IMPACTS OF THE MOUNTAIN PINE BEETLE IN THE BABINE RIVER ECOSYSTEM NETWORK

Prepared for the Babine Watershed Monitoring Trust

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PROJECT CONTEXT

PROJECT SCOPE

The Babine Watershed Monitoring Trust (BWMT) supports monitoring projects in the Babine Watershed that address critical management targets embedded in land use plans approved for the Babine watershed. Project 2011-2, "Ecosystem Network and Natural Disturbance" was considered to be a high priority in the 2011 BWMT Annual Monitoring Plan, and a contract was tendered to collect data to reduce uncertainty about the effectiveness of the designed ecosystem network. Two of three potential phases were included in the contract. Phase I involved determining the extent of pine and the extent of disturbance due to mountain pine beetle (MPB) in the ecosystem network, and phase II was about determining the impact of disturbance on biodiversity including the collection of field data to calibrate disturbance levels. Phase III, to be implemented at some future date, will be about the impacts of disturbance on selected species.

A primary objective of this study was to determine if the Babine Watershed ecosystem network is effective in maintaining biodiversity in the face of climate-induced disturbance from mountain pine beetle. Although ecosystems within the entire watershed have been considered, it is the impacts on Core Ecosystems (CEs) and Landscape Riparian Corridors (LRCs) within both the Bulkley and Kispiox Timber Supply Areas (TSAs) within the watershed that are the focus of the study. Some comments on pine beetle impacts in the Babine River Corridor Park (BRC) are also provided.

ECOSYSTEM ATTRIBUTES THAT MAINTAIN BIODIVERSITY

In determining whether the ecosystem network is effective in maintaining biodiversity, two important questions must be answered:

1. what are the key attributes of an ecosystem network that maintain biodiversity, and
2. how much change in these attributes can be sustained before the network is no longer effective?

In answering these questions, information from three sources was considered: land use plans approved for the Babine watershed, the BWMT's Knowledge Base, and literature on ecosystem resilience. Land use plans considered in assessing the degree to which biodiversity is being maintained include: the Land and Resource Management Plans for the Kispiox and Bulkley TSAs, the West Babine Sustainable Resource Management Plan (the SRMP), the Babine Landscape Unit Plan (Babine LUP), the Nilkitkwa Land Use Plan (Nilkitkwa LUP), and the 2006 order establishing land use objectives for the Bulkley TSA. Information in the Babine River Corridor Provincial Park Management Direction Statement was also considered. Key direction on biodiversity in the land use plans is summarized in Appendix IV. Information in the BWMT knowledge base on acceptable thresholds of change was used to augment information in the plans. Recent literature on ecosystem resilience was considered but, because biodiversity attributes that explicitly address climate change and ecosystem resilience have not yet been developed or approved, it was not used directly in assessing whether biodiversity is being maintained. Some of the basic ecological concepts underlying recent thinking on ecosystem resilience are discussed, however, in Appendix III – Supporting Ecological Concepts.

The final selection of attributes used to evaluate the impacts of mountain pine beetle on biodiversity within the ecosystem network included:

1. Area in mature and old forest in core ecosystems and LRCs.
2. Area harvested within core ecosystems.
3. Area harvested within LRCs.

4. Kilometers of road within core ecosystems and LRCs as well as road density.
5. Size of harvested areas in LRCs.
6. Linear proportion of LRCs in which there is no interior forest condition (i.e. areas within the LRCs that, because of logging, will be less than 500m wide in any direction).
7. Area of red and blue listed ecosystems that are disturbed.
8. Within mature forest areas in the network, the degree to which stand structure is intact with respect to tree species and size, snag levels and decay class, CWD levels and decay class, and understory vegetation composition and levels.

METHODS

A combination of methods was used to evaluate the impact of pine beetle in the ecosystem network (including the impact of logging associated with pine beetle salvage and control). GIS analysis was used for broad indicators like harvested areas, road density, and rare ecosystems; and field assessments were completed to evaluate stand structure in beetle-affected stands and unaffected stands. Field information was also used to evaluate the reliability of GIS data obtained from other sources regarding mountain pine beetle disturbance, road construction and timber harvesting, and the vegetation resources inventory (VRI). Data sources used in the analysis have been summarized in table 1.

Table 1. Data used in the analysis of biodiversity in the ecosystem network.

Data	Vintage	Source
VRI database and forest cover, Kispiox	1992, proj to 2010	MoFLNRO, District
VRI database and forest cover, Bulkley	2008, proj to 2010	MoFLNRO, District
PEM Kispiox	2002	MoFLRNO, District & Region (D.Morgan)
PEM Bulkley	2010	Timberline Natural Resources Group
BEC Units	2008	Geo BC
Ecosystem Network	July 2007	ILMB (provided by J. Pfalz)
Cumulative Kill (pine beetle)	May 2010	MoFLNRO, Adrian Walton
Harvest areas	Mar 2012	MoFLNRO, Results
Roads, Kispiox	July 2011	Geo BC, Forest Roads
Roads, Bulkley	Dec 2011	PIR HLPO Analysis
Stand Structure	Sept/Oct 2011	Field assessments, this project
Base Mapping	Mar 2012	WMS Server: http://openmaps.gov.bc.ca/mapserver/base3?
Air photo and Landsat Imagery	2005 photos	WMS Server: http://openmaps.gov.bc.ca/imagex/ecw_wms.dll?

GIS ANALYSIS

In assessing the impacts of mountain pine beetle on the ecosystem network, GIS analysis was used to evaluate: amount and size of harvested areas, road levels, the proportion of LRCs in which there is no interior forest condition, and potential area of red and blue listed ecosystems that could have been disturbed. A project map was created in ArcView 9.2 using the data sources indicated above. A variety of extraction and overlay tools were used to clip, intersect, or union selected features with the ecosystem network, and associated data tables were exported to Excel where data analysis was performed using filters, pivot tables, IF statements, and statistical functions. A number of queries were also completed in ArcView on attribute tables to isolate data of interest. A more complete description of the steps involved for the mature and old forest analyses is included in Appendix V as an example. Resulting layers were added to the project map and verified for accuracy against original line work as well as against underlying aerial photography and Google imagery. There were some inconsistencies between data layers/sources as well as missing data and inaccuracies in the data relative to field information. These anomalies have been summarized in the Results section under Data Calibration.

ANALYSIS OF STAND STRUCTURE

The objective of field sampling was to obtain an appreciation of the potential impacts that mountain pine beetle might have on stand structure including tree species composition and diameter distribution, crown closure, snag levels, coarse woody debris levels, conifer regeneration, and understory vegetation. Budget constraints and a paucity of unlogged stands that had been attacked for more than five years, limited the field work to a relatively small selection of stands.

Before any field sampling was conducted, an area-at-risk analysis was conducted using GIS technology, VRI data, predictive ecosystem mapping (PEM), and information generated from the MoFLNRO Mountain Pine Beetle Model on cumulative beetle kill from 1999 to 2010. The primary objective of this aspect of the analysis was to determine if there was sufficient susceptible pine in the watershed to be concerned about the potential impacts of pine beetle, but a secondary objective was to identify where sampling should be conducted. During the area-at-risk analysis, a matrix was developed for the watershed as a whole, as well as the ecosystem network, summarizing area by level of pine (<33%, 33-66%, >66%), potential pine mortality (<11%, 11-50%, >50%), and by site series based on PEM mapping (poor dry, poor wet, mesic, and rich). The original intent of field sampling was to sample across a range of site series but it became apparent from the GIS analysis that most of the area that had been attacked by pine beetle by 2005 (the date used as a cutoff for when the impacts of beetle attack would be manifest in stand structure) was either mesic or rich. During field sampling, very little area could be found that was not mesic and so field sampling was restricted to circum mesic sites.

Potential plot locations were identified based on the results of the area-at-risk analysis and examination of air photos. Two types of plot locations were chosen: a) unaffected areas in which there was no evidence from aerial overview flights or from the mountain pine beetle model that pine beetle had affected the area, and b) areas which had been attacked by mountain pine beetle in 2005 or earlier according to the mountain pine beetle model but which had not been logged. An equal number of plots was established in each type.

To maximize sampling efficiency two 5.62m radius (1/100th ha) plots were established in each location at least 30m apart. Data collected in each plot included:

- geographic coordinates (UTM);
- BEC unit and site series;
- level of beetle attack - number of trees affected and class of attack (X-dead and grey, Y2-attack that is two years old, Y1-attack that is one year old, C-attack in the current year, or none);
- tree species and number;
- tree crown closure;
- tree diameter;
- number of snags and decay class;
- regeneration levels by species and size class (<1.3m height, 1.3m ht to 7.5 cm diameter at breast height (dbh), 7.5 cm dbh to 12.5 cm dbh, > 12.5 cm dbh);
- understory vegetation species (including tree regeneration) and abundance;
- coarse woody debris data (number of pieces and diameter on a 30m transect);
- digital photos of the plot.

At each location, one 30m coarse woody debris transect was established at the first plot centre (at a bearing of 360 degrees from the centre). The length and diameter of every piece of coarse woody debris the transect crossed was measured. Volume measurements were determined using the following formula from the MoFLNRO Vegetation Resources Inventory Sample Data Compilation Process (Mar 2009, ver. 4.1):

$$CWD\ Volume/ha = \frac{1.234}{L} \bullet \sum \left[\frac{D^2}{Cos(A)} \right]$$

Where:
L = length of transect
D = diameter of each piece
A = tilt angle from horizontal in degrees

Appendix II contains a map showing all sampling locations and an Excel spreadsheet with all plot data, metadata, and analysis has been attached under separate cover (Plot_Data_Analysis).

RESULTS

DATA CALIBRATION

Field assessments of stand structure were used in conjunction with 2005 orthophotos, and 2005 Google Earth imagery, to evaluate the reliability of road construction and timber harvesting information, information on mountain pine beetle disturbance, and information on tree species and stocking levels in the VRI database. It is important to consider how this information was derived, and the intended scale of use when using it to evaluate whether biodiversity is being maintained in the Babine River ecosystem network. Reliability considerations are summarized below by type of data.

ROAD CONSTRUCTION AND TIMBER HARVESTING DATA

Three different sources of cutblock data were assessed for accuracy and completeness: VRI data, MoFLNRO Results data (see http://www.for.gov.bc.ca/his/results/index.htm for a description of Results) for harvested polygons, and cutblock and road information provided by Pacific Inland Resources that was produced during an analysis of the 2006 government Higher Level Plan (HLP) Order objectives for the Bulkley TSA. Each of these sources was evaluated against 2005 air photos and, on the Bulkley side of the watershed, against field information. None of the sources were complete. With each data source, there were areas of harvesting that were not included. VRI data and Results data were generally accurate on the Kispiox side of the watershed because market conditions have not been conducive to harvesting and little has occurred in the watershed since 2005 (Glen Buhr, pers. comm., 2012). On the Bulkley side of the watershed, based on a visual inspection of the photography against the Results cutblock layer, it was apparent that some cutblocks were not shown on the aerial photography. The Results cutblocks layer was the most comprehensive, however, and was available across both TSAs. It also included all of the cutblocks identified in the HLP Order Analysis conducted by PIR and was, therefore, used in all analyses involving cutblocks except in the analysis of interior forest conditions in LRCs, where cutblock data from all sources was used. It is estimated that more than 97% of cutblock area within the ecosystem network was adequately represented in the Results Harvesting layer (based on a visual inspection of all other pertinent data sources).

The general accuracy for roads was similar to that for cutblocks. The forest roads layer available in the GeoBC data warehouse was used for the Kispiox side of the watershed and accurately reflected 2005 aerial photography. On the Bulkley side of the watershed, the shp file used in the PIR HLP Order

Analysis accurately reflected roads visible on aerial photography with only a few road fragments missing. When the GeoBC roads layer was added, the missing road fragments were captured. The GeoBC layer was not as accurate overall, however, in terms of completeness or in terms of spatial accuracy. As was the case with cutblocks, the aerial photography on the Bulkley side of the watershed did not show new roads created since 2005 but the shp file from the HLP Order Analysis did reveal a number of new roads, not shown on the photo. No additional roads beyond those visible in the HLP Order Analysis shp file were noted during field work.

With respect to road status, no reliable information was obtained for the analysis. There are no specific criteria used to determine if a road is permanent or not except whether a licensee declares a road to be temporary or permanent, normally based on whether it has been deactivated. This type of information is not consistently tracked by individual licensees (pers. comm., Dave Ripmeester, 2011) and it is not in any provincial database. This deficiency was also noted in the HLP Order analysis, which did not include findings on whether higher level plan criteria regarding permanent roads were met. It was not possible in this project, therefore, to determine if roads within the ecosystem network were permanent or not.

INFORMATION ON MOUNTAIN PINE BEETLE DISTURBANCE

A fundamental aspect of this project was to determine current and projected impacts of mountain pine beetle on biodiversity in the ecosystem network. The primary source of information on beetle occurrence is the provincial MoFLNRO Mountain Pine Beetle Model (see http://www.for.gov.bc.ca/ftp/hre/external/!publish/web/bcmpb/year9/BCMPB.v9.BeetleProjection.Update.pdf) which uses forest cover maps, the Provincial Aerial Overview of Forest Health, and information from a stand level mountain pine beetle model, to estimate the current extent of pine mortality and to project a possible course of the infestation into the future. The model provides a landscape level indication of where pine beetle has been and where it is projected to occur up to the year 2020, but the information appears to be somewhat broad for use in predicting future impacts at the stand level. Grid code values (incidence) are produced from sketch maps which are hand drawn by someone in a fixed wing aircraft as they fly past an infested area, and the sketch mapping is then used to generate severity classes (0-no data, 1-trace, 2-low, 3-moderate, 4-severe, 5-very severe) from which a mid point is taken and assigned to a 1200m x 1200m map grid. Four hundred metre square pixels are then placed onto locations within the grid where pine occurs in the inventory label (the label describes which tree species occur within the inventory polygon). The pixel shape is rectangular and does not correspond to inventory polygon boundaries. Tree species information in the model is based on VRI data from 1999 to 2002 which is much older than the current VRI for the Bulkley.

The way the field data is processed, in conjunction with older inventory data (for the Bulkley side), means that the information for any particular inventory polygon has a good chance of being incorrect. For example, a map check revealed examples where high pine mortality had been modeled in polygons with no pine in them, and other polygons in which current inventory data indicated high levels (e.g. 70%) of older (180 years) pine that was modeled to have only 15% mortality by 2020. Statistical analysis of field data for MPB incidence in affected stands (table 2 and figure 1 - dark red and light red bars) indicated that it was significantly higher at 74% than incidence shown in the MPB model for these stands (6%), although this was not the case for unaffected stands. The reliability of the inventory data regarding pine abundance was also called into question. The percent pine in sampled stands (prior to attack) was significantly different than the percent pine for these same stands contained in the VRI database (table 2). After attack, the differences were even more pronounced as can be seen in figure 1 (dark green and dark brown bars). Dave Ripmeester (pers. comm. 2011) indicated that his company (Pacific Inland Resources Ltd.) had been finding occasional errors in the Bulkley inventory data with respect to species composition and pine. Information on the proportion of pine in each stand, and pine beetle incidence in trees >12.5cm dbh in each affected and unaffected plot is contained in appendix V1.

Adrian Walton the primary author of the Provincial-Level Projection of the Current Mountain Pine Beetle Outbreak indicates that caution must be used when drawing conclusions about cumulative mortality generated by the mountain pine beetle model for areas that are not at a landscape scale (pers. comm. 2012). Hubert Burger, a MoFLNRO timber supply analyst involved in the Bulkley re-inventory, echos this same concern for inventory data, indicating that the probability of VRI data providing a reliable answer at a landscape level of analysis is good but that at the stand level caution must be exercised. It seems apparent, therefore, that the GIS data from the MoFLNRO on vegetation resources and beetle incidence, should not be used for stand level assessments of biodiversity but that at the level of the watershed and ecosystem network it will be more reliable. An important proviso, however, is that VRI data on live tree species composition, crown closure, and volume is unlikely to be accurate in areas affected by mountain pine beetle given that the last re-inventory was in 2008 (in the Bulkley and earlier in the Kispiox) before the greatest pressure from pine beetle occurred.

Table 2. Single factor Anova comparing field observations of pine beetle incidence in pine >12.5 cm dbh with pine beetle incidence forecast with the MPB Model, and comparing percent pine observed in the field with percent pine in the VRI database for the same stands. When F is larger than FCrit, the null hypothesis is false (that there is no difference between field observations and GIS data) at the level of probability indicated under P.

	F	P-Value	F Crit
% Pine Observed vs VRI % Pine (Affected Plots)	15.511	<0.0001	4.098
MPB Incid Observ vs 2010 MPB Model (Affected Plots)	190.752	<0.0001	4.098
% Pine Observed vs VRI % Pine (Unaffected Plots)	11.292	0.002	4.098
MPB Incid Observ vs 2010 MPB Model (Unaffected Plots)	0.098	0.756	4.098

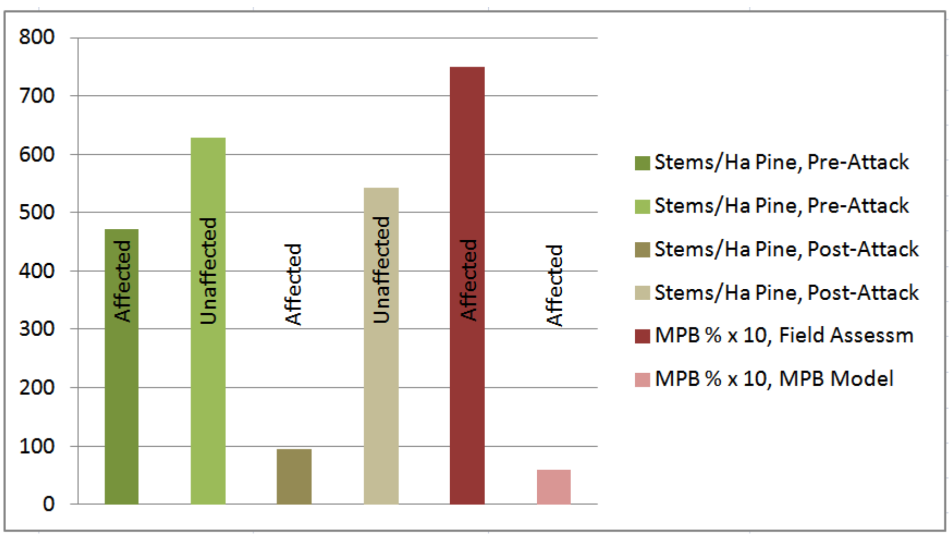

Figure 1. Differences between affected and unaffected stands with respect to mean stems/ha >12.5 cm dbh before and after pine beetle attack; and differences with respect to mean pine beetle incidence observed during field assessments of affected stands versus incidence produced from the 2010 BC Mountain Pine Beetle Model for these stands.

THE HLP ORDER ANALYSIS CONDUCTED BY PIR

The data acquired and used by PIR in assessing higher level plan objectives, was also reviewed and assessed for utility in calibrating information in this project. As noted above, information on roads did appear to be better than other sources for roads on the Bulkley side of the watershed, however, most other data used in the PIR analysis was the same as that used in this project (see page three of the PIR report entitled Higher Level Plan Order Analysis regarding data sources). The analysis undertaken by PIR was different than the analysis used for evaluating the impacts of pine beetle on biodiversity, however, and these differences make it impossible to compare findings. Analysis methods and metrics were both different. Some examples include:

a. The PIR analysis included only the Bulkley side of the watershed whereas the biodiversity analysis includes both the Kispiox and Bulkley sides.
b. In the PIR analysis, a less complete cutblock layer was used which excluded areas harvested before January, 1998 whereas in the biodiversity analysis all harvested areas were included regardless of date of disturbance.
c. Importantly, the PIR analysis summarized results by geographic unit within each LUP in the TSA rather than for the Core or LRCs in the watershed.
d. The HLP Order analysis focused on identifying core ecosystems with more than 50% of the area in stands <50 years of age (a metric and threshold not used in the biodiversity analysis and which was not part of the landuse plans, although it is used in timber supply analysis).
e. The PIR analysis included, as part of the assessment of seral stage distribution in LRCs, stand ages as low as 80 years of age (all species) and 60 years of age (pine leading), whereas the biodiversity analysis focused on only old and mature stages.

No attempt was made, therefore, to either emulate the work done in the PIR analysis using data from the biodiversity project, or to refine the PIR analysis to extract data that would be comparable to the biodiversity analysis. Without this kind of additional analysis, comparing PIR findings with the results in the biodiversity project would be like comparing “apples to oranges” and could conceivably provide similar results since the base data would be the same in both cases.

EXTENT OF PINE AND MPB

Many of the indicators for biodiversity are expressed as a percentage relative to the watershed as a whole or the ecosystem network in its entirety. Table 3 summarizes area statistics for the watershed.

Table 3. Area summary for various land categories in the Babine River watershed.

Area (Ha)	% of Watershed	Category
413,900	100	Area in Watershed
84,677	20	Area in EN
47,994	12	Area of EN Bulkley
36,683	9	Area of EN Kispiox
37,998	9	Area of Core Bulkley and Kispiox
15,371	4	Area in the Babine Rv Corridor Park[1]
46,679	11	Area of LRC Bulkley and Kispiox
18,352	4	Total Area in Core Bukley
29,642	7	Total Area in LRC Bulkley
19,646	5	Total Area in Core Kispiox
17,037	4	Total Area in LRC Kispiox
29,268	7	Area of CFLB Core Bulkley and Kispiox[2]
35,655	9	Area of CFLB LRC Bulkley and Kispiox
12,441	3	CFLB Area in Core Bulkley

[1] Note that some Core areas on the Kispiox side of the watershed overlap with the park.

[2] CFLB – crown forest land base (gross area netted down to remove areas that are not treed and, therefore, not part of the CFLB including NPBr, NCBr, NSR, S - swamp, RIV, R - rock, M - meadow, L - lake, G - gravel bar , CL - clay bank, A - alpine, U - Urban, or other land with <10% tree cover).

21,690	5	CFLB Area in LRC Bulkley
16,828	4	CFLB Area in Core Kispiox
13,965	3	CFLB Area in LRC Kispiox

VRI information reveals that pine is a leading species on about 5% of core ecosystems and that it is leading in LRCs between 4% of the time (Kispiox) and 14% of the time (Bulkley). These low values for pine occurrence within core ecosystems is not surprising given the propensity of planners to locate CEs in riparian areas, areas with a high proportion of wetlands, in older age classes, and on higher elevation sites. Evaluating how mountain pine beetle might impact the ecosystem network by looking at only those stands in which pine is the dominant species, would be underestimating the area at risk however. The last column of table 4 indicates that there are significant additional areas in the ecosystem network (16% of the EN and 27% of the Bulkley LRC) in which pine represents at least 10% of a stand.

Table 4. Area within various sections of the ecosystem network (total area, area in which pine is the leading species, area in which pine greater than 40 years of age is leading, and area in which the pine greater than 40 years of age represents at least 10% of the stand).

Unit	Total Area (Ha)	Area Pl Leading	Area Pl Ldg, 40+ Yrs*	Area Pl >10%, 40+ Yrs
Bulkley Core	18,352	775 (4%)	641 (4%)	1754 (10%)
Bulkley LRC	29,642	4,170 (14%)	3,729 (13%)	8073 (27%)
Kispiox Core	19,646	1,246 (6%)	1,246 (6%)	2041 (10%)
Kispiox LRC	17,037	654 (4%)	648 (4%)	1513 (9%)
Total	84,677	6,845 (8%)	6,264 (7%)	13,381 (16%)

*40 years was chosen as an age below which there is a low probability of beetle attack.

Table 5 summarizes the area in which pine stands greater than 40 years old have been affected by mountain pine beetle as indicated by the Mountain Pine Beetle Model produced by Adrian Walton.

Table 5. Area (ha) in pine-leading polygons affected by mountain pine beetle within the EN.

Pl Mortality at **2000**									
	< 10% Pl Mortality[1]			11-50% Pl Mortality			>50% Pl Mortality		
	0-33% Pl[2]	33-66% Pl	67-100% Pl	0-33% Pl	33-66% Pl	67-100% Pl	0-33% Pl	33-66% Pl	67-100% Pl
Poor Dry[3]	24	11	73	0	0	0	1	0	0
Poor Wet	0	0	9	0	0	0		0	0
Mesic	53	61	71	3	0	0	1	0	0
Rich	186	151	197	4	0	0	7	0	0
Pl Mortality at **2005**									
	< 10% Pl Mortality[1]			11-50% Pl Mortality			>50% Pl Mortality		
	0-33% Pl[2]	33-66% Pl	67-100% Pl	0-33% Pl	33-66% Pl	67-100% Pl	0-33% Pl	33-66% Pl	67-100% Pl
Poor Dry[3]	34	11	73	0	0	0	1	0	0
Poor Wet	0	0	9	0	0	0	0	0	0
Mesic	71	75	117	17	6	3	13	3	0
Rich	273	159	249	50	28	11	18	0	1
Pl Mortality at **2010**									
	< 10% Pl Mortality[1]			11-50% Pl Mortality			>50% Pl Mortality		
	0-33% Pl[2]	33-66% Pl	67-100% Pl	0-33% Pl	33-66% Pl	67-100% Pl	0-33% Pl	33-66% Pl	67-100% Pl
Poor Dry[3]	235	96	266	47	6	37	10	4	0
Poor Wet	64	24	61	10	2	1	0	0	0
Mesic	264	166	259	114	76	88	45	26	11
Rich	791	382	403	383	131	160	119	31	10

[1] Observed % Pl Killed (see Cumulative_Pine_Mortality_2009\BCMPB.v7.CumKill.Data-1.pdf)
[2] Proportion of stand that is pine (including leading, second, and third species) from the VRI files
[3] Site quality based on PEM site series in the SBSmc2, ICHmc1, ESSFmc, and ESSFwv

Poor Dry = SBSmc2 02,03; ICHmc1 02; ESSFmc 02,03,04; ESSFwv 02,03
Poor Wet = SBSmc2 04,07; ICHmc1 06; ESSFmc 09; ESSFwv 08
Mesic = SBSmc2 01; ICHmc1 01; ESSFmc 01; ESSFwv 01,04
Rich = SBSmc2 05,06,09,10; ICHmc1 04,05; ESSFmc 05,06,07,08,10,51; ESSFwv 05,06,07,09,51

Table 5 shows that, by 2010, only about 1300 ha within the ecosystem network had experienced greater than 10% mortality of pine because of mountain pine beetle.

Although this analysis focused on core and LRC ecosystems because that is the metric for biodiversity in the land use plans, it is also important to note that, according to Daust and Price (2012), pine ecosystems cover almost half (44%) of the Babine River Corridor Park. Eleven percent (~600 ha) were reported to be susceptible to substantial mortality (where susceptible is defined as >10% pine and > 60 years of age). Daust and Price conclude that beetle disturbance poses a higher risk to values within the park than within core ecosystems, although data from this analysis (table 4) indicate that it is about the same (i.e. about 10% of core ecosystems are occupied by stands in which pine greater than 40 years of age represents at least 10% of the stand). Daust and Price also note that a high proportion of SMZ2 (the buffer surrounding the park) includes pine ecosystems (42% of the zone with some pine; 13% of the zone with more than two thirds pine) making it more susceptible than the park.

STAND STRUCTURE ATTRIBUTES IDENTIFIED DURING FIELD SAMPLING

DESCRIPTION OF STRUCTURE IN THE PLOTS

Twenty-two stand structure sample locations (11 affected and 11 unaffected) were identified in unlogged areas on the Bulkley side of the watershed and two plots were established at each location for a total of 42 plots (see appendix II for plot locations). Most plots were established outside the ecosystem network because there were few locations within the network that had been attacked in 2005 or earlier. All but one of the plots was within the SBSmc2 (and the anomalous plot was transitional to the SBSmc2). Nine of 42 plots (21%) were not established on mesic sites (site series 01) and the nine plots that weren't mesic, were fresh to moist sites (site series 05). Twenty-two, 30 m long coarse woody debris transects were also established, one at each plot location. Of the 21 plot locations that had been indicated to be affected in the Mountain Pine Beetle Model, 14 were indicated to be affected by 2000, and the rest were indicated to be affected by 2005. During field sampling, many pre-selected plot locations had to be dropped because they had been logged (current harvest maps were not available from PIR) and pine beetle attack in many of the affected plots that had **not** been logged, was not significant until recently (circa 2007). New pine beetle attack continues to occur in the area (nearly two thirds of affected stands had current attack) and it is unlikely, therefore, that the effect of pine beetle on some structural elements will have been fully expressed in most plots. Differences between affected and unaffected plots, therefore, may not be as pronounced for some attributes at they might be at a future date. Trends in the data should be considered to be preliminary. Some of the key structural features apparent in the data have been summarized in table 6.

Tree species composition of the largest trees (>12.5 cm dbh) in both affected areas and unaffected areas was predominantly pine. Pine was the leading species in all but three of the 42 plots. A total of 574 trees were sampled (L1-L3) of which 439 were live and 187 were live pine. In L1 there were 255 trees, of which 195 were live and 172 were live pine.

Differences between affected plots and unaffected plots were not surprising with respect to live trees/ha, pine beetle incidence, snags/ha, snag diameter, coarse woody debris diameter, and coarse woody debris volume. As can be seen in table 6, statistically significant differences were apparent for the following structural elements:[3]

- live L1 trees/ha;
- diameters of live L1 trees;
- mountain pine beetle incidence;
- snag diameters (but not number likely because of the wide variation in number);
- CWD diameters (but not volumes, again likely because of wide variation in levels).

Table 6. Stand structure data for plots affected by, and unaffected by, mountain pine beetle. When F_Observed is larger than F_Crit, the null hypothesis is false (that there is no difference between affected and unaffected plots) at a level of probability indicated under P_Value.

	Unaffected		Affected		ANOVA (Single Factor, alpha 0.05)		
Attributes:	Mean	95% Confid	Mean	95% Confid	F_Observ	P_Value	F_Crit
Live L1* Trees/Ha	681.0	34.0	252.4	31.2	37.73	<0.001	4.08
DBH Live L1 Trees	25.5	2.0	30.4	1.4	32.31	<0.001	3.89
Crown Closure	39.4	3.2	36.8	0.8	1.59	0.215	4.08
MPB Incidence (% Pine Affected)	8.1	3.7	74.2	9.2	115.98	0.000	4.10
Snag/Ha	271.4	19.8	404.8	102.5	1.98	0.168	4.08
Snag DBH (D trees)	19.4	3.1	22.8	1.4	10.44	0.002	4.01
CWD Diameter (cm)	14.9	1.4	20.2	2.6	10.12	0.005	4.35
CWD Volume (m3/ha)	97.6	7.9	167.1	63.1	3.75	0.067	4.35
Shrub Cover (%)	35	6.7	30.7	5.3	0.76	0.390	4.08
Herb Cover (%)	22.4	3.1	22.6	3.9	0.01	0.926	4.08
Moss Cover (%)	87.1	1.7	85.7	3.5	0.33	0.569	4.08
Shrub Spp Prevalence (top 4 spp)	Alnuvir, Abielas, Loniinv, Vaccmem						
Ht L1 (m)	25.1	1.4	26.3	2.1			
Ht L2 (m)	16.3	1.6	16.3	2.7			
Ht L3 (m)	5.1	1.3	6.1	1.0			
Ht L4 (m)	1.2	1.0	1.3	0.3			
Regen (stems/ha)	4619	99	5248	1660	0.29	0.592	4.08
Regen Spp Comp	Bl, Sxw, Pl, Hw						

* Where L1 = trees > 12.5 cm dbh, L2 = trees between 7.5 cm and 12.5 cm dbh, L3 = trees > 1.3m in ht and < 7.5 cm dbh, and L4 = trees < 1.3m in ht.

Average pine beetle incidence in affected plots, as a proportion of L1 pine trees, was 74.2%, varying between 25 and 100%. Average incidence in unaffected areas was much lower at only 8.1%. A similar trend was apparent for the number of L1 trees per hectare with nearly three times the stems/ha in unaffected areas versus affected areas. These results are not surprising given that mountain pine beetle preferentially kills L1-size trees and that the plots were purposefully picked to be either affected or unaffected.

The number of snags per hectare was inversely related to the number of L1 stems per hectare, with fewer snags in unaffected areas than affected areas (33% less), again likely because of the increased mortality of pine trees in affected areas. The fact that the difference is not even greater indicates that there is

[3] To test the assumptions of normality and equality of variance that must be met for an analysis of variance (ANOVA), histograms were used to visually inspect data for L1 trees/ha, coarse woody debris pieces/ha, and snags/ha. Although using histograms when sample size is small is less effective, the distribution was approximately symmetrical indicating normality. Variability in affected plots also appeared to be similar to variability in unaffected plots. Sample sizes were equal and individual samples were independent (that is, data in one plot in no way influences values for data in another plot).

substantial dead structure even in stands relatively unaffected by pine beetle. The diameter distribution of snags (shown in figure 2) in unaffected plots was skewed to the smaller end of the range relative to affected plots.

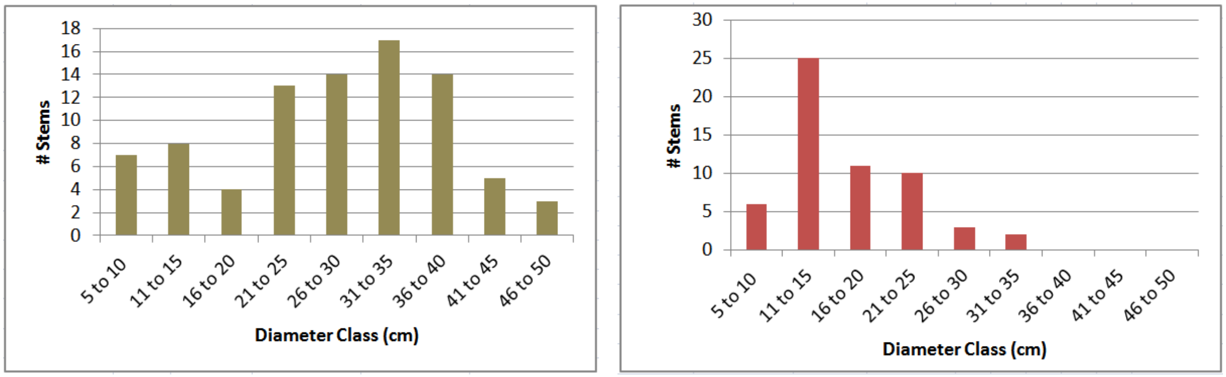

Figure 2. Diameter distribution of snags in affected plots (left) and unaffected plots (right).

These findings are similar to Lloyd et al (2007) in which live and dead standing stems and downed wood were measured in 140 plots that had been disturbed by fire, wind, and insects over the previous 50 years in the SBS and ESSF biogeoclimatic zones. They found that even the most severe beetle disturbances left live trees and that wind and beetles left more large than small snags and downed wood.

The pattern for coarse woody debris in our study was similar to that for snags, although more pronounced, with volume in affected areas nearly double that of unaffected areas (172%). It is probable that many of the trees that were killed by pine beetle more than three years earlier have fallen over in the wind or from snow press and this could explain why the difference between affected and unaffected is not as high for snag levels as it is for CWD. Mean butt diameter in affected areas was 20.2 cm versus 14.9 cm in unaffected areas (136% larger). The diameter distribution for coarse woody debris is shown in figure 3 and length distribution is shown in figure 4.

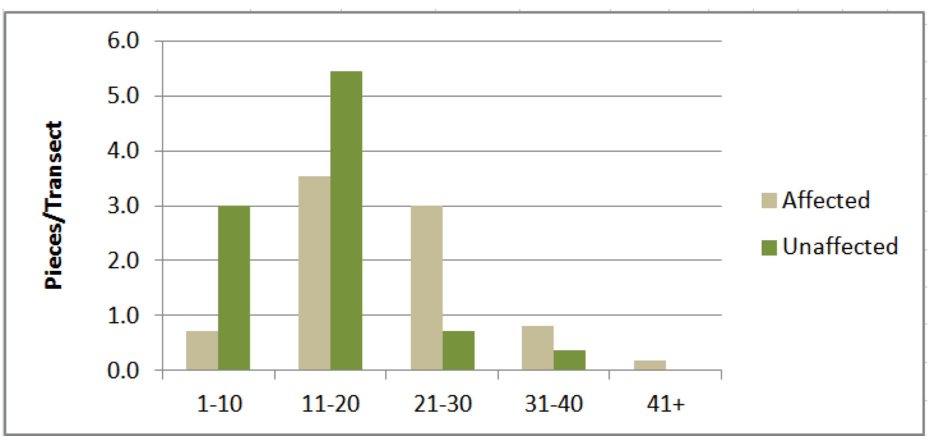

Figure 3. CWD mean pieces/transect by diameter class (cm)

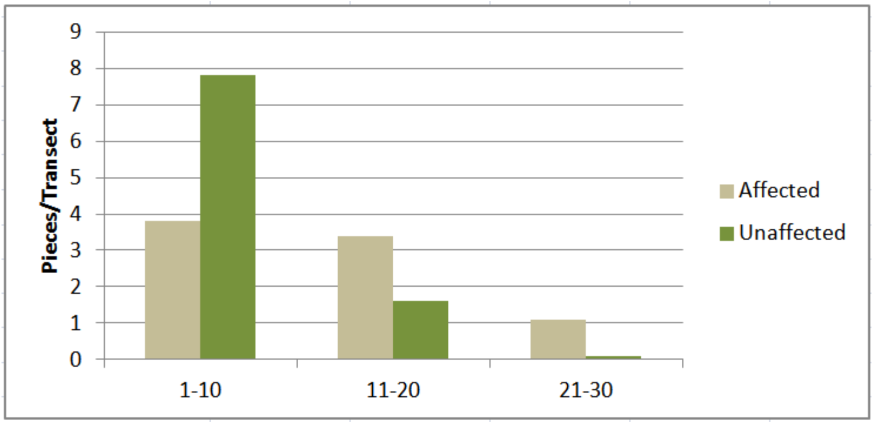

Figure 4. CWD average pieces/transect by length class (m)

While there are about the same number of pieces of CWD per transect in unaffected and affected transects, the diameter and length in unaffected transects is smaller than in the affected transects and, therefore, CWD volume in the beetle-affected stands is higher.

While differences in the number of L1 trees, and sizes and levels of snags and coarse woody debris is about what one would expect when comparing beetle affected areas with unaffected areas, one surprising anomaly was the mean diameter for live L1 trees. Diameter at breast height was actually larger in affected plots than unaffected plots (30.4 cm versus 25.5 cm respectively). This is probably because there are many more L1 stems, with a broader range of diameters left in the unaffected areas resulting in a smaller average diameter. The relatively small difference in crown closure is also surprising - only 3% higher in unaffected areas. This may be because, despite the fact that there are fewer L1 stems in the affected areas, there is a substantial understory of L2 and L3 trees which also contribute to crown closure. In fact, 67% of L1, L2, and L3 trees in affected plots were not attacked. This is consistent with other studies of beetle impacted stands which have found substantial legacy structure (Coates and Hall, 2005). Daust and Price (2012) and Lloyd and Price (2008) both point out that mountain pine beetle leaves higher levels of many structural elements than managed stands of the same age.

GIS ANALYSIS OF BIODIVERSITY ATTRIBUTES

It is clear from the analysis in the previous section that pine beetle does impact stand structure, although there is a substantial legacy of live structure that mitigates the impact on interior forest condition, and there is likely an increase in elements such as coarse woody debris, snags, and understory vegetation. A potentially more important impact is the logging that is associated with salvage of beetle-affected stands. Relative to beetle-affected stands, logged stands normally have less retention of live structure, less large coarse woody debris, fewer snags, relatively high levels of understory disturbance, and artificial linear corridors (roads). Most of the indicators used to determine whether the ecosystem network is effective in maintaining biodiversity are related to logging disturbance including area in mature and old forest, harvesting within the core and LRC areas, kilometres of road within the LRC, proportion of the LRC in which interior forest condition is compromised, and area of sensitive ecosystems that is disturbed. Guidance in land use plans pertaining to these indicators is as follows:

- maintain the structural and functional features of old forest within Core Ecosystems:
    - no harvesting within Core Ecosystems except for incidental tree cutting for mining and exploration purposes;

    - no road building within Core Ecosystems except for accessing timber that would otherwise be inaccessible, and for mineral development;
    - allow natural processes (e.g. fire and insects) to occur within Core Ecosystems except where those processes threaten resources outside the zone.
- maintain connectivity of old and mature forest cover within LRCs as follows:
    - maintain at least 70% retention of structure within Landscape Riparian Corridors;
    - no alteration of fluvial or floodplain ecosystems that may be subject to frequent or infrequent flooding;
    - winter harvesting only;
    - no road building except to access areas that would otherwise be inaccessible (access into Landscape Riparian Corridors should be temporary unless no other alternative is reasonable for ecological or economic reasons);
    - harvest predominantly small patches within Landscape Riparian Corridors (0.3 to 3.0 ha) depending on stand type and age and level of cut in adjacent stands.
- no reduction of functional area of red and blue listed ecosystems (pertains to all areas including the ecosystem network and includes the following plant communities - ICHmc2/54, ICHmc2/51, SBSmc2/05, ICHmc1/02, ICHmc2/02, ICHmc1/06)[4].
- 12% old growth retention within each mid-sized watershed (pertains to the entire Babine watershed and has been deemed to be met by the Core Ecosystems and assuming a 200 year rotation for areas managed for old forest retention).

Licensees on the Bulkley side of the watershed also use the Bulkley 2011 timber supply analysis data package (table 31) as guidance, which assumes that no more than 5% of core areas will be less than 50 years of age. Results of the GIS analysis used to evaluate each of these indicators are summarized below.

AREA IN MATURE AND OLD FOREST IN THE ECOSYSTEM NETWORK

Core Ecosystems

The land use plans contain seral stage targets for mature and old forest that are applied across entire BEC units within the plan area, and which are expected to be met, to large extent, from mature and old forest within core and LRC ecosystems. The biodiversity indicator used for old and mature forest in core ecosystems is whether any harvesting has occurred within them. Table 7 summarizes the area that has been logged within the Core by biogeoclimatic unit. A total of 206 ha (0.5% of the total area or 0.7% of the CFLB) has been logged, although much of this pre-dates 1998 when core ecosystems were established.[5]

Table 7. Area that has been logged in core ecosystems by age class.[6]

Age Class	ESSFmc	ICHmc1	SBSmc2	Total
1	46.1	10.2	35.4	91.8
2	54.8	0.0	48.9	103.7
3&4	0.5	0.0	5.8	6.3
blank	1.6	0.2	2.0	3.8
Total	103.0	10.3	92.2	205.5

Although only 206 ha has been logged to date, there is an additional 1910 ha (table 8) within Core areas that is greater than 60 years old with more than 33% pine that has the potential for impaired ecosystem

[4] At the time the plan was written, these ecosystem associations were blue listed. Today most are no longer blue listed - see Area Of Red And Blue Listed Ecosystems That Are Disturbed below for current blue listed communities.
[5] The total area in core ecosystems in the watershed is 37,998 ha, of which 29,269 ha (77%) is within the crown forest land base.
[6] Age class 1 = 1 to 20 years, 2 = 21 to 40 years, 3 = 41 to 60 years, 4 = 61 to 80 years, 5 = 81 to 100 years, 6 = 101 to 120 years, 7 = 121 to 140 years, 8 = 141 to 250 years, and 9 = 2501+ years.

function in the future because of mountain pine beetle. The potential spread of mountain pine beetle within the watershed is shown in figure 5.

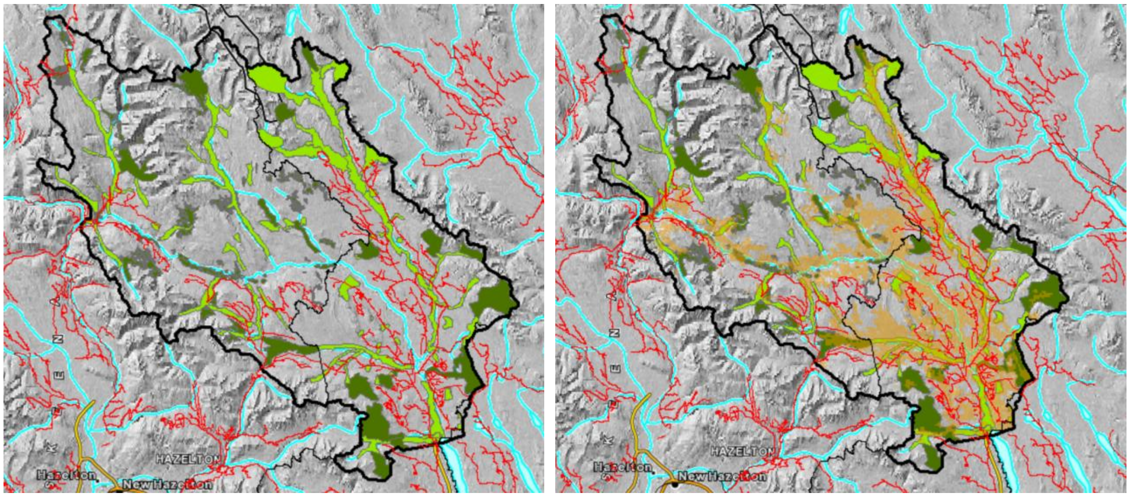

Figure 5. Simulated beetle spread by 2020 (orange polygons). Left is without beetle, right is beetle occurrence. Source: Walton, 2011, BC Mountain Pine Beetle Model.

Table 8. Area within the Core that is susceptible to mountain pine beetle and proportion that is mature (green highlight) or old (brown highlight).

Age Class	ESSFmc	ESSFwv	ICHmc1	SBSmc2	Total
4				0.4	0.4
5	7.0			79.4	86.4
6	89.4			227.1	316.5
7	464.6		0.6	395.4	860.6
8	132.1	2.2	0.0	511.5	645.8
9					
Total	693.2	2.2	0.6	1213.9	1909.8

Of the 1910 ha within Core areas that are susceptible to mountain pine beetle,1733 ha are classified as mature or old (~6% of the area in CFLB within core ecosystems). Percent area in mature and old forest that is left after accounting for existing logging and deducting all area that is at least 60 years old with more than 33% pine is shown in table 9. These values assume a worst case scenario in which all beetle-affected areas would be considered unsuitable as old or mature forest. Even after deducting all potentially affected area, 86% of the CFLB within core ecosystems is still mature or old forest. This value falls to 67% in the SBSmc2 biogeoclimatic unit, however, where pine is most prevalent and pine beetle pressure is expected to be highest.

Table 9. Area as a percent of crown forest land base in core ecosystems that is mature or old after adjusting for logging and potential future pine beetle impacts.

	BAF, ESSF	ICH	SBS	Total
% Area Mature	48.7	51.1	16.9	42.9
% Area Old	40.8	47.7	50.3	43.2
% Area Mature+Old	89.5	98.8	67.2	86.1
% Area Other Ages	10.5	1.2	32.8	13.9

Landscape Riparian Corridors

The total area in LRCs in the watershed is 46,679 ha, of which 35,655 ha (76%) is within the crown forest land base. Table 10 summarizes the area that has been logged within the LRCs by age class and biogeoclimatic unit. 1280 ha (2.7% of the total area or 3.6% of the CFLB) has been logged and, as was the case for the Core areas, some of this pre-dates 1998 when the ecosystem network was established.

Table 10. Area that has been logged in the LRCs.

Age Class	ESSFmc	ICHmc1&2	SBSmc2	Total
1	63.5	3.6	588.0	655.1
2	27.6	0.0	467.5	495.1
3&4	1.3	0.0	23.0	24.4
blank	16.7	78.6	10.4	105.7
Total	109.1	82.2	1088.9	1280.2

Additionally, there are 4086 ha within the LRC that are greater than 60 years old with more than 33% pine (table 11) that have the potential for impaired ecosystem function in the future because of mountain pine beetle (figure 6).

Table 11. Area within the LRC that is susceptible to mountain pine beetle and proportion that is mature (green highlight) or old (brown highlight).

Age Class	ESSFmc	ESSFwv	ICHmc1	ICHmc2	SBSmc2	Grand Total
4	15.6			15.6	96.2	127.4
5	49.9				223.0	272.9
6	587.0		10.1	3.5	439.0	1039.6
7	271.9		0.5		368.2	640.6
8	543.2	221.6	14.0		1205.3	1984.1
9					21.8	21.8
Grand Total	1467.6	221.6	24.6	19.1	2353.5	4086.4

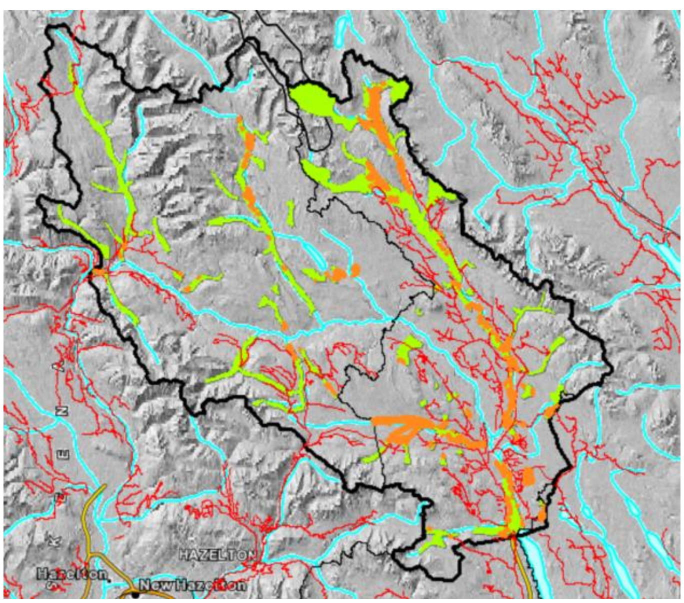

Figure 6. Areas (orange) within the LRC that could be potentially affected by MPB by 2020. Source: Walton, 2011, BC Mountain Pine Beetle Model.

Of the 4086 ha within LRC areas that are susceptible to mountain pine beetle, 3099 ha are either mature or old (15% of the CFLB within the LRC). Percent area in mature and old forest that is left in the crown forest land base after accounting for existing logging and deducting all area that is at least 60 years old with more than 33% pine is shown in table 12. As was the case with core ecosystems, these values assume a worst case scenario in which all beetle-affected areas would be considered unsuitable as old or mature forest. Even after deducting all potentially affected area, 77% of the CFLB within LRC ecosystems is still mature or old forest. This value falls to 63% in the SBSmc2 biogeoclimatic unit, which is below the 70% threshold for retention of structure in the land use plans.

Table 12. Area as a percent of crown forest land base in LRC ecosystems that is mature or old after adjusting for logging and potential future pine beetle impacts.

	BAF, ESSF	ICH	SBS	Total
% Area in Mature	46.9	45.6	7.4	29.9
% Area in Old	36.2	52.9	55.7	46.9
% Area in Mature+Old	83.1	98.5	63.2	76.8
Blanks	0.0	0.0	0.3	0.1
% In All Other Ages	16.9	1.5	36.5	23.1

ROADS WITHIN THE ECOSYSTEM NETWORK

There are two land use plan objectives respecting roads: to avoid any roads in core ecosystems and to ensure access into the landscape corridors is temporary unless no other alternative is reasonable. The West Babine SRMP also includes a target for road density of 0.6 km per square kilometer for at least 80% of two watersheds, the Shedin and the Hanawald. Areas where roads cross through LRCs (light green) or core ecosystems (dark green) within the watershed are indicated with red in figure 7.

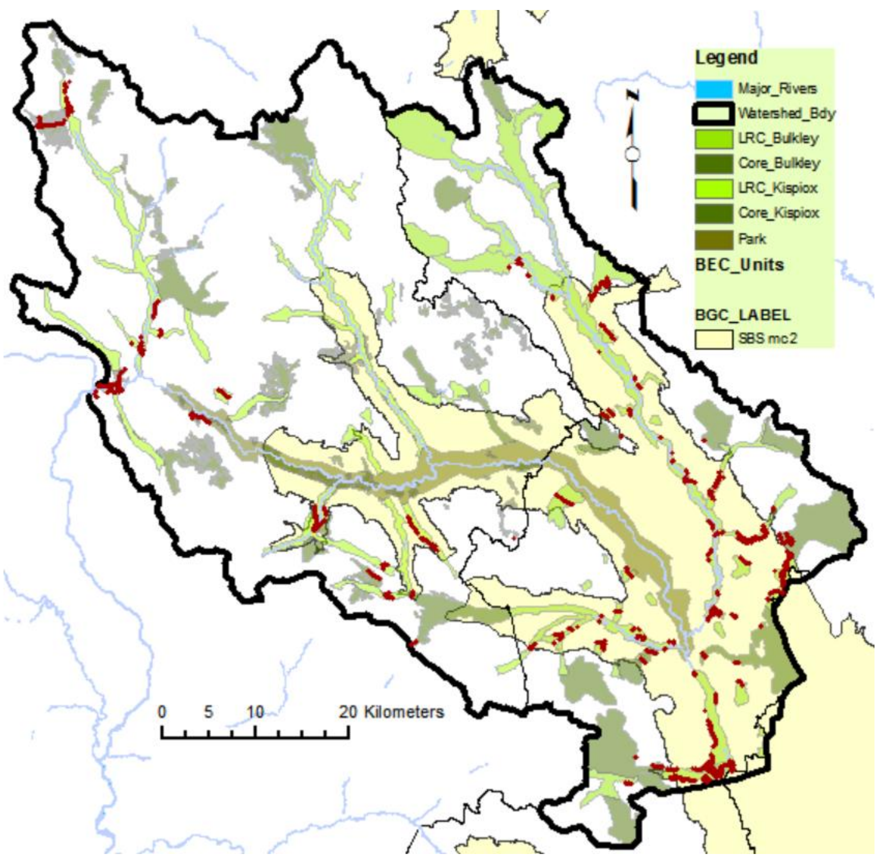

Figure 7. Locations (red) within the watershed where roads pass through the ecosystem network (source for roads - GeoBC for the Kispiox District and the HLP Objectives Analysis conducted by PIR for the Bulkley District).

It is clear from the map in figure 7 that there are many locations where roads pass through the ecosystem network. The heaviest concentration of roads within the network is in the SBSmc2 BEC unit (about 95% of such roads). The length of road passing through the ecosystem network is summarized in table 13 by District, stand age, and whether they are in a core ecosystem or LRC. In the Bulkley, there are nearly 100 km of road within the ecosystem network, 33 of which are located in mature or old forest, and 10 of which are located in a core ecosystem. In the Kispiox there are about 41 km in the ecosystem network, 32 of which are in mature or old forest, and 13 of which are in core ecosystems. Although the concept of permanence is somewhat arbitrary, and there was no information available in the GIS layers on road status, it is clear from field observations and air photo analysis that many of the roads in the LRC will have long term impact on ecosystem function (figures 8 and 9).

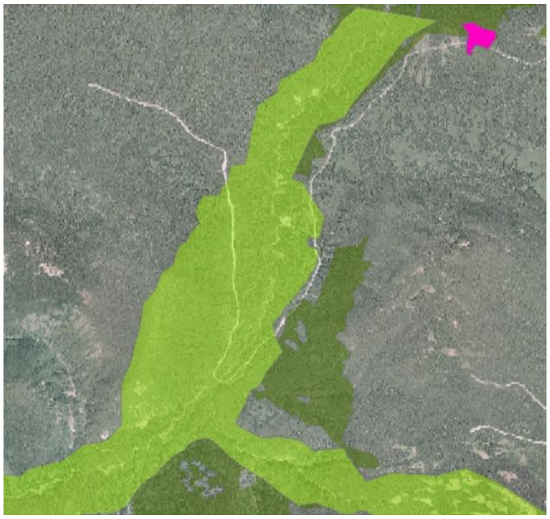

Figure 8. Road through the LRC in the Kispiox.

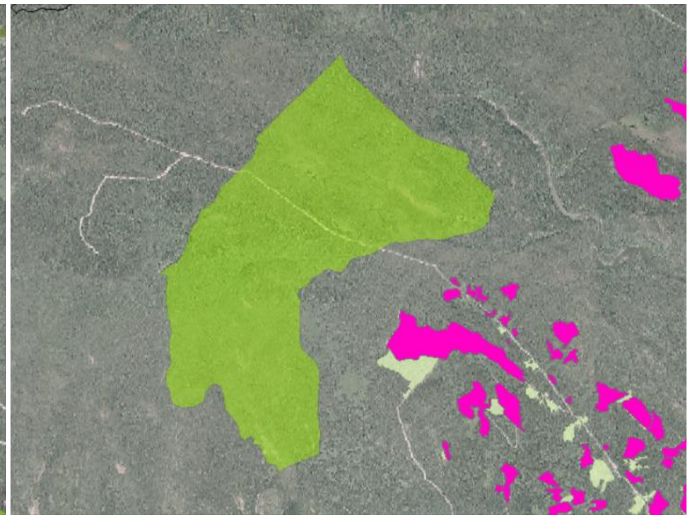

Figure 9. Road through the LRC in the Bulkley.

Table 13. Kilometers of road by ecosystem type, TSA, and age category in the ecosystem network.

Road Length (km)	Bulkley EN			Kispiox EN			Grand Total
	Core	LRC	Tot Bulkley	Core	LRC	Total Kispiox	
In Old	1.0	24.6	25.6	7.0	10.3	17.3	42.8
In Mature	0.9	6.3	7.2	5.4	9.3	14.7	21.9
In Other	8.6	58.0	66.6	1.0	7.8	8.8	75.4
Total Roads	10.4	88.9	99.4	13.4	27.4	40.7	140.1

The intent in the land use plan appears to be to avoid constructing any roads in core ecosystems and to avoid permanent roads in LRCs but provisos in all of the plans mean that determining whether such objectives have been achieved is quite subjective. Examples of this type of subjectivity include:

- no roads in core ecosystems except as necessary for accessing timber that would otherwise be inaccessible, and for mineral development.
- access into Landscape Riparian Corridors should be temporary unless no other alternative is reasonable for ecological or economic reasons.
- where alternative access is not possible, roads can be built through a core ecosystem to avoid alienating operable timber outside the core ecosystem.
- prevent timber harvesting in core ecosystems unless it is necessary for protecting the integrity and function of the ecosystem.

Another road indicator that is often described in the literature as a way to measure ecosystem integrity is road density. The only reference to road density in the land use plan for the Babine Watershed, however, is for the Shedin and the Hanawald drainages and it relates to minimizing impacts on grizzly bear populations. The target for maximum road density in these two drainages is 0.6 km of road per square kilometer in at least 80% of the watershed area. Table 14 reveals that, if this measure were used as a target, there would be no areas in the ecosystem network in which road density would compromise ecosystem function (although road density in the Bulkley LRC is approaching the threshold at 0.41 km/km^2). Additionally, as noted earlier, some roads in the EN will be temporary roads and it is expected that winter roads and deactivated roads in cutblocks in particular will have relatively little incremental impact on ecosystem function.

Table 14. Road density by ecosystem type, District, and age class as a proportion of all area in the ecosystem network and as a proportion of the crown forest land base in the network.

	For All Area								
	Bulkley			Kispiox			Ecosystem Network		
Indicator	Core	LRC	All Area	Core	LRC	All Area	Core	LRC	All Area
Area (km2)	184	296	480	196	170	367	380	467	847
Km/km2	0.06	0.30	0.21	0.07	0.16	0.11	0.06	0.25	0.17
	For Crown Forest Land Base (CFLB)								
	Bulkley			Kispiox			Ecosystem Network		
Indicator	Core	LRC	All Area	Core	LRC	All Area	Core	LRC	All Area
Area (km2)	124	217	341	168	140	308	293	357	649
Km/km2	0.08	0.41	0.29	0.08	0.20	0.13	0.08	0.33	0.22

SIZE OF HARVESTED AREAS WITHIN THE LRC

One of the strategies in the West Babine SRMP for maintaining connectivity of old and mature forest cover within LRCs is to harvest predominantly small patches (0.3 to 3.0 ha) depending on stand type and age and level of cut in adjacent stands. The Babine and Nilkitkwa LUPs include nearly identical strategies. Using the intersection of cutblocks and LRCs, it was possible to generate a profile for cutblock size class distribution within LRC areas. Figures 10 and 11 show the area in each size class and the number of polygons by size class that have been logged in LRCs. While there are many small polygons, the majority of the logged area in the LRC is in openings that are larger than 3 ha. To date 116 openings greater than 3.0 ha in size have been harvested within the LRC (figure 7), and there are 37 openings with a footprint that is greater than 10 ha within the LRC (not shown in the charts).

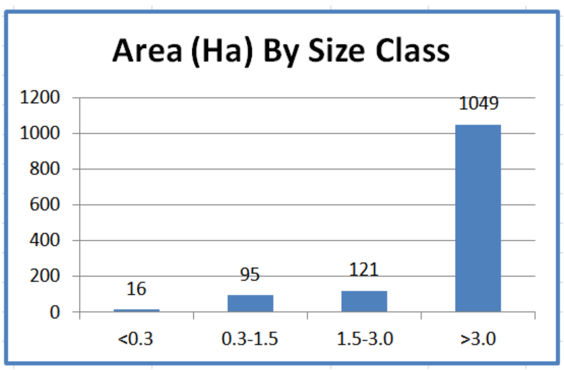

Figure 10. Area in various cutblock size classes within LRCs in the Babine Watershed.

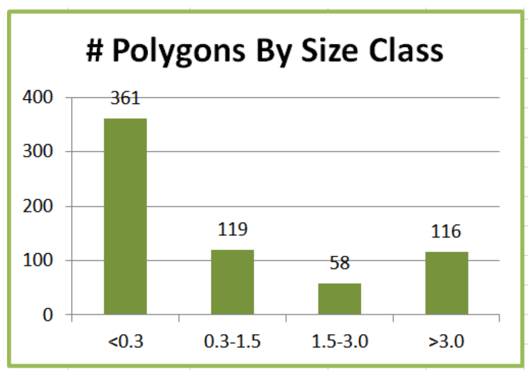

Figure 11. Frequency of cutblock size classes within LRCs in the Babine Watershed

LINEAR PROPORTION OF THE LRC IN WHICH THERE IS NO INTERIOR FOREST CONDITION

One of the objectives for biodiversity in the SRMP is to maintain connectivity of old and mature forest cover within LRCs. Similarly, an objective in the Bulkley higher level plan order, and the LUPs, is to maintain biodiversity by ensuring that there is a representative cross section of naturally-occurring ecosystems in Core areas that maintain some areas with interior conditions. The literature and guidance in government documents on biodiversity, and on wildlife tree patches, suggest that forest patches less than 400m wide will generally contain little, if any, forest interior (Voller 1998, the Biodiversity Guidebook, Appendix I, 1995). The biodiversity guidebook recommends targeting 600 m as a minimum width when a management objective is to provide interior forest conditions and minimize edge effect. In the analysis for this project we asked the question "**are there areas of mature or older forest within the LRC that, because of logging, are less than 500m wide in any direction**?

The linear extent along the LRC of such areas was measured using GIS tools (shown in figure 12). When there were small patch clearcuts within an area, their width was subtracted to determine if the 500 m rule was met. If only 1 dimension was less than 500m, it was still highlighted as an area of concern. Parts of the LRC that were less than 500m by design, were not included in the summary. The exercise described above was also repeated using 100m as a cutoff instead of 500m.

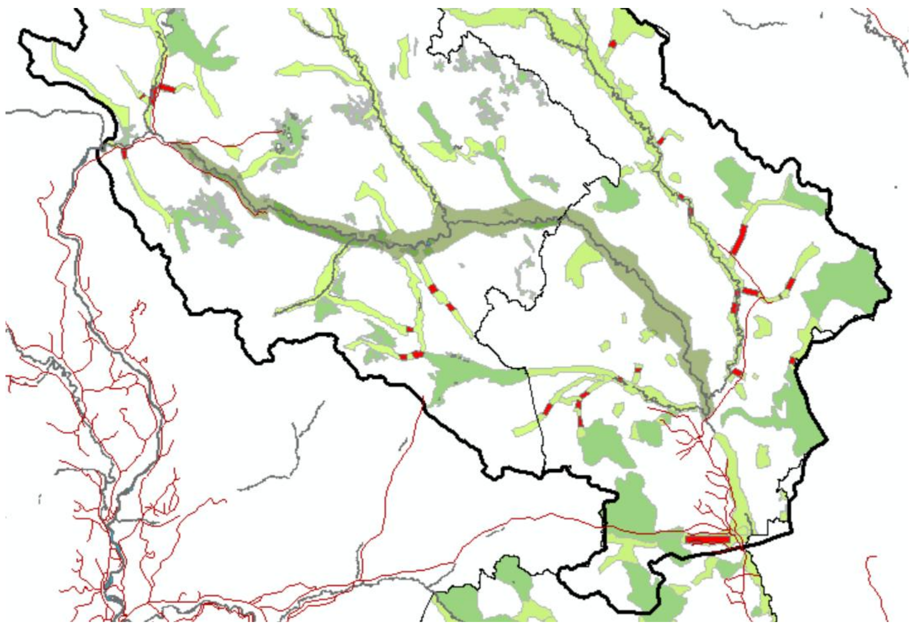

Figure 12. Areas in the LRC where logging has occurred and, as a result, the width of the LRC is not at least 500m in all directions.

The results of this exercise indicate that there 28 places where the LRC is not at least 500m wide, totaling 31 km in linear extent (about 5% of the total length of the ecosystem network). There is only 1 spot where LRC is less than 100m wide and the length of this stretch is small at about 80m (figures 13 and 14).

Figure 13. Road and cutblocks within the LRC.

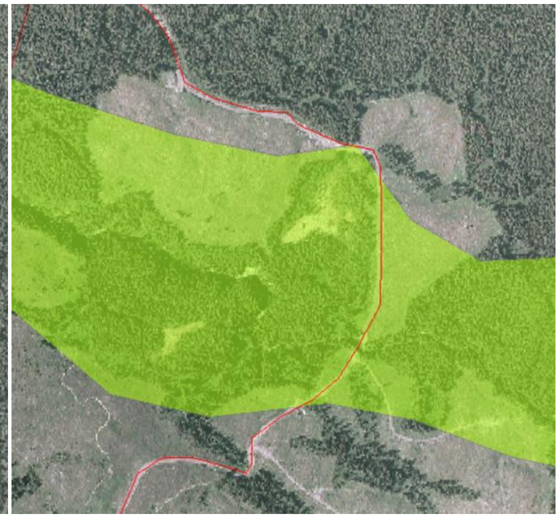

Figure 14. LRC boundary (light green).

The implication from these findings is that the functionality of the ecosystem network is potentially compromised in these areas. In forming a conclusion around this finding however, one would need to consider the extent and type of mature forest adjacent to the area that is logged and whether it is a suitable substitute. It is also important to think about potential future impacts that might occur if the beetle attack projected to occur in figure 6 were to be logged.

AREA OF RED AND BLUE LISTED ECOSYSTEMS THAT ARE DISTURBED

The West Babine SRMP indicates that there are seven blue-listed plant communities that potentially occur in the Kispiox side of the watershed (the ICHmc1/02, ICHmc1/06, ICHmc2/02, ICHmc2/51, ICHmc2/54, SBSmc2/05, and the AT Poa rupicola). Direction in the SRMP indicates that measures are required to conserve rare ecosystems where these sites are identified on the landbase. In the Babine and Nilkitkwa LUPs, the blue listed ecosystems include the ESSFmc/02, the ESSFmc/03, the SBSmc2/03, cottonwood/spruce/dogwood floodplain sites in the SBSmc2, and montane forb meadows in any of the biogeoclimatic units. Direction regarding protection of these sites in the LUPs is similar to that in the SRMP.

Blue-listed ecosystems are considered to be vulnerable and “at risk” but not yet endangered or threatened. As mapping and field work are completed and a better understanding of the extent of various ecosystems is completed, the list of ecosystems in the red and blue categories in the B.C. Conservation Data Centre (CDC) changes. As of 2012, the ecosystems of concern listed in the land use plans had become inconsistent with the CDC list of ecosystems. Rather than evaluating the ecosystems listed in the land use plans, therefore, we assessed the extent to which Conservation Data Centre red or blue-listed ecosystems could be impacted by logging or mountain pine beetle. Sensitive **forest, floodplain, or wetland** ecosystems currently listed in the CDC database include the:

- ICHmc1 and mc2/02 - western hemlock-kinnikinnick-cladina lichen ecosystems;
- ICHmc1 & 2/Fm 03 - black cottonwood-subalpine fir-devil's club floodplain-mid bench ecosystems (most similar to the cottonwood/spruce/dogwood site series - the /05 (mc1) and /06 (mc2));
- ICHmc1 & 2/Fl 02 - mountain alder-red-osier dogwood-lady fern ecosystems (most similar to the cottonwood/spruce/dogwood site series - the /05 (mc1) and /06 (mc2));
- ICHmc2/Ws09 - black spruce-skunk cabbage-peat-moss ecosystems (most similar to the hemlock/cedar/spruce/skunk cabbage ecosystem – the /06 (mc1) and /07 (mc2));
- Wetland bogs and wetland fens in the ICH ecosystems (site series 31 and 32).

There were no red listed ecosystems and nothing was listed for the ESSF or SBSmc2 in the CDC database.

To determine where logging had occurred on potentially sensitive sites we evaluated the ecosystem network using GIS mapping software to identify where sensitive site series predicted with PEM mapping coincided with cutblock location (from the government's Results database). Actual site series data for cutblocks were not available, or considered to be too broad, and so were not used. Results of this analysis are shown in table 17.

Table 17. Area of sensitive site series (based on PEM mapping) that has been logged.

BEC Unit/Site Series	Tot Area(Ha)	Logged Area (Ha)	Percent Logged
ICHmc1/02	383.9	0.7	0.2
ICHmc2/02	15.4	0	0.0
ICHmc1/05	1.4	0	0.0
ICHmc2/06	3.3	0	0.0
ICHmc1/06	202.8	0.3	0.1
ICHmc2/07	1.3	0.0	0.0
ICHmc1/wetland	60.4	0	0.0
ICHmc2/wetland	0	0	0.0
Total	668.5	0.9	0.1

PEM mapping indicates that the area of blue-listed site series within the ecosystem network is relatively small at 668 ha and that very little of this coincides with area that has been logged (only 1 ha). However, Bartemucci and Williston (2012) in a draft report for the BWMT undertook a comprehensive analysis of existing data on rare ecosystems in the watershed in terms of reliability and quality, and identified a total of 25 occurrences of eight blue-listed ecosystems in the watershed (maps were produced but not available at the time this report was written). They cautioned that the small number of rare ecosystems reported for the Babine River watershed reflects a low effort to document rare ecosystems in the area and may not represent all rare ecosystems. They also cautioned against using PEM mapping on its own as a source of information because of issues with accuracy and resolution. While the reliability of PEM mapping is relatively poor at 65 to 70% for the dominant correct site series, it is intuitive that there would not be much logging in the ecosystems assessed in this report or the Bartemucci and Williston report because they typically have little timber of commercial value. There is also little chance that mountain pine beetle would significantly impact these ecosystems given that pine would normally be a relatively minor component on all these sites except 02 site series (principally in the SBSmc2) and potentially white bark pine ecosystems occurring on sites other than 02 site series.

CONCLUSIONS AND RECOMMENDATIONS

EFFICACY OF THE ECOSYSTEM NETWORK IN MAINTAINING BIODIVERSITY

In this study, the impacts of mountain pine beetle and associated logging in the ecosystem network were evaluated against indicators of biodiversity contained in higher level plans, in particular, the extent and size of logged areas, changes in the proportion of mature and old forest, road levels, connectivity/interior forest condition, and disturbance of sensitive ecosystems. In general, risk for these indicators is low on the Kispiox side of the watershed because there is less pine there, and less harvesting and road construction has occurred in recent years. There is also relatively low risk in core ecosystems throughout the watershed because pine is the leading species on only about 5% of the area in the core. Within LRCs, pine is the leading species on 4% to 14% of the area (Kispiox and Bulkley respectively) and susceptible pine stands (>10% pine greater than 40 years old) occupy about 16% of the ecosystem network. It is a significant component of many stands in localized areas, however, particularly in the SBSmc2 on the Bulkley side of the watershed, where it is the leading species on about 27% of the LRC and in the special management zone surrounding Babine River Corridor park where 13% of the zone is more than two thirds pine.

The effect of mountain pine beetle on stand structure, in the absence of logging, will be to create conditions that are less like *forest interior* with fewer mature trees and less overstory cover. Mountain pine beetle will also result, however, in more structure in terms of snag levels, coarse woody debris, and understory vegetation, including conifer regeneration, and in most stands in the watershed, there will be a substantial legacy of live mature trees. Whether these changes are positive or negative with respect to ecosystem function and biodiversity depends on which species is targeted and what objectives the land manager has.

Impacts become more significant when beetle-affected areas are logged. Stand structure in clearcut areas is usually substantially different than that in beetle affected areas that aren't logged (Lloyd and Price 2008 , Daust 2012). However, only 206 ha (<1% of core ecosystems) and 1280 ha (~3% of LRC ecosystems) have been logged. While the target for core ecosystems is no logging, 82% of openings that have been created are less than 3 ha. There are only 37 openings with a footprint that is greater than 10 ha within the ecosystem network. If all stands that are currently greater than 60 years old with more than 33% pine are attacked by pine beetle, an additional 1910 ha in core ecosystems and 4086 ha in LRC ecosystems will be affected. Overall, even with aggressive assumptions on pine beetle impacts like these, 86% of core ecosystems and 77% of the LRC (as a percentage of the CFLB) will still be mature or old forest. The risk to biodiversity in the SBSmc2 portion of the ecosystem network, however, would be substantially greater, with only 67% of the Core and 63% of LRC in mature or old forest. Within the SBSmc2, if all susceptible pine stands are attacked and subsequently logged, the target threshold for 70% of structure and function would not be met. If they were attacked but were not logged, field data indicate that considerable structure will be retained but the number of large live trees and future snag and coarse woody debris recruitment might be compromised. Other structural elements would likely benefit from beetle impacts.

The potential impact of roads may be more significant than beetle attack or cutblocks. Land use plan objectives respecting roads are to avoid any in core ecosystems and to ensure that access into the landscape riparian corridors is temporary unless no other alternative is reasonable, yet there is considerable road development within the ecosystem network totalling ~140 km. There are 14 km of road through mature or old forest within Core ecosystems and an additional 50 km through mature or old forest within LRC ecosystems. Daigle (2010) summarizes the impact of roads by their effects on soil, water, aquatic wildlife and habitat, and terrestrial wildlife and habitat; and includes such things as direct loss of habitat, disrupted migration, increased pressure on wildlife from hunting, fishing, poaching, and road kill, altered hydrology, impeded fish passage, altered migration patterns, decreased terrain stability, changes in riparian vegetation, spread of invasive species, habitat fragmentation, altered disturbance patterns (from changes in beetle/fire control), increased disturbance of wildlife and human/wildlife conflicts, artificial predator-prey relations along "hard edge" habitat, and introduction of contaminants, amongst others. It is unlikely that all roads within the ecosystem network will have such negative consequences for ecosystem function, however, because some roads are gated, some will be deactivated, others will be built for winter use (within cutblocks) and unlikely to support vehicle traffic and, once roads are decommissioned, they will eventually become re-vegetated and support forest cover. Furthermore, it cannot be said that all road activity within the network is a result of beetle management.

While there are no measurable criteria in the land use plans describing the level of road development that is acceptable in the ecosystem network, and there is an absence of direction on roads in the HLP Order (2006), the level of road development to date does not appear to be entirely consistent with the intent in the original land use plans. It is clear that roads do impact biodiversity as it is defined in the land use plans and they increase uncertainty with respect to connectivity, predation mortality, hunting mortality, spread of invasive species, and altered riparian habitat. Densities of 0.41 km/km^2 in the Bulkley LRC is approaching a level that raises a red flag. Wellwood (pers. comm. 2012) indicates that road densities exceeding 0.5 km/km^2 create high levels of uncertainty, as the implementation and effectiveness of strategies to reduce or mitigate risk to grizzly bears associated with roads in the area have not yet been explored. Several studies have found that in order to maintain a naturally functioning landscape with sustained populations of large mammals, road density must be below 0.6 km/km2 (Switalski 2006, Trombulak and Frissell 2000, Nielsen et al 2009).

Cutblocks also have a direct influence on habitat fragmentation. Habitat connectivity and the maintenance of interior forest condition is an objective in all the land use plans although no criteria have been provided to determine acceptable levels of connectivity. There are 28 places where cutblocks within the LRC have created a condition where the landscape corridor itself is not at least 500 m wide potentially resulting in little or no interior forest condition. The linear extent of the area in which the corridor is not at least 500 m is 31 km. This metric indicates that there are areas in which the corridor itself is unlikely to provide the attributes necessary for full ecosystem function and the maintenance of biodiversity as it is defined in the land use plans, however, in many cases, mature or old forest exists outside the corridor adjacent to these sections thus reducing the degree to which ecosystem function is potentially impaired.

The variable which appears least likely to be affected by mountain pine beetle and associated logging is rare or sensitive ecosystems. CDC blue and red listed ecosystems are uncommon and generally have low levels of pine and/or low commercial timber value. Where such ecosystems are identified during site inspections prior to logging, they are normally excluded from the block boundaries or included in wildlife tree patches that are not logged. There is relatively little risk that biodiversity will be compromised as a result of the impacts of pine beetle on rare and sensitive ecosystems.

In summary, threshold levels for biodiversity indicators in the ecosystem network of the Babine Watershed, as they are defined in the land use plans, have been exceeded as a result of the cumulative impacts of mountain pine beetle and timber harvesting that may be associated with it, in a number of ways:

- limited logging has occurred in core ecosystems.
- limited road construction has occurred in core ecosystems.
- substantial road development, some of which appears to be permanent, has occurred in the LRC.
- just under 70% of mature structure and function has been maintained in the SBSmc2 portion of the LRC, with this potentially dropping to 63% with future beetle impacts.
- limited areas greater than 3.0 ha in size have been logged in the LRC.
- sections of the ecosystem network are not wide enough (< 500m) to maintain interior forest condition.

The majority of these deficiencies will have relatively low impact on ecosystem function because they are limited in extent. Disturbance in the SBSmc2, however, is approaching or exceeding threshold levels on a larger scale. Although field assessments indicate that the impact of pine beetle alone would not be as high as the cumulative impact of pine beetle plus logging, it will have negative impact on species requiring large live trees, high overstory shade, and continuous mature forest cover. Future planning should provide a hedge against uncertainty by finding ways to avoid new permanent road construction in the network and to avoid clearcut harvesting in sections of the network which are close to the 70% threshold for mature structure and function. This is especially important where opportunities to replace the existing network with other areas with the same functional attributes are limited. There are few areas outside the existing network that could replace it with respect to the extent and type of riparian vegetation, age class distribution, continuity, and potential as a migratory corridor.

Other recommendations arising from this analysis include:

1. Land use plan objectives are vaguely written and measurable indicators and targets are largely absent. While this provides flexibility, it does not provide the type of direction necessary to determine whether ecosystem function is adequately maintained. Unprecedented climate change compounds the complexity of the issue. Maintaining composition and amount and spatial distribution of structural elements that reflects natural historic patterns is not likely an appropriate

way to maintain biodiversity in the future. It is recommended that new strategic direction be developed by stakeholders that describes the desired future conditions that will sustain ecological services and human socio-economic needs in the face of climate change. Stakeholders will need to identify enduring features and refugia and manage for stability, resistance, or resilience within them, creating conditions outside these areas that mitigate functional loss today, but are well suited to anticipated ecological drivers in the future (more detail on this approach is contained in Appendix III). Measurable, geographically specific objectives, indicators, and targets will need to be developed for things like, for example:

   a. different disturbance patterns possibly including reintroduction of fire in the landscape, concentrated disturbance over broader geographic areas followed by extended periods of rest, or development of more multi-cohort stands.
   b. area in refugia outside the network that are stable, resistent, or resilient that could serve as replacements for the areas within the network in the event of functional loss.
   c. new tree species mixes including more emphasis on Douglas-fir, western larch, and paper birch as well as different establishment densities.
   d. critical habitat for keystone species.

Developing a regulatory and policy environment that supports adaptation strategies and provides forest licensees with incentives to implement them will also be required.

2. Development of new objectives, indicators, and targets should be completed for a variety of scales, including specific targets for the ecosystem network.
3. It is recommended that the boundaries of the ecosystem network be adjusted to ensure that it is at least 600 m wide at its narrowest point and to adjust for recent harvesting within the network.
4. Information on road status was not available for this analysis and may not be well tracked by licensees. It is expected that a relatively simple field form could be developed (perhaps borrowing from the FREP program or the watershed assessment procedure) and that a combination of field inspection and photo analysis could be used to determine current road condition and potential impact on ecosystem function. This information would be useful in determining whether land use plan objectives are being achieved as well as in designing strategic objectives for the future.
5. As noted above, roads can have significant impact on ecosystem function and it is recommended that measurable targets be set for roads within the ecosystem network, particularly the LRC, as well as actions that will be undertaken should targets be exceeded.
6. It is recommended that no further logging occur within core ecosystems or within sections of the LRC that are close to the 70% threshold, whether there is beetle activity in the area or not. There is no added risk that beetles will spread if an area is not logged (i.e. they are already ubiquitous).
7. It is recommended that any new strategic direction that is completed include an updated list of rare or endangered ecosystems and species that reflects findings from Bartemucci and Williston (2012) and that a commitment be made to periodically refer to the CDC database to ensure the list is current.
8. A new forest re-inventory is needed for the Kispiox side of the watershed (given that the last one was in 1992) and will be needed on the Bulkley side of the watershed by 2015 once the pine beetle has largely run its course. Neither planning nor monitoring will be accurate with inadequate forest cover information. For the purposes of the BWMT, a re-inventory does not need to extend beyond the watershed boundary.
9. Any future strategic planning should include a monitoring and adaptive management framework which includes detail on how cumulative effects will be evaluated, how monitoring will be funded, and how results of the work will be disseminated to stakeholders and interest groups. Part of the process of developing a revised monitoring framework would be to ensure that the work the Babine Watershed Monitoring Trust has done, and the framework and knowledge base they have developed, is considered.

FURTHER WORK

There are a number of opportunities for further study directed at providing information to develop the knowledge base and to improve planning and operations. Some suggestions include:

- Convene stakeholder workshops to develop more current resource objectives and targets for the watershed. An initial workshop could include presentations on climate change and ecological principles pertaining to it, a review of current land use plan objectives and data supporting them, a presentation on current conditions for existing indicators, a brainstorming session on watershed values, breakout groups to identify resource objectives for the watershed, and breakout groups to identify desired future conditions (in terms of structural elements and ecological processes) for key values. This information would be used in conjunction with scenario modeling by a contractor to develop potential indicators, targets, management guidelines and strategies, and a monitoring plan. A follow-up workshop would also be required with the same stakeholder group to obtain consensus regarding objectives, targets, and thresholds. Where objectives deviate from the higher level plan order, a process will need to be described to reconcile these differences. This type of plan, in which climate change impacts are directly accounted for in describing desired future conditions, may serve as a model for other areas in the interior of B.C. Don Morgan (2010) has completed some aspects of this work in a series of workshops in the Nadina Forest District which dealt with adapting forest management in the area to climate change, and this may serve to inform the process for the Babine River Watershed.
- Evaluate the impact of pine beetle on grizzly bear ecology, behavior, and population dynamics. This will likely need to be done in conjunction with of a broader project to revisit existing grizzly bear habitat mapping and interpretations. Deb Wellwood (pers. Comm. 2012) identifies several issues with land use plan mapping and objectives including for example, limited area-specific scientific information on grizzly bear ecology and behaviour, low reliability of mapping and grizzly bear habitat interpretations used in land use plans (although better on the Kispiox side of the Watershed – see Mahon and MacHutchon, 2004), lack of genetic sampling to determine grizzly bear population dynamics, and unclear management direction regarding access in land use planning confounded by data limitations regarding roads. She recommends, amongst other things, gathering expert knowledge (possibly in an expert workshop which is separate from a stakeholder workshop to ensure knowledge-based information is separated from land-use planning tradeoffs) to develop land use planning and monitoring at a scale that is relevant in terms of behavior and ecology, updating an analysis of road density in the area including road related risk of human-caused mortality, completing an analysis of core secure areas based on best practice recommendations in the literature, and identifying potential impacts associated with disturbed habitats that have moderately high or high foraging potential that may attract bears. An extension of this last point would be to study the relationship between bears and berry habitat enhancement using prescribed fire in areas that are relatively inaccessible. This type of work might be an effective approach to inducing different habitat use patterns and reducing bear-human conflicts.
- Acquire additional data on the impact of pine beetle on stand structure including:
    - How the period of pine beetle attack within stands in the Babine Watershed varies. Beetle attack in all areas evaluated in this project spanned several years while in other areas of the province, epidemic attack resulted in nearly 100% kill in a single year. Knowing when no further pine mortality is likely to occur will improve predictions about future structure and function.
    - Time it takes for live snags to fall over, whether this occurs in pulses, and controlling factors if so.
    - How long CWD persists.
    - How shrub, herb, lichen and graminoid composition and percent cover change over time.

More data on stand structure impacts will be useful in understanding best approaches to habitat restoration and mitigation measures.

- Undertake research on the population dynamics for wildlife species such as marten which require large live trees and larger areas of continuous mature forest cover, as well as how population dynamics change for species such as woodpeckers that are well adapted to take advantage of conditions in beetle-affected stands. More information about the impact of pine beetle on goshawks, an important indicator species that require large trees for their stick nests, could also provide valuable insight into raptor-prey relationships in beetle affected areas. Information on the relationship between the wolf population in the area and ungulate species could also provide important insights into the impacts of pine beetle on ecosystem function as well as useful information on hunting opportunities.

Except for the workshop to identify objectives, targets, and indicators, these other opportunities for further study could require longer term monitoring and this will mean ensuring funding that spans several years is identified prior to committing to the project.

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APPENDICES

I - GLOSSARY

Abiotic: Pertaining to the non-living parts of an ecosystem, such as soil particles bedrock, air, and water.
Adaptive Management: managing forests and incorporating into decisions the experience gained from the results of previous actions. Adaptive management rigorously combines management, research, monitoring, and means of changing practices so that credible information is gained and management activities are modified by experience.
Age Class: Any interval into which the age range of trees, forests, stands, or forest types is divided for classification. Forest inventories commonly group trees into 20-year age classes. In this analysis, age class 1 = 1 to 20 years, 2 = 21 to 40 years, 3 = 41 to 60 years, 4 = 61 to 80 years, 5 = 81 to 100 years, 6 = 101 to 120 years, 7 = 121 to 140 years, 8 = 141 to 250 years, and 9 = 2501+ years
Annual Allowable Cut (AAC): The allowable rate of timber harvest from a specified area of land. The Chief Forester sets specific AACs for Timber Supply Areas and Tree Farm Licences in accordance with Section 8 of the *Forest Act*.
Biogeoclimatic Ecosystem Classification (BEC): A hierarchical system for classifying ecosystems that integrates regional and local factors. At the regional level, vegetation, soils, and topography are used to infer the regional climate and to identify geographic areas that have relatively uniform climate (Zones, Subzones, and Variants). These geographic areas are termed biogeoclimatic units. At the local level, segments of the landscape are classified into site units that have relatively uniform vegetation, soils, and topography (site association, site series, and site type). Several site units are distributed within each biogeoclimatic unit, according to differences in topography, soils, and vegetation. Within the Babine watershed there are three BEC Zones: the ESSF – Engelmann Spruce-Sub Alpine Fir, ICH – Interior Cedar Hemlock, and SBS – Sub-Boreal Spruce zones and a number of subzones and variants. Also see Site Series.
Biodiversity: The word 'biodiversity' was coined by biologist E.O. Wilson in 1986 as a contraction of the phrase 'biological diversity'. Biodiversity is the variety of living things, including diversity within species (genetic diversity), diversity between species, and diversity of ecosystems. In a properly functioning ecosystem the components are inseparable and act upon each other. When biodiversity characteristics are assessed, three attributes are generally considered - *Composition* (the component parts), *Structure* (physical characteristics and elements of the ecosystem), and *Function* (ecological processes).
Biological Richness (species richness): Species presence, distribution, and abundance in a given area.
Coarse Woody Debris (CWD): Downed woody material of a minimum diameter or greater, either resting on the forest floor or at an angle to the ground of 45 degrees or less. Coarse woody debris consists of sound and rotting logs and branches, and may include stumps when specified. Generally a log is considered as being a minimum of 2 m in length and 7.5 cm in diameter at one end. CWD provides habitat for plants, animals and insects, and a source of nutrients for soil development.
Conserve: Keep from harm or damage.
Crown Forest Land Base: forest land within the area of interest that is treed, not a wetland, and not non-productive (e.g. lake, rock, sand bar, river, etc) and which may or may not support commercially valuable timber.
Cultural Feature: Unique or significant places and features of social, cultural or spiritual importance, such as an archaeological site, recreational site or trail, cultural heritage site or trail, historic site, or protected area.
DBH (diameter at breast height): The stem diameter of a tree measured at breast height, 1.3 meters above the ground.

Desired Future Condition: In the context of the Babine River Ecosystem Network means the target set of structural attributes necessary to maintain ecosystem function and provide the ecological services and forest products considered to be important by stakeholders.
Ecosystem: A dynamic complex of plants, animals and micro-organisms and their non-living environment interacting as a functioning unit. Ecosystems can be defined at any scale.
Ecosystem Degradation: An ecosystem is considered to be degraded or vulnerable when it is missing structural elements and ecological processes that are important for achieving a future condition that will sustain ecological function and human socio-economic needs.
Ecosystem Resistance: is an ecosystem's ability to maintain its structural and functional attributes in the face of such stresses/disturbances. Examples of resistant ecosystems might include those with low fuel loads, diverse species mixes, and/or multiple ecological processes.
Ecosystem Resilience: There are many definitions of resilience but most are about the capacity of an ecosystem to regain structural and functional attributes that have changed because of a disturbance.
Ecosystem Restoration: A commonly used definition is the process of assisting with the recovery of an ecosystem that has been degraded, damaged or destroyed by re-establishing its structural characteristics and ecological processes.
Ecosystem Stability: An ecosystem that is stable retains its functional and structural characteristics and successional trajectory in spite of stress/disturbance. Stable ecosystems are often in a state of dynamic equilibrium rather than a steady state. Disturbances of sufficient magnitude and duration may force an ecosystem to reach a threshold beyond which a different regime of processes and structures predominates (a different system state).
Ecosystem Vulnerability, the counterpart of resilience, vulnerability is the lack of capacity to cope with, resist, and recover from a disturbance.
Edge Habitat: Habitat conditions, such as degree of humidity and exposure to light or wind, created at or near the boundary dividing ecosystems, for example, between open areas and adjacent forest.
Forest and Range Practices Act (FRPA): The *Forest and Range Practices Act* brings in the application of a results-based system for the management of forest and range resources. It replaced the *Forest Practices Code of British Columbia Act* in December 2005.
Forest Health Factors: Biotic and abiotic influences on a forest that have an adverse effect on the health of trees and other plants." "Biotic influences include fungi, insects, plants, animals, bacteria, and nematodes. Abiotic influences include frost, snow, fire, wind, sun, drought, nutrients, and human-caused injury.
Inoperable: Lands that are unsuited for timber production now and in the foreseeable future because of a range of factors including: elevation; topography; inaccessible location; low value of timber; small size of timber stands; and steep or unstable soils that cannot be harvested without serious and irreversible damage to the soil or water resources. Inoperable lands may also be designated as parks, wilderness areas, or other uses incompatible with timber production.
Interior Forest: Forest that is far enough away from a natural or harvested edge that the edge does not influence its environmental conditions, such as light intensity, temperature, wind, relative humidity, and snow accumulation and melt.
Managed Forest Land: Forest land that is managed under a forest management plan, utilizing the science of forestry.
Merchantable Timber: a tree or stand that has attained sufficient size, quality and/or volume to make it suitable for commercial harvesting.
Natural Disturbance: Events such fire, insect or disease infestations, wind, landslides, and other natural events not caused by humans that damage or destroy stands of trees.
Natural Disturbance Unit (NDU): Large geographic areas that have similar topography, climate, disturbance dynamics (e.g., fire cycle, patch size), stand development and successional patterns.
Patch: A particular unit with identifiable boundaries and different vegetation from its surroundings.
Permanent Access: A structure, including a road, bridge, landing, gravel pit or other similar structure that

provides access for timber harvesting and is shown on a forest development plan, access management plan, logging plan, road permit or silviculture prescription/site plan as remaining operational after timber harvesting activities on the area are complete.

Predictive Ecosystem Mapping (PEM): A computer-GIS, and knowledge-based method that divides landscapes into ecologically oriented map units for management purposes. PEM is a new and evolving inventory approach designed to use available spatial data and knowledge of ecological-landscape relationships to automate the computer generation of ecosystem maps.

Productive Capability: The current and future ability of forest ecosystems to produce biomass.

Productivity: The natural ability of a forest ecosystem to capture energy, support life forms, and produce goods and services.

Provincial Forest: Forest land designated under Section 5 of the [Forest] Act as provincial forest. Designation as “provincial forest” restricts land use activities and alienation for other purposes, which can occur more easily on vacant Crown land. This ensures that activities on, or any removal of land from, the provincial forest undergoes due process and consideration.

Riparian: An area of land adjacent to a stream, river, lake or wetland that contains vegetation that, due to the presence of water, is distinctly different from the vegetation of adjacent upland areas.

Riparian Habitat: Vegetation growing close to a watercourse, lake, swamp, or spring that is generally critical for wildlife cover, fish food organisms, stream nutrients and large organic debris, and for streambank stability.

Road Deactivation: measures taken to stabilize roads and logging trails during periods of inactivity, including the control of drainage, the removal of sidecast where necessary, and the re-establishment of vegetation for permanent deactivation. Road deactivation ranges from temporary to permanent.

Stakeholder: A person with an interest or concern with resource management within a defined area (i.e. community, forest district, defined forest area).

Seral Stage: Any stage of development of an ecosystem, from a disturbed, non-vegetated state (early seral) to a mature plant community (late seral).

Site Index: The height of a tree at 50 years of age (age is measured at 1.3m above the ground) In managed forest stands site index may be predicted using either (1) the biogeoclimatic ecosystem classification for the site or (2) the Site Index Curve which uses the height and age of sample trees over 30 years old.

Site Plan: A site level plan that supports the strategic (and legal) results and strategies contained within a proponents Forest Stewardship Plan (FSP). The site plan identifies the appropriate standards for specific cutblocks, including: stand-level biodiversity, permanent access, soil disturbance limits, stocking requirements, regeneration date, and free-growing date at the standards unit level.

Site Series: A landscape position consisting of a unique combination of soil edaphic features, primarily soil nutrient and moisture regimes within a biogeoclimatic subzone or variant. Soil nutrient and moisture regimes define a site series, which can produce various plant associations (see definition of "plant association"). In the BEC system, site series is identified as a number (e.g., 01, 02, 03,).

Soil Moisture Regime: The amount of moisture in the soil. Generally shown on a scale going from **xeric** (being deficient in moisture - dry) to **mesic** (characterized by moderate or a well-balanced supply of moisture) to **hydric** (characterized by excessive moisture).

Snag: A standing dead tree, or part of a dead tree, found in various stages of decay—from recently dead to very decomposed.

Species at Risk: A list of wildlife species at risk maintained by the Government of Canada. Addition of species is done annually by the Minister of the Environment, based on a report from the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), an independent committee of wildlife experts and scientists. The list contains five categories for species: special concern, threatened, endangered, extirpated, and extinct. The goal of the Species At Risk Act is to protect endangered or threatened organisms and their habitats.

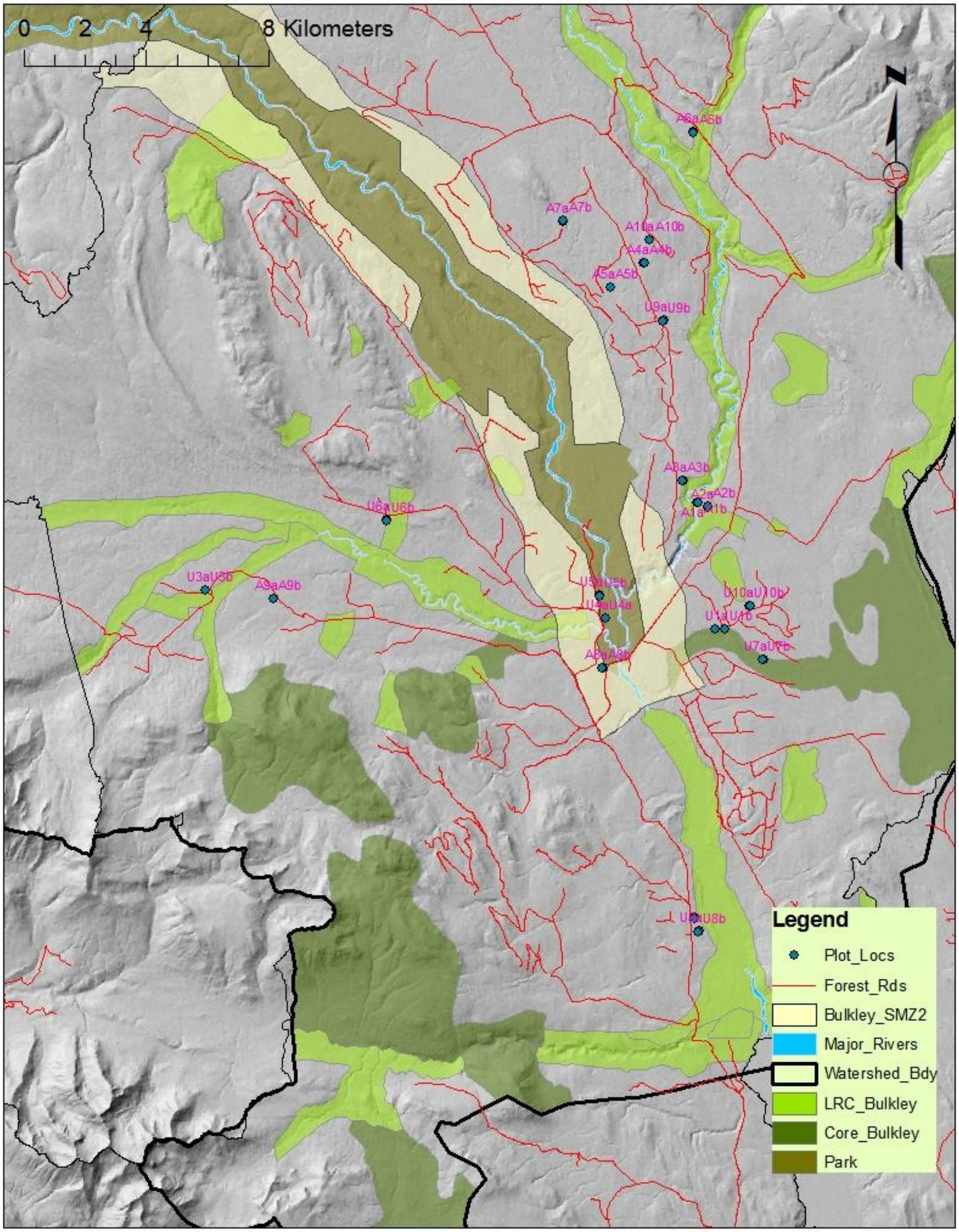
Timber Harvesting Land Base (THLB): The portion of the total area of the Defined Forest Area considered to contribute to, and to be available for, long-term timber supply. The harvesting land base is defined by reducing the total land base according to specified management assumptions and tends to change slightly over time.

Unmerchantable: of a tree or stand that has not attained sufficient size, quality and/or volume to make it suitable for harvesting.

Wetland Ecosystems: Ecosystems that support vegetation but which are periodically or permanently inundated including:

- Organic sedge fen - sedge dominated fen, organic soils
- Marsh - semi-permanently to seasonally flooded mineral wetland dominated by emergent vegetation
- Wet meadow - herbaceous meadow
- Organic open bog - shrub dominated organic bog (tree canopy cover less than 10%)
- Organic treed fen - treed fen on organic soils (tree canopy cover greater than 10%)
- Organic shrub fen - shrub dominated fen on organic soils
- Organic treed bog - treed dominated organic bog (tree canopy cover less than 10%)
- Lowbench shrub floodplain - shrub dominated floodplain
- Lowbench sedge/herb - floodplain herb dominated floodplain
- Shrub swamp - shrub dominated mineral swamp
- Treed swamp - treed mineral swamp

II – PLOT LOCATION MAP



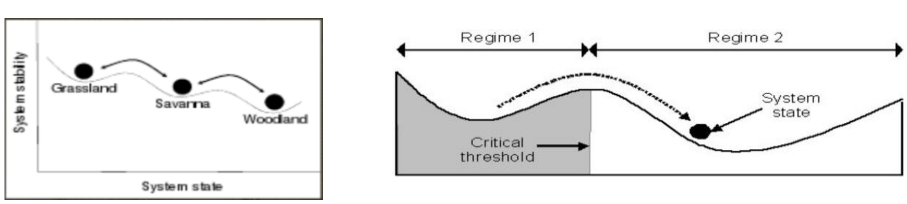
III- SUPPORTING ECOLOGICAL CONCEPTS

Literature on ecosystem resilience often includes the idea that maintaining species composition, and amount and spatial distribution of ecosystems that reflects natural historic patterns, is most likely to maintain biodiversity. Much of the Babine Watershed has been classified as an NDT2 ecosystem - infrequent stand-initiating events (ESSFmc, ICHmc1, and ICHmc2), with significant areas on the Bulkley side classified as NDT 3 -frequent stand-initiating events (SBSmc2), and a smaller area as NDT1 - rare stand-initiating events (ESSFwv). Fire, wind events, insect outbreaks, flooding, and avalanches are examples of types of disturbance that could occur, but the fire return interval heavily influences NDT categorization. There is considerable evidence, however (and a great deal of opinion), that we are in a period of unprecedented climate change, caused by an increase in green house gases, the most abundant of which is CO^2.

Climate BC (ver. 3.2), a program developed by MoFLNRO Research Branch in collaboration with scientists at UBC, predicts significant changes in temperature and some changes in precipitation within the Babine Watershed by the year 2080. The program downscales future climate datasets for the 2020s, 2050s, and 2080s generated by various global circulation models used by the International Panel on Climate Change (and others), and integrates this with local climate data. The user can select different time periods and circulation models to test the range of possible outcomes. Using the CGCM2_A2 data set, the program predicts an increase in mean annual temperature for the Babine Watershed of about 4 degrees by the 2080s with small increases in mean annual precipitation in all areas. It is notable, however, that on the Bulkley end of the watershed, summer time precipitation is expected to decrease by about 10 to 30% depending on elevation and latitude (and stay about the same on the Kispiox side). Most other models in Climate BC predict less significant changes in temperature.

Climate shift is expected to have considerable impact on the types and frequency of disturbance including, for example, increased frequency of extreme fire, insect, disease, and wind events, changes in stream flow (increasing in winter with higher peak flows and decreasing in summer), summer time soil moisture deficits, changes in wetland and riparian vegetation, shifts in upland vegetation species and cover, increased tree growth at high elevation and decreased growth at low elevation, and migration and extirpation of forest fauna. Of course, some changes will occur more rapidly than others. Vegetation shifts will take time and future structure and function will not necessarily conform to current patterns.

The premise in land use plans is that maintaining biodiversity will maintain ecological function. Because of the unprecedented climate shifts noted above, however, maintaining ecosystem structure and function, may no longer be about maintaining biodiversity as it is defined in the land use plans. It could be more about managing towards a set of desired future conditions that will sustain ecological services and human socio-economic needs in the face of such a shift. A more effective scenario may be one in which practicioners identify refugia and manage for attributes that make an ecosystem stable, resistent, or resilient, within them, and elsewhere try to create conditions that mitigate functional loss today, but create future conditions that service socio-economic needs and support ecosystem function given anticipated ecological drivers in the future. Maintaining composition and amount and spatial distribution of ecosystems that reflects natural **historic** patterns is not likely an appropriate way to maintain biodiversity given the high potential for a climate-induced state shift and associated changes to external stressors like fire, wind, drought, flooding, epidemic insects and disease outbreaks, avalanches, and pollution, etc.



Examples in which a disturbance has changed an ecosystem to such an extent that it has shifted it to a new state with different structure and processes (adapted from Beisner et al, 2003).

An ecosystem is **resistant** when it is able to maintain its structural and functional attributes in the face of external stressors. Examples of resistant ecosystems might include old forests, those with low fuel loads, diverse species mixes, and/or multiple ecological processes. An ecosystem that is **stable** retains its functional and structural characteristics and successional trajectory in spite of stress/disturbance. There are many definitions of **resilience**, but most are about the capacity of an ecosystem to regain structural and functional attributes that have changed because of a disturbance. Increasing human disturbance in the face of increased natural disturbance will negatively impact ecosystem resilence. If an ecosystem is not resistant, stable, or resilient it will change and this could be interpreted to mean, degraded. An ecosystem might be considered to be degraded or vulnerable when it is missing structural elements and ecological processes that are important for achieving a future condition that will sustain ecological function and human socio-economic needs. Examples of vulnerable ecosystems might include those with:

- excessively uniform species distribution (a lack of diversity).
- introduced species whose growth and spread is not constrained by ecological processes characteristic of the ecosystem.
- a low number of individuals that cannot sustain the population.
- isolated populations which are not integrated into a larger ecological matrix (no opportunity for migration and biotic and abiotic flow).
- unnatural levels of one or more structural elements because of past human activity (e.g. high slash loads because of fire suppression).
- epidemic levels of a forest pest.
- lack of a critical structural element for a given stage of development (e.g. coarse woody debris, berry producing shrubs, large organic debris in a stream, riparian vegetation, old large trees, an important browse species, vegetative cover on erodible soils, etc).
- impeded ecological function (e.g. impeded or excessive above ground or sub-surface water flow, insufficient photosynthesis, impeded carbon fixation, lack of connectivity, disrupted mating or calving, disconnected functional link, etc).
- impaired hydrological regimes that result in loss of function or productivity.

What this means in terms of an appropriate design for an ecosystem network, a primary purpose of which is to maintain “biodiversity”, is that land managers will need to identify areas that could serve as refugia, using indicators of resilient, resistant, or stable ecosystems to monitor their condition, and then elsewhere experiment with new patterns to create conditions anticipated to be favourable in the future. Scenario modeling could be an important tool to help in this process. Land managers should consider historic ecosystem function and structure to help understand how ecosystems might reorganize in the face of external drivers like climate, but they should not use the historic range of variation as a benchmark for future conditions. Land managers will need to become more skilled at adapting to future conditions by purposefully experimenting today with the development of different functional and structural attributes at the landscape and stand level (e.g. different disturbance patterns, greater hydrological intervention, new tree species mixes, developing more multi-cohort stands, protecting refugia that are most resilient, etc). They will need to fully embrace adaptive management and create a variety of forest structure outcomes to hedge against an uncertain future.

IV – KEY DIRECTION ON BIODIVERSITY IN LAND USE PLANS AND THE BWMT KNOWLEDGE

In this project, whether or not biodiversity is being maintained was based on the degree to which objectives and strategies in the land use plans pertinent to this project were achieved. Key direction from these plans is summarized below.

The LRMPs

Direction in the LRMPs is more general than the other land use plans, but there are a number of important statements to consider:

- Biodiversity will be managed at the landscape level over an entire district, and will provide management objectives and strategies for the following:
  - ecosystem representation within the ecosystem network and Protected Areas;
  - retention of old growth;
  - seral stage distribution;
  - landscape connectivity;
  - stand structure;
  - species composition;
  - temporal and spatial distribution of cutblocks;
  - endangered plant and animal life;
  - designation of sensitive areas;
  - special management or protection status of specific areas; and,
  - varied stocking densities and patterns.
- Boundaries of the ecosystem network are not intended to be legislated, rather, borders are deliberately flexible to allow adjustment by the Ministry of Forests district manager and the designated environment official.
- Corridor widths will be flexible enough to take advantage of local opportunities to protect and enhance biological diversity and wildlife habitat. As well, connectivity may not be required in all cases if a better opportunity to maintain older forest conditions and reduce fragmentation exists outside the corridor.
- The degree of flexibility permitted in management prescriptions will reflect the extent to which biodiversity attributes are being maintained in the landscape surrounding the corridor.

The West Babine SRMP

For the purpose of determining the potential impact of mountain pine beetle on biodiversity within the ecosystem network, the SRMP and LUPs contain more measurable direction including:

- maintain the structural and functional features of old forest within Core Ecosystems as follows:
  - no harvesting within Core Ecosystems except for incidental tree cutting for mining and exploration purposes;
  - no road building within Core Ecosystems except for accessing timber that would otherwise be inaccessible, and for mineral development;
  - allow natural processes (e.g. fire and insects) to occur within Core Ecosystems except where those processes threaten resources outside the zone.
- maintain connectivity of old and mature forest cover within LRCs as follows:
  - maintain at least 70% retention of structure within Landscape Riparian Corridors;
  - no alteration of fluvial or floodplain ecosystems that may be subject to frequent or infrequent flooding;
  - winter harvesting only;
  - no road building except to access areas that would otherwise be inaccessible (access into Landscape Riparian Corridors should be temporary unless no other alternative is reasonable for ecological or economic reasons);
  - harvest predominantly small patches within Landscape Riparian Corridors (0.3 to 3.0 ha) depending on stand type and age and level of cut in adjacent stands.

- no reduction of functional area of red and blue listed ecosystems (pertains to all areas including the ecosystem network and includes the following plant communities - ICHmc2/54, ICHmc2/51, SBSmc2/05, ICHmc1/02, ICHmc2/02, ICHmc1/06)[7].
- 12% old growth retention within each mid-sized watershed (pertains to the entire Babine watershed and has been deemed to be met by the Core Ecosystems and assuming a 200 year rotation for areas managed for old forest retention).

The Bulkley Higher Level Plan Order and Objectives

In 2006, government led an initiative to streamline legal objectives in the Bulkley TSA. This process involved a review of existing plans and the development of new wording to be consistent with the intent of the original plans. Although the order establishing the new objectives replaced objectives in existing plans, it was recognized that the existing plans provided important legal direction, context, and strategies for the management of forest resources consistent with public and legislated expectations, and it was recommended that the existing plans continue to be used as a reference in developing and implementing forest management plans. It was also recognized that objectives could be revisited to address issues arising from catastrophic events such as mountain pine beetles or fire. Finally, it was foreseen that where objectives were established to meet a special management intent in an area that affected timber supply, such objectives could be modified elsewhere in the plan area to reduce timber supply impacts, with the goal of maintaining a 10% cumulative impacts "budget" – the accepted timber supply impact in the LRMP. Key objectives in the Bulkley HLP review included:

- maintaining biodiversity by ensuring a representative cross section of naturally-occurring ecosystems in Core areas that:
  - maintain some areas with forest interior conditions;
  - retain representative examples of rare and endangered plant communities;
- preventing timber harvesting in core ecosystems unless it is necessary for:
  - protecting the integrity and function of the ecosystem;
  - mineral and energy exploration and development;
  - providing access to timber outside the core ecosystem that would otherwise be isolated;
  - forest health control where there is a risk to operable timber outside of the core ecosystem.
- preventing the expansion of range use in core ecosystems.
- maintaining habitat connectivity across the landscape (thus allowing movement and dispersal of organisms) by maintaining landscape corridors dominated by mature tree cover and containing most of the structure and function associated with old forest.
- maintaining a diversity of attributes of old forest, such as coarse woody debris and standing dead and live trees in wildlife tree patches in managed stands in specific percentages (1 to 7% for the Babine and Nilkitkwa LUPs).

The Babine and Nilkitkwa LUPs

The Babine Landscape Unit Plan, which borders the West Babine, was prepared by the Bulkley Forest District to provide more detailed direction consistent with the Bulkley LRMP including objectives and strategies for biodiversity. The plan states that the ecosystem network provides for old growth retention, protection of the diversity of ecosystems (including rare ecosystems), forest interior conditions, and habitat connectivity and that the ecosytem network is intended to be flexible and will be modified as new information and inventories become available. Text in the Nilkitkwa LUP is nearly the same. Key objectives from the LUPs include:

- within Core Ecosystems, maintain a representative cross-section of ecosystems, retain representative examples of old seral age classes (age classes 8 and 9), provide some areas with forest interior conditions, and retain representative examples of rare and endangered plant communities by:

7 Note at the time the plan was written, these ecosystem associations were blue listed. Today most are no longer blue listed. See the Results section of this report for current blue listed communities.

  - allowing natural processes of insect feeding or disease to occur within core ecosystems unless infestations or infections threaten to spread into areas outside the core ecosystem (if intervention is required, then low impact treatments such as fall and burn or modified harvesting are acceptable – where a pest may cause imminent damage to a stand, and BC Environment and the District Manager agree, and timber will be at risk outside the Core or timber at risk in the Core will put Core values at risk, various sized openings up to two ha can be harvested or felled and burned depending on how big the infestation is and how much of the stand is pine versus other species).
  - prohibiting harvesting in core ecosystems unless harvesting is necessary to:
    - address forest health problems
    - permit incidental tree cutting for mining and exploration purposes.
  - where harvesting is necessary, avoid road construction (employ long skids or helicopter logging) and use modified harvest practices such as single tree selection (to maintain old growth structure) or small openings (<2 hectares to create or maintain early seral conditions).
  - where alternative access is not possible, roads can be built through a core ecosystem to avoid alienating operable timber outside the core ecosystem.
  - allowing natural processes to occur within core ecosystems, including the natural succession of existing early seral areas.
- Within the LRCS, the objective is to maintain landscape corridors dominated by mature tree cover and containing most of the structure and function associated with old forest to:
  - provide habitat connectivity within the landscape, and
  - permit movement and dispersal of plant and animal species.

Strategies include ensuring access into the landscape corridors is temporary unless no other alternative is reasonable for ecological or economic reasons, and harvesting small patches (0.3 to 3.0 ha) depending on stand type and age, level of cut, and level of regeneration in adjacent stands.

The Babine River Corridor Provincial Park

A park was also established along the Babine River in 1999 to protect the wilderness values of the river corridor for fish, bears, and wilderness recreation. Management direction for the park is provided in the form of strategies which are consistent with direction from other land use plans for Core ecosystems including the requirement that no permanent roads run through the park. A special management zone was also established in the LRMP and SRMP documents to envelope the park. Direction for special management zone 2 stipulates that temporary roads should be at least 300 m from the park boundary and that there will be no permanent unrestricted road access. Areas designated as special management zones allow industrial activity if they are carried out sensitively to ensure that impacts on identified values, such as visual quality, wildlife habitat, recreation or sensitive soils, are minimized.

The BWMT Knowledge Base

In addition to considering objectives and management direction in the land use plans, information in the BWMT knowledge base was used to augment information in the plans on acceptable thresholds of change for key biodiversity indicators. The BMWT Knowledge Base (KB) was developed in 2005 to provide information to use in estimating risk, uncertainty, and the probability that higher level planning objectives will be achieved, for a range of forest values (including such things as biodiversity, wildlife, fish and water, recreation, etc). The knowledge base:

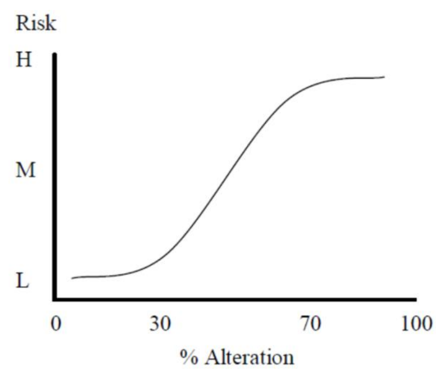
- summarizes information in the land use plans regarding the objective, information that might be available to assess the objective, and information to determine the monitoring priority, and costs and benefits of monitoring;
- provides an overview of current knowledge about risk and uncertainty (including identification of potential indicators) and what data might be available to support the evaluation of risk and uncertainty; and
- provides broad conclusions about level of risk and uncertainty (e.g. low, medium, or high risk).

Indicators identified in the KB which could pertain to mountain pine beetle impacts in the EN include:

- % alteration in core ecosystems;
- connectivity in corridors (% mature and old, area in cutblocks >3ha, km road/km^2, and % winter harvesting);
- rare ecosystems;
- stand structure (volume of downed wood per hectare by subzone, number of snags per hectare by size class and subzone, number of live trees per hectare by size class and subzone), and tree species diversity and relative importance.

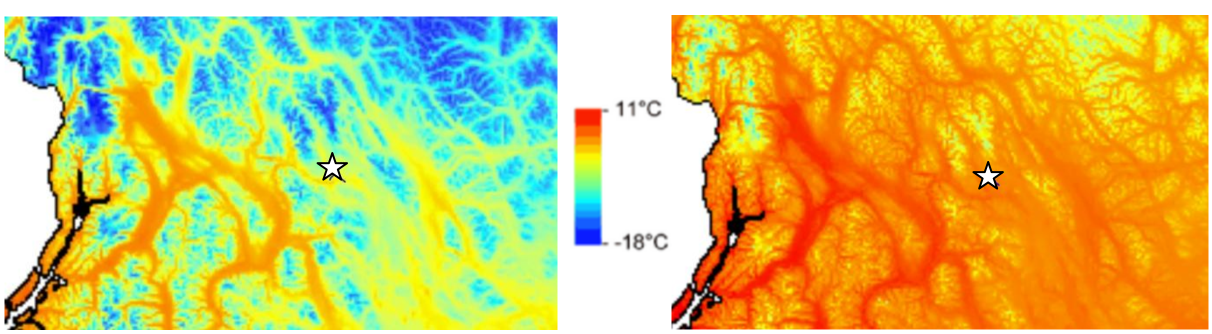
There are many other indicators in the KB but they are not specific to the ecosystem network and so were not used in this analysis (e.g. seral stage distribution across BEC units, patch size distribution, percent alteration of fluvial ecosystems, etc.).

In this report, indicators in the knowledge base (e.g. % alteration in core areas) are used to help identify thresholds beyond which EN function is compromised. An example of the type of guidance available is shown in Figure 1.   This figure depicts a sigmoidal relationship between risk and the percent alteration of natural levels of habitat and indicates that risk becomes low under 30% and high after about 70% alteration.



Risk to ecosystem integrity in core areas as a function of alteration in core areas (from the BWMT Knowledge Base, 2005).

The KB indicates that “the general sigmoidal curve is based on theoretical and empirical studies of a wide variety of organisms in a wide variety of ecosystems. Most studies consider the absolute amount of habitat rather than the percent of habitat relative to natural levels. Curves for absolute amount, however, vary tremendously among organisms and can only be drawn for particular, well-studied species.” Use of these curves is further complicated by potentially significant climate shifts forecast for the area (see the figure below) which have generally not been integrated into the curves. For this reason, risk information in the knowledge base serves as general guidance only.



Mean annual temperature (left 1975, right 2085) determined using Climate BC, ver 3.2 in watershed area.

V – DETAILED GIS METHODOLOGY FOR IMPACTS ON MATURE AND OLD FOREST

1. Use Core(LRC)_Bulkley_Kispiox to clip VRI_2011_WS = VRI_CliptoCore(LRC),
2. Export table = Core(LRC)_Mature_Old.xlsx,
3. Use pivot table to summarize area for the Core or LRC by BEC and Age Class
4. Intersect VRI_ClipToCore(LRC) and Results_Cutblks = VRI_2011_Core(LRC)_Intersect_Cutblks and recalculate geometry
5. Export the table = Core(LRC)_VRI_Cutblks_Intersect.xlsx, and check and remove duplicates
6. Using the data from step 5, identify, by BEC unit, all polygons in which the VRI field “Proj_Age_1” indicates a stand that is age class 6 or older but the Results Cutblock file shows that it is logged.
7. Check a sample of these polygons in the Arcview using the underlying photography to see if there is anything anomalous.
8. Summarize all areas by BEC unit and age class which have been logged but which are listed in the VRI data as old (see file LRC(Core)_VRI_Cutblks_Intersect).
9. Subtract the values from step 8 in the Old/Mature summary table in the spreadsheet Core(LRC)_Mature_Old.
10. Identify the Crown Forest Land Base in the “Core(LRC)_Mature_Old” spreadsheets (i.e. net down Core/LRC total area to remove areas that are not Treed and, therefore, not part of the CFLB (these include NPBr, NCBr, NSR, S - swamp, RIV, R - rock, M - meadow, L - lake, G - gravel bar , CL - clay bank, A - alpine, U - Urban, or other land with <10% tree cover) and create a new summary table along side the one created in step 8.
11. Subtract the values from step 8 in the new summary table developed in step 10 in the Old/Mature summary table in the spreadsheet “Core(LRC)_Mature_Old”.
12. Summarize how many additional ha may have to be removed from Core(LRC)_Mature_Old.xlsx because of potential beetle incidence (create a separate table). Using Adrian Walton’s Cumulative Kill modeling is not really appropriate because the occurrence pixels are not the same shape as polygons, a pixel may have many VRI polygons, a VRI polygon may be intersected by more than one pixel, and the gridcode value seems only weakly correlated with amount of pine in the polygons. Adrian’s work on beetle spread is a rough indication of where beetles will occur in the future and a very rough indicator of the level of kill that will occur. It should be used only for an indication of spread over time. For this project, instead, an assumption was made that all stands greater than 60 years of age, with more than 33% pine would be attacked and that there would be 100% mortality within the next decade (given that the peak is supposed to be this year for the Bulkley). After netting out non-forest areas to obtain the CFLB, the attribute table in the layer VRI_2011_CliptoLRC(Core) was queried as follows to identify potentially affectable stands: "PROJ_AGE_1" >59 AND "SPEC_CD_1" = 'PL' AND "SPEC_PCT_1" >33 OR "PROJ_AGE_1" >59 AND "SPEC_CD_2" = 'PL' AND "SPEC_PCT_2" >33.
13. Summary tables in the Core(LRC)_Mature_Old” spreadsheets are then modified to obtain potential area of mature and old after beetle impacts by BEC unit and age class.

V1 – LEVELS OF PINE AND PINE BEETLE INCIDENCE IN TREES >12.5CM DBH BY PLOT

Plots Chosen As Affected By Pine Beetle

Plot #	% Pine Pre-Attack	% Pine in VRI Data	MPB Incid Field Obs	MPB Incid MPB Model	Stems/Ha Pine Pre-Attack	Stems/Ha Pine Post-Attack
A1a	100	70	86	0	700	100
A1b	100	70	50	0	200	100
A2a	100	20	100	5	700	0
A2b	100	20	83	5	600	100
A3a	71	90	80	0	500	100
A3b	100	90	50	0	400	200
A4a	100	85	67	12	1200	200
A4b	100	85	67	12	300	0
A5a	100	90	80	6	500	100
A5b	100	90	50	6	400	200
A6a	100	80	80	6	500	100
A6b	100	80	50	6	200	100
A7a	100	70	100	10	500	0
A7b	33	70	100	10	100	0
A8a	100	65	67	2	600	200
A8b	75	65	67	2	300	100
A9a	100	70	100	7	400	0
A9b	67	50	100	7	200	0
A10a	100	15	83	15	600	100
A10b	100	15	83	15	600	0
AL2	100	70	25	6	400	300
Average	93	65	75	6	471	95

Plots Chosen As Unaffected By Pine Beetle

Plot #	% Pine Pre-Attack	% Pine in VRI Data	MPB Incid Field Obs	MPB Incid MPB Model	Stems/Ha Pine Pre-Attack	Stems/Ha Pine Post-Attack
U1a	100	83	0	6	900	900
U1b	86	83	0	6	600	500
U2a	100	80	0	2	800	700
U2b	100	80	0	2	300	300
U3a	100	65	0	5	700	700
U3b	100	65	0	5	500	500
U4a	100	75	0	10	400	400
U4b	100	75	0	10	600	600
U5a	100	55	0	10	700	700
U5b	100	55	0	10	600	500
U6a	75	78	0	0	300	300
U6b	33	78	0	0	400	200
U7a	100	30	56	6	900	500
U7b	64	30	33	6	900	600
U8a	100	100	0	3	700	700
U8b	78	100	0	3	700	700
U9a	100	90	0	7	700	700
U9b	91	90	0	7	1000	900
U10a	100	20	40	20	500	200
U10b	100	20	33	20	600	400
UL1	100	95	0	5	400	400
Average	92	69	8	7	629	543

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