review). Target Journal: Forest Ecology and Management

Vyse, A., C. Ferguson, S. Simard, T. Kano and P. Puttonen. Canopy cover effects on the performance of three underplanted conifer species at the Opax Mountain Silvicultural System Project. (In review). Target Journal: Canadian Journal of Forest Research

Manuscripts currently in preparation

Dickinson, T.E., E.E. Leupin, and D. Clark. (in preparation). Response of songbirds to timber harvesting in dry Douglas fir forests: community recovery with persistent changes. Target Journal

Arsenault, A. (in preparation). Fire history along an elevation gradient in an interior Douglas-fir forest landscape near Kamloops, British Columbia. Target Journal: Canadian Journal of Forest Research

Unpublished reports

Arsenault, A. and R. Walton. 2004. Bibliography of the Opax Mountain Forest research project: 1997-2003. (Available upon request).

Klenner, W. , I. Cameron, and R. Walton. 2004. Assessing the likely consequences of stand density on forage and timber production in dry-belt IDF stands.

Merler, H. (in prep.) Forest Health conditions at the Opax Mountain Silvicultural Systems study: An update nine year following logging.

Stark, K. 2004. Seed bank literature review. Unpublished draft report.

Abstracts of published manuscripts

Arsenault, A. 2003. **A note on the ecology and management of old-growth forests in the Montane Cordillera. Forestry Chronicle 79(3): 441-454.**

The Montane Cordillera ecozone that spans British Columbia's central and southern interior and a portion of southwestern Alberta contains the greatest variety of old-growth coniferous forest types in Canada. The diverse climates of this region, which include some of the driest, warmest, wettest, and coldest found in southern continental Canada, have directly contributed to the richness of old forest types. Associated with this range in climatic conditions are radically different natural disturbance regimes that have profoundly influenced the distribution, abundance, and structural characteristics of old-growth forests. Old forests tend to be more abundant and to contain more old-growth-dependent organisms in wetter climates. The high number of old-growth-dependent epiphytic lichens in old inland rainforests is a clear expression of this phenomenon. Conversely, old forests are much less abundant in dry landscapes. These forests, often dominated by Ponderosa pine (*Pinus ponderosa* P. Laws. ex C. Laws.) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), have been subject to more frequent natural disturbances, and have been more profoundly influenced by human activities. Although fewer species appear to be dependent on old growth in dry forests, a number of them require certain old-growth structural attributes for their survival. A better understanding of the ecological characteristics of the old-growth forests of Canada's Montane Cordillera will assist in developing informed land-use decisions.

Arsenault, A. 2004. **Fire ecology of dry forests in the Southern Interior Region. Streamline Watershed Management Bulletin 7(4):17**

British Columbia's southern Interior is characterized by diverse climates, which range from very dry to very wet, and from very warm to very cold. Associated with these climatic conditions are radically different fire regimes and vegetation types. Fire frequency can range anywhere from 12 to over 800 years. Fire severity can also vary from light surface fires to catastrophic crown fires. Disturbance types corresponding to biogeoclimatic variants have been divided into four main groups in British Columbia: 1. rare stand-initiating events (e.g., inland rainforests) 2. infrequent stand-initiating events (e.g., moist interior cedar-hemlock forests) 3. frequent stand-initiating events (e.g., dry lodgepole pine forests) 4. frequent stand-maintaining fires (e.g., dry Douglas-fir forests) (but see below). Although fire regimes are somewhat related to biogeoclimatic gradients, they are also highly variable in time and space. Some strongly believe that fire suppression has drastically affected the natural ecosystem processes of dry-belt forests in British Columbia resulting in "unhealthy forests," in "ecological slums," and, ironically, in a higher risk of stand-replacing wildfire. We critically examined the hypothesis that dry-belt forests were historically in a low-severity fire-maintained disturbance regime, and discuss some of the implications of our results on the management of these forests. We examined four sources of information that lend some insight into past disturbance regimes and the stand structure conditions that likely prevailed: (1) accounts by early explorers and systematic surveys before extensive management, (2) fire scar analysis, (3) fire and lightning history records, and (4) timber harvesting practices and records. Our analyses consistently indicate that natural disturbances were likely complex and not in equilibrium, creating changing patterns over space and time in both stand structure and landscape condition. In addition, timber harvesting has affected much of the dry forest types in the Southern Interior Forest Region, and shaped stand structure for over a century. Several interacting factors including climate, harvesting, fire suppression, and patterns of insect pest attack are key drivers in creating and maintaining today's conditions. The wide range of conditions that have occurred in the last 10 000 years, and the uncertainty associated with predicting future conditions limit the utility of the concept of natural or historic variability. No one point in time should be chosen as the "ecologically correct"

reference period. This conclusion questions the utility of the “ecosystem restoration” concept within a science-based dry forest management framework. A science-based approach should focus on clearly defining desired stand conditions, the commodity objectives that will be met with these conditions, and the most effective economic, social, and ecologic tools for achieving these objectives.

Hope, G.D., C. E. Prescott, and L. L. Blevins. 2003. **Responses of available soil nitrogen and litter decomposition to openings of different sizes in dry interior Douglas-fir forests in British Columbia. *Forest Ecology and Management*. 186: 33-46**

Selection of an appropriate silvicultural system that maintains productivity requires an understanding of the effects of harvest type on post-harvest changes in nitrogen availability. The effects on inorganic nitrogen availability and litter decomposition of various harvesting systems, including partial canopy removal and a range of clearcut opening sizes, were investigated in a dry Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) forest in southern British Columbia. We measured concentrations of ammonium and nitrate after 6-week buried bag incubations of forest floor and mineral soil samples in replicated plots within uncut forest, within partially harvested forest, and in openings of 1.7, 0.4, and 0.1 ha, from two to seven growing seasons after harvest. Post-incubation nitrate and the proportion of inorganic N as nitrate in forest floor and mineral soil were elevated from 2 to 7 years after harvesting in the 1.7 ha openings. There was no consistent trend of higher ammonium concentration in either uncut forest or 1.7 ha openings. The proportion of inorganic N as nitrate was consistently the lowest in the uncut forest, and often significantly different from any opening treatment, including partial cutting. The increased proportion of inorganic N as nitrate occurred within 11 m of the uncut forest edge. At very low moisture contents, nitrate concentrations tended to zero only in the uncut forest. Leaching of the increased available nitrate is unlikely because of the large increase in grass biomass that occurs after harvesting, and the dry soil moisture conditions during the growing season. Decomposition of Douglas-fir, lodgepole pine and trembling aspen litters, or forest floor was inconsistently, or not affected by any harvest treatment or by distance from, or aspect of, the edge of the forest. The post-harvest increases in nitrate concentrations cannot be attributed to faster decomposition.

Huggard, D.J., and W. Klenner. 2003. **Grylloblattids in managed forests of south-central British Columbia. *Northwest Science* 77: 12-18.**

We collected 147 specimens of grylloblattids (*Grylloblatta campodeiformis*) in pitfall traps in subalpine spruce-fir forest and lower elevation cedar-hemlock forest at two study sites in south-central British Columbia. Grylloblattids are of conservation interest because of the high degree of endemism in western North America and because little is known of the ecology of these insects. Mature grylloblattid individuals were caught primarily in early spring or late fall, while immature individuals were caught in traps set under the snow in winter. Grylloblattids occurred in clearcuts, partial cuts and uncut forest at both sites. Year-round collections of grylloblattids from a variety of forest habitats have not previously been reported. However, the insects were rare at one study site in old clearcuts and had different seasonal patterns of captures in recent clearcuts with intensive site preparation compared to partially-cut or uncut areas. At a second study site, they showed an affinity for cutblock edges and small patch cut harvest treatments that produce abundant edge. No grylloblattids were collected during similar sampling at a third site in dry Douglas-fir forest. The unexpected abundance of grylloblattids at two sites suggests that they may be widespread in wetter forest sites, but dry forests with low snowfall may act as a geographic barrier. Grylloblattids appear to tolerate or benefit from forest harvesting, other than in large clearcuts with intensive site preparation.

Abstracts of draft manuscripts (Subject to change until published)

Campbell, R., D. Smith, and A. Arsenault. (in review). **Multicentury historical patterns of western spruce budworm outbreaks in Interior Douglas-fir forests near Kamloops, British Columbia. Target Journal: Canadian Journal of Forest Research.**

Western spruce budworm (*Choristoneura occidentalis* (Freeman)) is a native defoliator of the Interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Mirb.) Franco) forests of British Columbia, Canada. This paper used dendrochronology and the software program OUTBREAK to reconstruct a defoliation history of Douglas-fir for nineteen forest sites near Kamloops in central British Columbia. By comparing the radial growth response of non-host ponderosa pine trees to Douglas-fir trees growing in nearby but separate stands, seven western spruce budworm outbreaks were distinguished over the past 300 years. Although there is considerable variation in the timing and duration of these western spruce budworm events at the stand level, synchronous outbreaks have occurred at approximately 37-year intervals. Climate variation appears to have been important to budworm outbreaks in the 20th century. Notable outbreaks tended to occur during years of early springs with average air temperature, following winters with lower than average precipitation. Based on this finding, it is proposed that with high overwintering survival, increased population growth rates, and a longer growing season, the extent of future outbreaks will shift northward and may increase in size.

Herbers, J., and W. Klenner. (in review). **Effects of logging pattern and intensity on small mammal demography. Target Journal: Journal of Wildlife Management.**

Partial harvesting silvicultural systems are being increasingly used as a tool to enhance biological diversity and maintain ecosystem function in managed landbases. Despite widespread application, there remains little empirical evidence describing the effects of partial harvesting on forest dependent species. We examined the affect of harvesting intensity and pattern on red squirrels (*Tamiasciurus hudsonicus*), northern flying squirrels (*Glaucomys sabrinus*), and northwestern chipmunks (*Tamias amoenus*) in mature Douglas-fir forests (*Pseudotsuga menziesii glauca*) in south central British Columbia. Our study was a twice-replicated randomized block design using 5 harvesting treatments and a control. Treatments varied by intensity and pattern of tree removal including: low volume mature tree removal as uniform partial cuts; high volume mature tree removal as uniform partial cuts; medium volume mature tree removal as uniform removal partial cuts with uncut reserves; low volume removal with patch cuts of 0.1 ha, 0.4 ha and 1.6 ha; and high volume removal with patch cuts of 0.1 ha, 0.4 ha and 1.6 ha. Squirrels were sampled 1 year before harvesting to 4 years after harvesting using open population mark-recapture censusing. All 3 species showed a strong response to intensity of tree removal. After a delay of 1 year, red squirrel density declined sharply with increasing tree removal (mean 43% decline with 50% tree removal). From 1 year and up to 4 years after logging, flying squirrel density also declined with increased logging (mean 66% decline with 50% tree removal). After a delay of 1 year, northwestern chipmunk had a marked increase in density with increased logging (mean 670% increase with 50% tree removal). In addition, flying squirrels and northwestern chipmunks responded to pattern of tree removal. From 2 to 4 years after harvesting patch cut treatments had 26% fewer flying squirrels and 85% more chipmunks than uniform removal treatments. In the short term, harvesting intensity is the most important determinate of squirrel density. Retaining >35% of pre-harvest residual structure in a harvested stands will provide habitat for forest dependent species such as red and flying squirrels, albeit at lower densities. Forest managers can use uniform rather than patch cut partial retention harvesting to enhance short-term flying squirrel density.

Huggard, D. and A. Arsenault (in review). **Opax Mountain silvicultural systems project Results for managing complex IDF forests. Target publication: British Columbia Ministry of Forests Research Program Extension Note**

The Opax Mountain Silvicultural Systems project was set up to assess how silvicultural systems affect many variables that are of concern to managers of complex dry IDF forests. The project includes 2 study areas, one in the IDFxh2 variant and one in the IDFdk2, with 6 operational-scale harvest treatments at each: uncut control, 20% removal individual tree selection (ITS), 50% ITS, 50% ITS with uncut reserves, 20% removal with a mixture of patch cuts of 0.1, 0.4 and 1.6 ha, and 50% removal with patch cuts. The project includes studies of: fire history and other natural disturbance agents; operational regeneration in openings and under partial canopy; edge effects on microclimate, snow melt and soils; effects of canopy density, gap sizes, site preparation and edges on planted seedlings, natural regeneration and vegetation (including cover layers, individual species and groups such as forage plants, weeds, forest associates and ectomycorrhizal hosts); and, harvest treatment effects and habitat relationships of wildlife groups ranging from terrestrial invertebrates and arboreal beetles to small mammals and songbirds to woodpeckers and ungulates. Natural disturbances at the site cover a wide spectrum of sizes, frequencies, severities and effects on stand structure. Responses of the many study variables show that no one management treatment will maintain all valued components in the IDF forest. Together, these results recommend a range of management practices broader than the restricted uneven-aged management widely practiced throughout the dry IDF. In particular, patch cut systems with openings >0.1 ha, and management that responds to local stand characteristics are needed complements for individual tree selection systems. Summaries of results are presented for many of the individual studies at Opax Mountain, dealing with the important management issues of natural disturbance regimes, regeneration, managing vegetation resources, and conservation of biological diversity in managed IDF stands.

Lloyd, D. and N. Brand, A. Arsenault and D. Huggard. (in review). **Edge effects on understory plant communities of dry Douglas-fir forests at Opax Mountain, British Columbia. Target Journal: Canadian Journal of Botany.**

This study investigated the vegetation community across clearcut edges in a Douglas-fir forest one and six years after harvest in British Columbia's southern interior. Plots were monitored at the north and south clearcut boundaries and at 6, 12, 24, and 48m into the cuts and into the adjacent forest. Both the north and south edges of each cut were monitored for the response of tree, shrub, herb, bryophyte and ground lichen species. The data was investigated with respect to primary succession, secondary succession and changes over time. Aikake's information criterion (AIC) was used to find the model that best described the pattern of vegetation abundance across the cut edges. No differences in the patterns of edge effects were found between subzones or between opening sizes for all strata. This illustrated that although species abundance or composition may differ between subzones the manner in which vegetation responds across edges did not. The strongest community edge effects were seen into the forest immediately after harvest in secondary successional plots. Here, the community expressed edge effects with a depth of less than 48m into the forest, and less than 6m into the cut. As time progressed, edge effects for the herbaceous layer increased in depth into the cut and into the forest, but all other strata displayed a more narrow depth that penetrated less than 24m into the forest. Hence there was a difference in strata response across edges. In contrast, there were very little edge effects seen in screefed plots. In this primary successional state, only shrubs and herbs displayed edge effects less than 6 and 12m respectively. Therefore, in this investigation the strongest edge effects appeared to be within a relatively narrow band during secondary succession, immediately following harvest.

Lloyd, D., N. Brand, and A. Arsenault. (in review). **Forage biomass response to canopy gaps, silviculture treatment and light in an Interior Douglas-fir forest. Target Journal: Journal of Range Management**

This study investigated several aspects of herbaceous biomass production in a dry Southern Interior Douglas-fir forest in British Columbia. Biomass production was assessed in relation to stand density, gap size class, and light in six silviculture treatments was estimated and compared. One hundred and seventeen 1x1 m plots were established in a variety of gap sizes within six silviculture treatments. Mean biomass for total herbs, suitable forage, and pinegrass was calculated for three stand classes and six gap size classes. There was no significant difference between the mean total herb biomass in dense, closed, and open stands, and gap size classes 1, 2, and 3. The mean total herb biomass in gap size classes 5 and 6 was significantly greater than for all other stand densities and gap size classes. The threshold for maximum biomass production appeared to be within gap class 5 (between 1000 and 1999 m²). The majority of the total biomass was found to be suitable as cattle forage, with pinegrass being the dominant species. A biomass estimate for each treatment unit was calculated for total herbs, suitable forage, and pinegrass. Biomass increased upon cutting in all treatment units. Upon the most intensive removal of 50%, the patch cut estimate yielded the most herbaceous biomass (1273 kg/ha). Regression analysis was used to compare total herbaceous biomass with light (in the form of global GLI) at each plot. A positive relationship was found between the total herbaceous biomass and global GLI ($r^2 = 0.54$, $P < 0.05$). Maximum biomass production occurs in gaps from 1000 to 1999 m², and high intensity cutting and patch cuts yield the most biomass compared to uncut and partial cut areas.

Miège, D., D. Lloyd, M. Doney, and A. Arsenault. (in review). **Canopy gap distribution and light regime of partially cut, dry Douglas-fir forests. Target Journal JEMS ONLINE.**

Interior Douglas fir (IDF) forests of British Columbia have a complex and variable structure resulting from a very heterogeneous topography and soil characteristics, and from a rich history of natural and anthropogenic disturbances. There is a great deal of debate about what forest structure was like in the past and which silviculture systems should be used to produce desired conditions. However, very little work has been done on quantifying canopy structure and light regime in different silviculture systems of the IDF. This study presents an analysis of canopy structure and light regime in five different harvest treatments at the Opax Mountain silviculture systems study site. We also demonstrate how the results of this study have application for evaluating and modeling the effects of different harvest systems on the forest understory. Several different silvicultural treatments, all partial cuts, within Douglas-fir forests in two subzones of the IDF were compared using canopy gap transects. We confirm that the median size and frequency of canopy gaps are significantly different among the treatment units. Treatment units with similar volumes of wood removed, but using different harvesting methods (i.e. uniform versus patchcut) will result in canopy gaps with marked differences in canopy gap geometry. We speculate that the gradient of canopy gap sizes and respective light regimes selected for vegetation plots will correspond with differences in plant community, vegetation biomass, diversity, and regeneration success. Because the frequency and size of canopy gaps is not equal between the various silviculture treatments, we further speculate that observed differences in vegetation response will be recognized between treatment units. This study describes light as a surrogate for other environmental parameters (e.g. air and soil temperature, soil moisture, and snow lie). Six light classes presented here will form a baseline tool with which we can compare responses in plant community, diversity and biomass, tree seed germination success, and tree seedling survival.

D. Miège, M. Doney, A. Arsenault, D. Lloyd. **Germination and early survival and growth of Douglas-fir following site-preparation treatments across a light Gradient at Opax Mountain, British Columbia. Target Journal: Forest Ecology and Management**

In the southern interior of British Columbia, dry Douglas-fir (*Pseudotsuga menziesii* var *glauca* (Beissn.) Franco), forests are a dominant ecosystem and are important for wildlife habitat,

timber harvesting, cattle grazing, and recreation. Partial cut logging is a common silvicultural practice in these forests. At the Opax Mountain Silvicultural Research Area, situated 20km northwest of Kamloops, B.C., several research projects are in place to study the impact of partial cutting on sustainability, biodiversity and regeneration. This report is a summary of results from tree seed germination and seedling survival and performance studies. In addition to Douglas-fir, two other tree species were included in the seed germination trials: Lodgepole pine (*Pinus contorta* var. *latifolia* Engelm. Ex S. Wats), and Ponderosa pine (*Pinus ponderosa* Dougl. Ex. P. & C. Lawson). Douglas-fir germination was enhanced across the entire light gradient when seeds were placed on mineral soil rather than undisturbed or burned substrates. We observed increased regeneration success in study plots that receive approximately 25 to 81% of total available light; this corresponds to median canopy gap areas of 108 to 2000m². Seed predation from insects or birds and mammals had a significant affect on the total amount of seed available for germination. Similar results were noted for both Lodgepole pine and Ponderosa pine. Distinct differences in Douglas-fir seedling survival, and seedling height were noted between canopy gaps with different light regimes. Seedling survival is maximised in a light regime of approximately 35 to 63% of total seasonal light, which corresponds to median gap sizes of 180 to 399m². Seedling survival in larger openings can be maintained by using scalp site preparation or possibly other methods of vegetation control. Performance of established seedlings was better in larger openings than in small gaps or forest. Our results can assist forest managers and ecologists with an understanding of the effect of canopy openings of different sizes. Small patch-cuts or uniform selection logging may meet management objectives for planted seedling establishment without the need for site preparation. Site preparation is likely necessary for successful regeneration from seed only, or for seedling survival in large patch-cuts. Also, additional evidence for Douglas-fir ecology with regards to drought and shade tolerance is presented.

Vyse, A., C. Ferguson, S. Simard, T. Kano and P. Puttonen. **Canopy cover effects on the performance of three underplanted conifer species at the Opax Mountain Silvicultural System Project. Target Journal: Canadian Journal of Forest Research**

The effects of environmental factors on the growth of three species of seedlings were studied at a site in the very dry, hot Interior Douglas-fir sub-zone near Kamloops B.C. as part of the Opax Mountain Silvicultural Systems project. Douglas-fir, *Pseudotsuga menziesii* var *glauca* (Beissn.) Franco, Lodgepole pine, *Pinus contorta* var. *latifolia* Engelm. Ex S. Wats, and Ponderosa pine, *Pinus ponderosa* Dougl. Ex. P. & C. Lawson, seedlings were planted in mechanically site prepared patches under different canopy conditions created by logging one half to two thirds of the original stand volume. The prepared areas were selected to represent combinations of slopes from 0 to 66%, canopy closures from 0 to 100%, and all aspects. After four years survival of Douglas-fir, lodgepole pine and ponderosa pine was 84%, 84% and 79% respectively. Survival was not affected slope or aspect and was only reduced in the highest crown closure class (>81%). However, the number of seedlings in good condition was strongly influenced by crown closure class. Growth of lodgepole pine was greatest in all light levels but the growth rate of ponderosa pine increased more rapidly at the highest light levels. A multiple regression analysis showed that initial seedling size and % total light had a significant positive effect on root collar diameter after 4 years. The model explained only 38, 32 and 35% of the total variation for lodgepole pine ponderosa pine and Douglas-fir respectively. The use of % diffuse light improved the model predictions to 48, 32 and 41%. Basal area, aspect and slope did not improve the explanatory power of the model. $\delta^{13}C$ values of seedlings were significantly positively related to volume growth, seemingly indicating that the high $\delta^{13}C$ values were probably caused by increased nitrogen availability due to logging rather than by moisture stress.