Extension Note

BC Journal of Ecosystems and Management

Retention patches: Windthrow and recruitment of habitat structure 12–16 years after harvest

J. Douglas Steventon[1]

Abstract

Standing-tree retention in harvested areas, often in discrete patches, is a widely used biodiversity conservation practice. The purposes include retaining or recruiting key structural attributes diminished in managed forests. Minimizing windthrow of retained trees has also been deemed desirable, extending their standing value before becoming downed wood. I examined standing tree, coarse woody debris, and windthrow characteristics of 159 retention patches left in harvested areas of the Kispiox, Bulkley, and Morice timber supply areas in the early to mid-1990s. The patches were originally surveyed in 1998 (Kispiox) or 1994 (Bulkley/Morice) and resurveyed in 2007. At the second survey, in the Kispiox and Bulkley/Morice respectively, patches averaged 63 and 41 m^2/ha basal area of standing trees 7.5 cm dbh and greater, and 361 and 474 pieces per hectare of coarse woody debris, similar to unharvested mature forests. The patches achieved a good variety of standing tree and coarse woody debris sizes and condition. Best estimates of total windthrow rates (fallen basal area/total basal area) were about 9% (Kispiox) and 17% (Bulkley/Morice) after 12–16 years. Little net change in characteristics of the Kispiox patches was observed between the two surveys. However, an estimated 14% reduction in standing basal area was observed for the Bulkley/Morice patches, and a 25% increase in proportion of standing dead trees versus live trees between the two surveys. To minimize windthrow, previous rule-of-thumb criteria still apply; that is, create larger patches (> 1 ha), place patches in topographically sheltered locations, and minimize edge exposure to prevailing winds. Although understanding and minimizing windthrow remains a design consideration, I believe the greatest need is better understanding of retention requirements across spatial and temporal scales.

KEYWORDS: *green-tree retention; retention patches; west-central British Columbia; wildlife tree patches; windthrow.*

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Introduction

Retention patches (also known as "green-tree retention" and "wildlife tree patches") have become an established practice for maintaining and recruiting important "biological legacies" or wildlife habitat elements in managed forests (Bunnell et al. 1999; Rosenvald and Lõhmus 2008). Such legacies include large live trees, snags, and coarse woody debris (i.e., downed logs). Retention patches can also function as refuges ("life boats"), or re-colonization sources of vascular and non-vascular plants, small vertebrates, and invertebrates for the surrounding harvested stand (Rosenvald and Lõhmus 2008). Another general goal is designing patches to minimize windthrow (Delong et al. 2001), which retains the value of standing trees for as long as possible before recruitment into the downed wood category (coarse woody debris).

Retention patches have become an established practice for maintaining and recruiting important "biological legacies" or wildlife habitat elements in managed forests.

Here I report on standing tree and coarse woody debris characteristics, as well as windthrow rates and predictors, for 159 retention patches established in the early to mid-1990s in the Kispiox, Bulkley, and Morice timber supply areas in west-central British Columbia. These patches were measured previously in 1998 (Kispiox: Mahon et al.[1]) or 1994 (Bulkley/Morice: J.D. Steventon, unpublished data) and were used in a windthrow prediction meta-analysis conducted by Delong et al. (2001).

My objective was to examine the following questions.

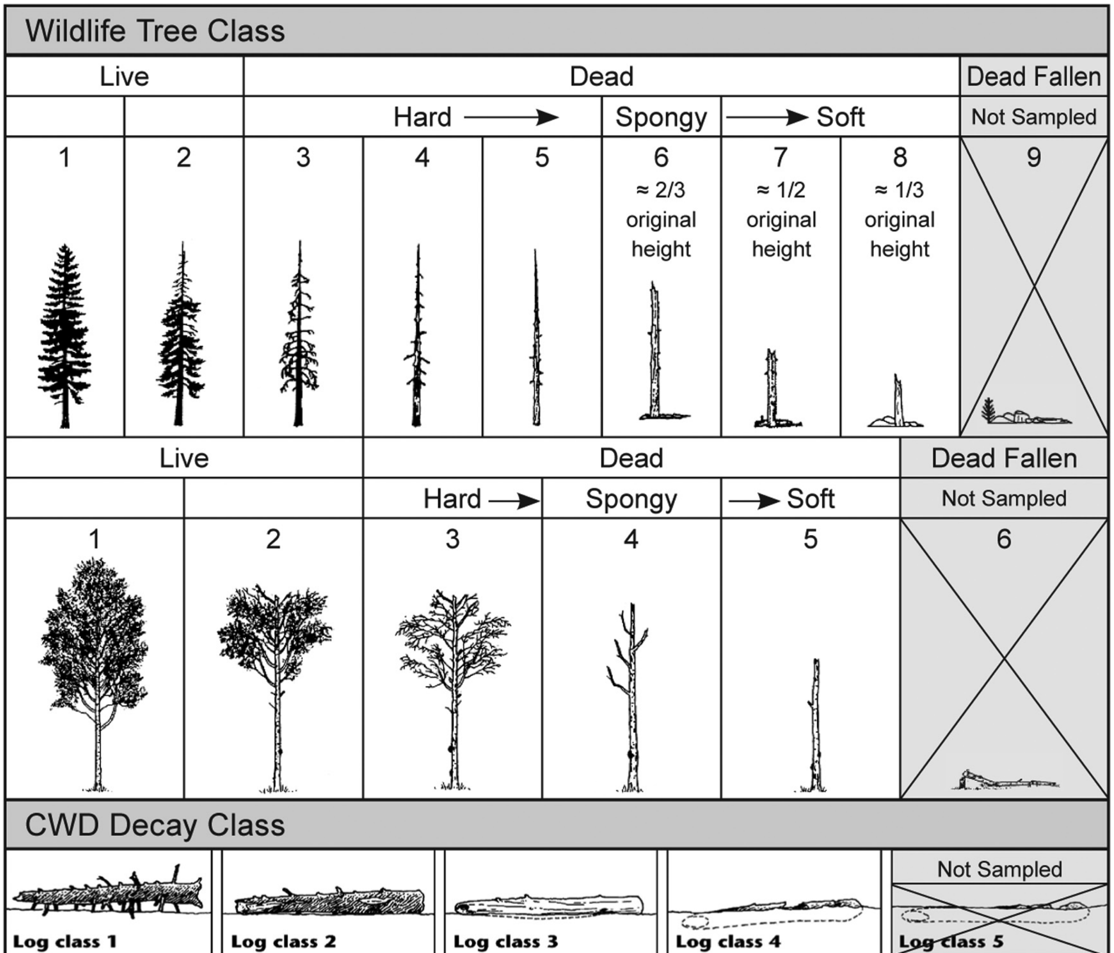
1. How successful has this practice been at providing standing tree and coarse woody debris elements?
2 How has standing tree and coarse woody debris abundance and characteristics changed since the initial surveys?
3 Do the predictors and design recommendations of Delong et al. (2001) for minimizing windthrow still hold?

Study area and methods

In 2007, we remeasured a subset of patches previously measured 1–4 years after harvest in 1998 in the Kispiox Timber Supply Area (TSA)[2] and in 1994 in the Bulkley and Morice TSAs (J.D. Steventon, unpublished data). The Kispiox patches were mostly in the Interior Cedar–Hemlock Moist Cold Hazelton (ICHmc2) biogeoclimatic variant and a few in the adjacent Coastal Western Hemlock Wet Submaritime Montane (CWHws2) variant (no CWHws2 patches were remeasured). The Bulkley/Morice patches were mostly in the Sub-Boreal Spruce Moist Cold Babine (SBSmc2) variant and adjacent Engelmann Spruce–Subalpine Fir Wet Very Cold and Moist Cold (ESSFwv/mc) subzones. The original sample was a random selection of all documented patches, with selection probability weighted by patch size. The weighting procedure ensured that the sample was not excessively dominated by very abundant small patches. Access constraints (road closures) determined the patches that could be sampled in this re-survey.

We followed the same basic field procedures as the original studies, using total stem counts for small patches (generally < 0.3 ha) and belt transects to sample larger patches. We could not reliably locate the original transects, so new transects were established for this re-measurement. We also elected to halve the transect width but double the number of transects. The first transect was established perpendicular to a randomly selected point along the central axis of the patch. Additional parallel transects were then systematically spaced at 20-m intervals. Standing trees of 7.5 cm or greater in diameter at breast height (dbh) were tallied within a 2 m perpendicular distance of the transect centre line. Stems of less than 7.5 cm dbh were counted within 1 m either side of the centre line. All standing trees were tallied by species, diameter at breast height, and wildlife tree classification (Figure 1). Fallen trees, or "windthrow," were defined as those with a greater than 45° lean from vertical that also originated within the belt transect; the direction of fall and type of fall (tipped or snapped) were recorded.

1 Mahon, T., L. Mahon, and S. Franklin. 1999. Inventory of wildlife tree patches in the Kispiox Forest District. Forest Renewal British Columbia. Unpublished report.
2 Ibid.



Log class 1	Log class 2	Log class 3	Log class 4	Log class 5
Hard	Sap rot (but still hard)	Advanced decay (spongy)	Extensive decay (crumbles/mushy)	Many small pieces, soft
Bark firm	Loose bark	Bark trace/absent	Bark absent	Bark absent
Elevated	Sagging	Sagging to settled on ground	Fully settled on ground	Partly sunken in ground
Hard branches with twigs	Soft branches	Branches stubs/ absent	No branches	No branches
Supports person	May not support person	Breaks easy	Shape collapses when stepped on	Collapsed oval
No invading roots	No invading roots	Roots in sapwood	Roots in heartwood	Roots in heartwood

FIGURE 1. Wildlife tree and coarse woody debris decay classes used for stand-level biodiversity resource stewardship monitoring in British Columbia (Province of British Columbia 2009).

Coarse woody debris (CWD) was defined as any stem of 7.5 cm or more in diameter at the transect centre line, with a tilt of 45° or more from horizontal, that did not originate within the transect. Pieces of CWD were tallied by diameter at the transect centre line, by decay class, and by species when possible. Total piece length was also measured.

The original Kispiox survey[3] applied a minimum tree diameter criterion of 15 cm dbh for standing trees; for comparisons between surveys, I also applied a 15 cm

[3] Mahon et al., 1999

limit to the re-survey data. I did not have CWD data available from the initial survey.

Incremental change in standing tree basal area since the first survey, which is an indication of net effect of windthrow and recruitment, was estimated as the difference in standing basal area by patch. Each patch was proportionally weighted by patch area for this analysis.

To re-examine windthrow predictors from Delong et al. (2001), I modelled the basal area proportion of fallen trees/total trees (windthrow) in the 2007 survey as a function of patch characteristics for each study area by using maximum likelihood logistic regression (PROC LOGISTIC, SAS 9.1, SAS Institute). The variables included were patch area, stand density (basal area), tree size (mean dbh), topographic exposure (depression/toe slope, flat or midslope, upper slope, exposed ridge top), perimeter/area (relative to a circle of the same size), and patch longest orientation as degrees difference from circular mean of patch windthrow direction. Competing models were compared using Akaike Information Criterion weights (Burnham and Anderson 2002).

Defining perimeter/area ratio and patch orientation was somewhat problematic. Orientation for circular or square patches is ambiguous and likely not meaningful, and orientation and perimeter/area ratio are likely not useful for very small patches where all trees are essentially exposed "edge" trees (Delong et al. 2001). In the logistic regression analysis, I therefore set the perimeter/area to 1 and the patch orientation to 0 for patches of less than 0.5 ha.

Results

Figures 2–4 and Tables 1–4 provide attribute summaries for the two study areas. All the parameters illustrate a high degree of variability. We re-sampled 159 patches totalling 96 ha, 16 361 trees of 7.5 cm dbh or greater, 6823 trees of less than 7.5 cm dbh, and 3133 pieces of CWD. The standing trees of 7.5 cm dbh or greater in the Kispiox patches were dominated by western hemlock (*Tsuga heterophylla*; 59%) and true firs (*Abies amabilis* and *Abies lasiocarpa*; 23%). The Bulkley/Morice patches were 68% sub-alpine fir (*Abies lasiocarpa*), 12% hybrid spruce (*Picea glauca* × *engelmannii*), and 10% lodgepole pine (*Pinus contorta*). In both areas, the dominant form of tree fall was uprooting of trees rather than breakage part way up the stem (2.9 times more common for Kispiox, and 3.8 times more common for Bulkley/Morice).

The CWD results (Tables 1 and 3, Figure 4) indicate an abundance and variety of decay classes, diameters, and lengths occurred within the patches. Based on the work of Delong et al. (2005) in spruce-fir forests, the decay class 1 pieces most likely represented post-harvest recruitment. With our methodology, the number of CWD pieces per hectare (Table 1) should be interpreted as a relative frequency rather than an absolute density.

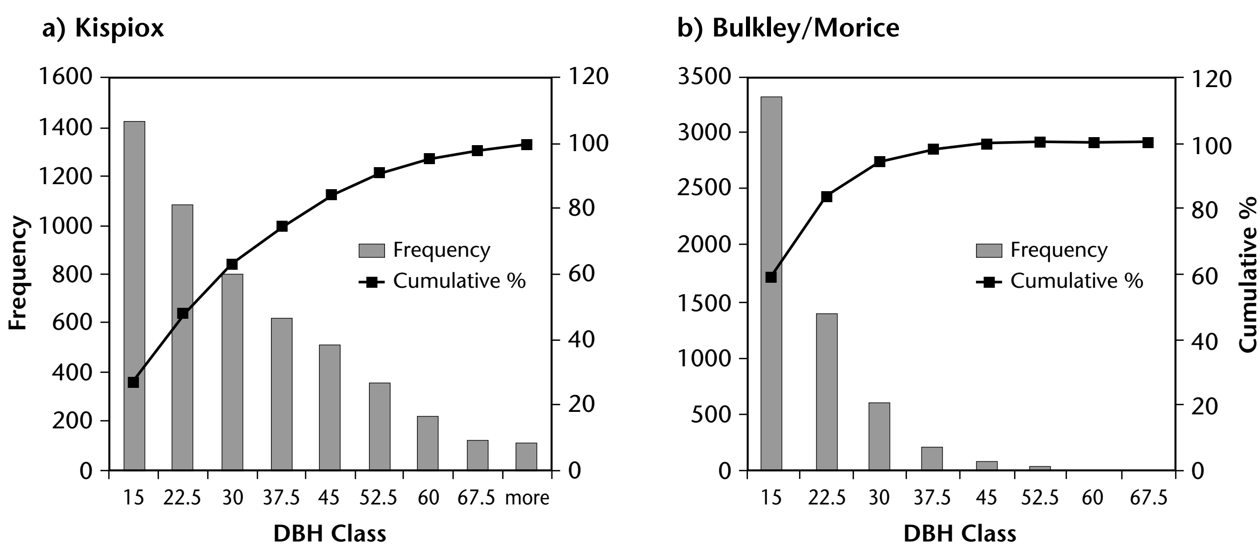


FIGURE 2. Frequency distribution of stems 7.5 cm dbh or greater (class values are upper thresholds) at second survey for (a) Kispiox and (b) Bulkley/Morice timber supply areas.

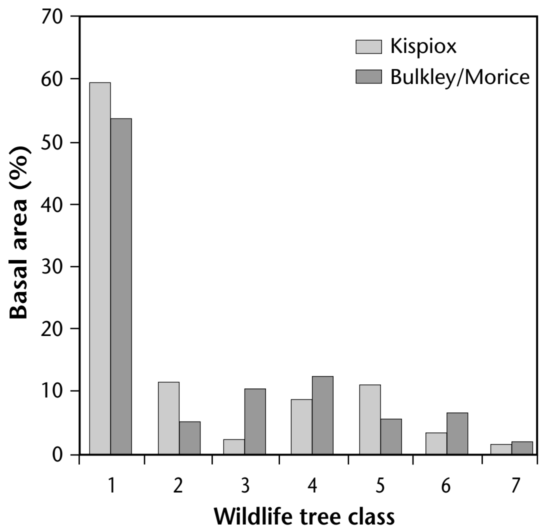


FIGURE 3. Percent of basal area (stems ≥ 7.5 cm dbh) by wildlife tree class at second survey.

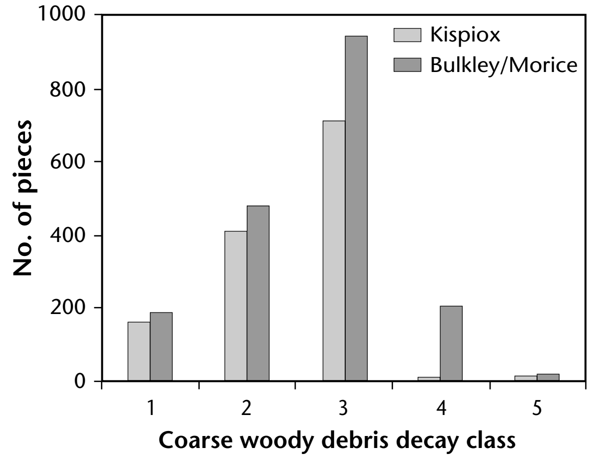


FIGURE 4. Percent of coarse woody debris by decay class at second survey.

TABLE 1. Summary attributes of sampled patches at 2007 survey

Attribute	Kispiox	Bulkley/Morice
Number of patches sampled	69	90
Total area of patches (ha)	52.8	44.4
Total area sampled within patches (ha)	7.24	8.17
Mean basal area trees ≥ 7.5 cm (m^2/ha)	63	41
Trees ≥ 20 cm dbh (%)	58	29
Mean trees < 7.5 cm dbh (stems per hectare)	989	1256
Mean CWD ≥ 7.5 cm (pieces per hectare)	180	226
Pieces CWD ≥ 20 cm dbh (%)	56	37

Estimated total windthrow rates (fallen/total basal area of stems ≥ 7.5 cm dbh; Table 4) for the second survey were 9% (±3%; 95% CI) for the Kispiox TSA, and 17% (±5%; 95% CI) for the Bulkley/Morice TSAs. The ratio of standing basal area between the second survey and first survey also indicated little change for Kispiox but a continued net loss of standing trees for Bulkley/Morice (Table 4). With 95% confidence intervals, the possibility of a net gain of standing stems (from recruitment into the ≥ 7.5 cm dbh size classes) cannot be ruled out in Kispiox, or even a small chance of a net gain for the Bulkley/Morice sample. In both areas, the most abundant size class (Figure 2) was 7.5–12.5 cm dbh, and there was a substantial number of stems below this size class as potential recruits.

TABLE 2. Mean (stems ≥ 7.5 cm dbh) diameter at breast height (dbh) by wildlife tree class at 2007 survey (standard deviation in parenthesis)

Wildlife tree class	Kispiox Mean dbh (cm)	Bulkley/Morice Mean dbh (cm)
1	26.4 (16.0)	16.3 (8.6)
2	31.3 (18.3)	15.7 (8.5)
3	33.2 (18.7)	20.2 (11.6)
4	35.2 (17.2)	20.0 (11.8)
5	25.5 (14.4)	17.5 (11.2)
6	33.7 (15.0)	18.1 (9.3)
7	37.7 (18.2)	21.0 (11.7)
8	28.8 (12.4)	25.3 (12.9)
9	25.8 (8.2)	25.0 (10.2)

TABLE 3. Mean diameter and length of coarse woody debris pieces at 2007 survey (standard deviation in parenthesis)

Decay class	Mean diameter (cm)	Mean length (m)	Mean diameter (cm)	Mean length (m)
1	29.1 (13.6)	7.2 (2.8)	16.4 (7.2)	5.5 (3.7)
2	27.0 (14.3)	6.6 (3.4)	17.8 (9.0)	6.1 (3.1)
3	22.0 (11.4)	5.8 (3.0)	17.6 (9.0)	5.3 (3.1)
4	19.7 (7.9)	10.4 (6.6)	24.3 (9.6)	4.8 (2.9)
5	22.1 (6.6)	7.8 (6.8)	27.3 (15.4)	4.9 (3.1)

TABLE 4. Estimated proportion of windthrow

	Kispiox		Bulkley/Morice	
Year	Mean	95% CI	Mean	95% CI
Survey 1[a]	0.09	0.05–0.13	0.10	0.07–0.13
Survey 2[b]	0.09	0.06–0.12	0.17	0.12–0.22
Survey 1 to Survey 2[c]	0.01	−0.15–0.16	0.14	−0.01–0.28

[a] Ratio of fallen to total m^2/ha in 1994 (Bulkley/Morice) or 1998 (Kispiox).

[b] Ratio of fallen to total m^2/ha in 2007.

[c] 1 – (standing m^2/ha at survey 2 ÷ standing m^2/ha at survey 1)

The direction of fall of windthrow in the Bulkley/Morice sample showed a distinct bias to the northeast (Figure 5), presumably reflecting the dominant southwesterly storm winds (Smithers Airport weather data, Environment Canada). The Kispiox sample had a less distinct pattern, with a possible small bias against southwesterly fall directions.

For both study areas, logistic regression results (Table 5) supported a model of strongly reduced windthrow with increasing patch size (Figure 6) and topographic position, and weakly reduced windthrow with increasing stand density (total basal area) and perimeter/area ratio. However, the addition of perimeter/area and orientation in the Bulkley/Morice model was not supported by Akaike Information Criterion weights (0.01 vs. 0.99). This is somewhat surprising given the clear bias in tree fall direction in the Bulkley/Morice sample. Greater tree size (mean dbh) was ambiguous, with a weak positive effect in the Kispiox and a weak negative effect in the Bulkley/Morice. Overall, the models explained 25% of the variability in estimated windthrow (Figure 6). These results are generally consistent with Delong et al. (2001).

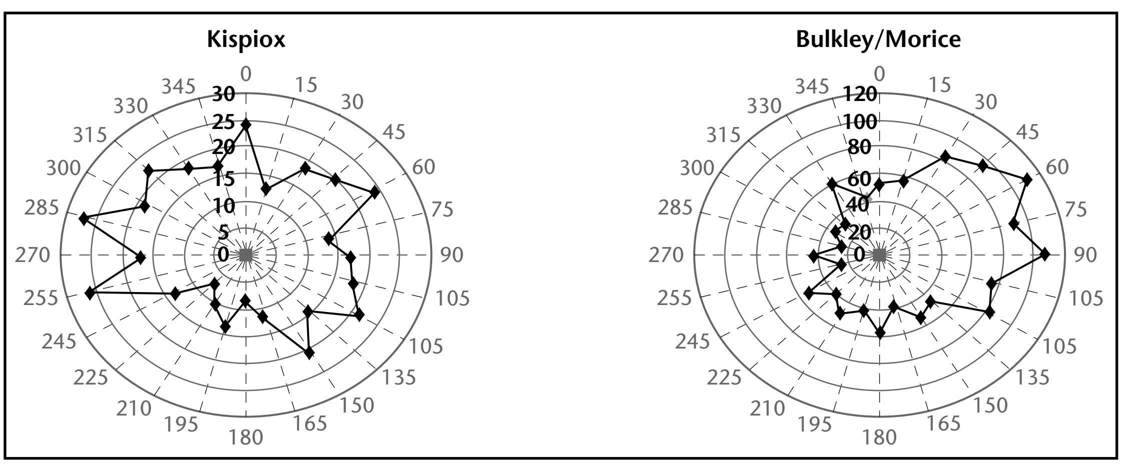


FIGURE 5. Frequency of windthrow by direction (15° increments) of fall (trees ≥ 7.5 cm dbh) at second survey.

TABLE 5. Logistic regression parameter estimates and odds ratios

		Kispiox				Bulkley/Morice			
Parameter	**DF**	**Estimate**	**Standard error**	**Wald chi-square**	**Pr > ChiSq**	**Estimate**	**Standard error**	**Wald chi-square**	**Pr > ChiSq**
Intercept	1	−3.0165	0.3195	89.1542	< 0.0001	−0.2666	0.2741	0.9457	0.3308
Patch_size	1	−0.2336	0.0764	9.3515	0.0022	−0.2356	0.0693	11.5478	0.0007
Basal_area	1	−0.00754	0.00147	26.4402	< 0.0001	−0.00794	0.0012	43.5581	< 0.0001
Mean_ dbh	1	0.0607	0.00837	52.6212	< 0.0001	−0.0597	0.0127	22.0886	< 0.0001
Topo	1	0.1373	0.0302	20.6945	< 0.0001	0.2171	0.0332	42.8828	< 0.0001
Perim_ area	1	−0.0352	0.0784	0.2013	0.6537	0.0133	0.1684	0.0062	0.9372
Patch_axis	1	−0.00807	0.00187	18.674	< 0.0001	0.000196	0.00292	0.0045	0.9465

Odds Ratio Estimates

Effect	**Units**	**Point estimate**	**95% Wald CI**		**Point estimate**	**95% Wald CI**	
			Lower CI	**Upper CI**		**Lower CI**	**Upper CI**
Patch_size	hectare	0.792	0.682	0.92	0.798	0.69	0.905
Basal_area	m^2/ha	0.992	0.99	0.995	0.992	0.99	0.994
Mean_dbh	centimetre	1.063	1.045	1.08	0.942	0.919	0.966
Topo	1–6	1.147	1.081	1.217	1.243	1.164	1.326
Perim_area	ratio	0.965	0.828	1.126	1.013	0.728	1.41
Patch_axis	degrees	0.992	0.988	0.996	1	0.994	1.006

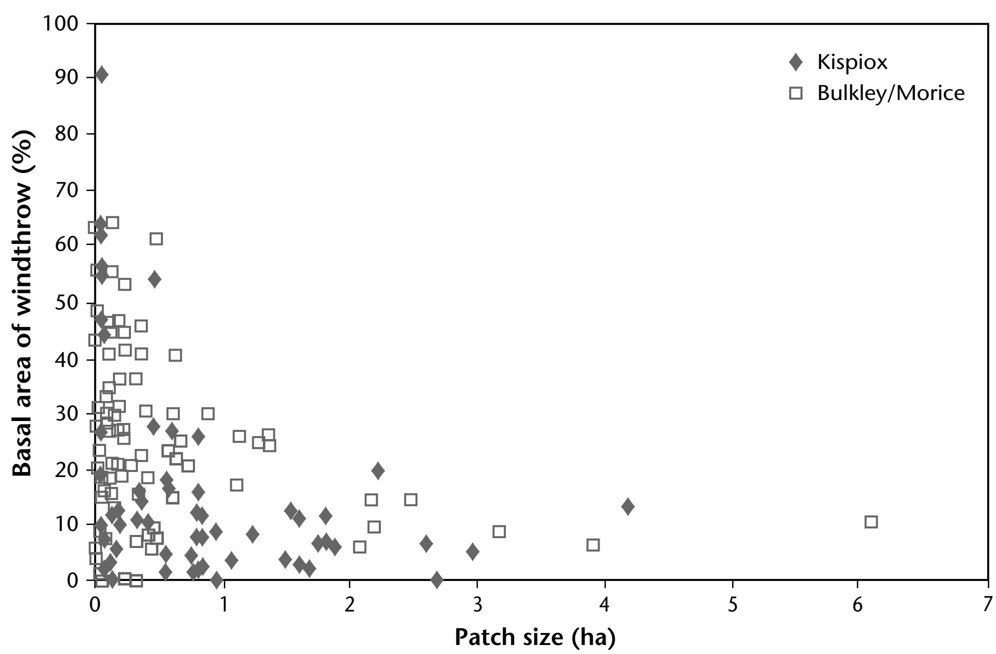


FIGURE 6. Percent windthrow (basal area) as function of patch size at second survey.

Discussion

In the aggregate, retention patches were diverse in characteristics (Figure 7) and effective at retaining habitat elements not otherwise present in the harvested areas. For the Kispiox patches, there was essentially no net change in the standing tree population (recruitment – loss) between the two surveys. For the Bulkley/Morice patches, however, there was higher tree mortality (an increase in proportion of wildlife tree classes ≥ 2) and a greater net loss of standing stems (ratio of fallen/standing tree basal area, and ratio of total standing basal area between the surveys). This difference perhaps reflects the ongoing attack by mountain pine beetle *(Dendroctonus ponderosae)* and balsam bark beetle (*Dryocoetes confusus*) in the Bulkley/Morice TSAs, or simply a difference in the forest dynamics between the two study areas.

All retained trees and CWD pieces provide habitat value (Delong et al. 2005, 2008), but retention strategies often focus on large live, declining, and dead trees, with CWD unlikely to be created in harvested areas on commercial crop rotations. These attributes were, for example, most predictive of foraging and nesting by cavity- and bark-nesting birds in ICHmc forests of the Kispiox TSA (Mahon et al. 2008), while Botting and DeLong (2009) found that CWD decay class, height above ground, and (to a lesser degree) diameter, were predictive of macrolichen and bryophyte diversity in spruce-fir sub-boreal forests.

However, unambiguous acceptable minimums that apply to all taxa do not exist for live and dead tree sizes or for abundance and spatial distribution through time (Ranius and Kindvall 2006; Müller and Bütler 2010). The patches we examined achieved substantive retention and

FIGURE 7. Examples of Kispiox patches.

(or) recruitment of larger stems both standing and as CWD in a diversity of vigour or decay classes, although live tree mean diameter at breast height was marginally lower than reportedly typical for mature natural forests (e.g., Coates et al. 1997 for ICHmc; Clark 1994 for SBSmc).

Mean windthrow rate (ratio of fallen to standing tree basal area) prior to the first survey in both study areas was about 2–5 times the reported background level in unharvested forest around the same time (Kispiox: Coates 1997; Bulkley/Morice: Burton 2001). On average, this rate dropped to something less than 1% per year between the two surveys in the Kispiox patches, and to about 2% per year for the Bulkley/Morice patches. It is not clear whether tree fall and recruitment have reached balance, especially for the Bulkley/Morice patches.

Windthrow rate was highly variable at the individual patch scale. The logistic regression models explained 25% of the variation in total windthrow among patches at the 2007 survey. Therefore, other variables, interactions among variables, sampling variability within and among patches, and (or) random chance play large roles. To minimize windthrow, however, the recommendations of Delong et al. (2001) remain valid: emphasize larger patches (≥ 1 ha) in topographically sheltered positions. Each 1-ha increase in patch size reduced the odds (Table 4) of windthrow by about 0.79 times (21% reduction). The most topographically exposed locations had about 7 times the odds of windthrow than the most protected. Although not found influential in this data set, minimizing perimeter length and minimizing edge exposure to prevailing winds are also potentially useful (Maxwell et al. 2010).

The aggregate windthrow losses we observed, even in the Bulkley/Morice sample, may not justify major effort to further minimize it, beyond the rules of thumb described above. Patch design effort is perhaps best spent on meeting the ecological objectives of retention patches; that is, protecting rare biophysical features within the harvest setting, and ensuring recruitment through time of large live and dead stems, both standing and as CWD.

Windthrow can be reduced by larger patch sizes, location in less wind-exposed topographic positions, perhaps by reduced perimeter to area ratio and with patch orientation that minimizes perimeter exposure to prevailing winds, and by higher basal area.

The greatest research need is to better understand how the abundance of large live trees and dead wood affects species and communities at varying spatial and temporal scales, and to translate that information into management prescriptions.

Here I have focussed on attributes within retention patches over a period of almost two decades. Despite some good preliminary work (e.g., Delong et al. 2008 and Ranius and Kindvall 2006), I believe the greatest research need remains gaining a better understanding of the amounts of retention required to achieve conservation objectives at varying spatial (patch, harvest block, landscapes) and longer temporal scales such as over multiple rotations.

Conclusions

As we approach two decades post-harvest, the sampled patches were diverse in characteristics and provided substantive diversity of live and dead standing trees and downed woody debris. To minimize windthrow, the recommendations of Delong et al. (2001), Burton (2001), and Maxwell et al. (2010) remain appropriate. Windthrow can be reduced by larger patch sizes (≥ 1 ha), location in less wind-exposed topographic positions, perhaps by reduced perimeter to area ratio and with patch orientation that minimizes perimeter exposure to prevailing winds, and by higher basal area.

While minimizing windthrow remains a consideration in designing patch retention, practitioners should perhaps focus on meeting ecological objectives of protecting rare features and ensuring recruitment of larger size trees and downed wood of varying condition. The greatest research need is to better understand how the abundance of large live trees and dead wood (standing and fallen) affects species and communities at varying spatial and temporal scales, and to translate that information into management prescriptions.

Acknowledgements

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References

Botting, R.S. and C. DeLong. 2009. Macrolichen and bryophyte responses to coarse woody debris characteristics in sub-boreal spruce forest. Forest Ecology and Management 258:S85–S94.

Bunnell, F.L., L.L. Kremsater, and E. Wind. 1999. Managing to sustain vertebrate richness in forests of the Pacific Northwest: Relationships within stands. Environmental Reviews 7:97–146.

Burnham, K.P. and D.R. Anderson. 2002. Model selection and multimodel inference: A practical information-theoretic approach. 2nd Edition. Springer-Verlag, New York, N.Y.

Burton, P. 2001. Windthrow patterns on cutblock edges and in retention patches in the SBSmc. In: Windthrow assessment and management in British Columbia: Proceedings of the Windthrow Researchers Workshop, January 31–February 1, 2001, Richmond, B.C. S.J. Mitchell and J. Rodney (compilers). pp. 19–31. ***http://www.for.gov.bc.ca/HFD/library/documents/windthrow.pdf*** (Accessed March 2010).

Clark, D.F. 1994. Post-fire succession in the sub-boreal spruce forests of the Nechako Plateau, central British Columbia. MSc thesis, University of Victoria, Victoria, B.C.

Coates, K.D. 1997. Windthrow damage 2 years after partial cutting at the Date Creek silvicultural systems study in the Interior Cedar–Hemlock forests of northwestern British Columbia. Canadian Journal of Forest Research 27:1695–1701.

Coates, K.D., A. Banner, J.D. Steventon, P. LePage, and P. Bartemucci. 1997. The Date Creek silvicultural systems study in the Interior Cedar–Hemlock forests of northwestern British Columbia: Overview and treatment summaries. B.C. Ministry of Forest and Range, Victoria B.C. Land Management Handbook No. 38.

Delong, S.C., P. Burton, T. Mahon, P. Ott, and D. Steventon. 2001. Factors affecting windthrow in reserves in northern British Columbia. In: Windthrow assessment and management in British Columbia: Proceedings of the Windthrow Researchers Workshop, January 31–February 1, 2001, Richmond, B.C. S.J. Mitchell and J. Rodney (compilers). pp. 32–41. ***http://www.for.gov.bc.ca/HFD/library/documents/windthrow.pdf*** (Accessed March 2010).

Delong, S.C., L.D. Daniels, B. Heemskerk, and K.O. Storaunet. 2005. Temporal development of decaying log habitats in wet spruce-fir stands in east-central British Columbia. Canadian Journal of Forest Research 35:2841–2850.

Delong, S.C., G.D. Sutherland, L.D. Daniels, B.H. Heemskirk, and K.O Storaunet. 2008. Temporal dynamics of snags and development of snag habitats in wet spruce-fir stands in east-central British Columbia. Forest Ecology and Management 255:3613–3620.

Mahon, C.L., J.D. Steventon, and K. Martin. 2008. Cavity and bark nesting bird response to partial cutting in northern conifer forests. Forest Ecology and Management 256:2145–2153.

Maxwell, S., D.S. Green, and W. Zhang. 2010. Identifying the determinants of windthrow damage in wildlife tree patches in the Boreal White and Black Spruce biogeoclimatic zone of northeastern British Columbia. BC Journal of Ecosystems and Management 10:1–8. ***http://www.forrex.org/publications/jem/ISS52/vol10_no3_art1.pdf*** (Accessed March 2010).

Müller, J. and R. Bütler. 2010. A review of habitat thresholds for dead wood: A baseline for management recommendations in European forests. European Journal of Forest Research 129:981–992.

Province of British Columbia. 2009. Protocol for stand-level biodiversity monitoring: Steps for field data collection and administration. B.C. Ministry of Forests and Range and B.C. Ministry of Environment, Forest and Range Evaluation Program, Victoria, B.C. *http://www.for.gov.bc.ca/hfp/frep/site_files/indicators/FS-1244-SLBD-FormD-Feb18-2009.pdf* (Accessed March 2010).

Ranius, T. and O. Kindvall. 2006. Extinction risk of wood-living model species in forest landscapes as related to forest history and conservation strategy. Landscape Ecology 21:687–698.

Rosenvald, R. and A. Lõhmus. 2008. For what, when, and where is green-tree retention better than clear-cutting? A review of the biodiversity aspects. Forest Ecology and Management 255:1–15.

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Test Your Knowledge . . .

Retention patches: Windthrow and recruitment of habitat structure 12–16 years after harvest

How well can you recall some of the main messages in the preceding Extension Note?
Test your knowledge by answering the following questions. Answers are at the bottom of the page.

1. Based on this article, what are two biodiversity purposes for green-tree retention?
   A) Maintaining/recruiting of key structural attributes in managed stands and providing recolonization sources or "life-boats" for some resident organisms
   B) Providing future timber supply and minimizing forest health risks
   C) Reducing windthrow at all costs, and providing visual aesthetics

2. Based on this article, what are the two strongest predictors of windthrow?
   A) Mean diameter of retained trees and patch orientation to prevailing winds
   B) Amount of coarse woody debris and tree species dominance
   C) Patch size and topographic position

3. In this study, the patches achieved which of the following?
   A) A clear net loss of standing large trees between surveys for both areas, resulting in obvious failure to meet structure retention goals
   B) A likely net loss of standing trees, especially live trees, in Bulkley/Morice, and neutral in the Kispiox
   C) A clear net recruitment of large standing trees and coarse woody debris in both areas

ANSWERS

1. A 2. C 3. B