Project Title: Evaluation of stand dynamics after a 25-30 year old MPB attack in the Flathead Region of south eastern British Columbia.

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Final Technical Report

Abstract

A retrospective study was undertaken in an old Mountain Pine Beetle (MPB) attacked forest to gain insight in stand dynamics post-beetle attack. Extent of mortality, regeneration delay, release of advance regeneration and other surviving residual trees and post-beetle stand growth was determined. Five plots were established in each of 22 stands representing a range of MPB attack intensity. Pre-attack basal area varied between 29 and 58 m^2 ha^{-1}. The percent of basal area killed by beetles varied from 42 to 100% with most stands between 60 and 80%. Six stands exceeded 80% basal area mortality and 3 stands were below 60% mortality. In 2007, twenty-five to 30 years after attack basal area varied between 4 and 51 m^2 ha^{-1}. Five stands, ranging in mortality at time of attack from 51 to 79%, had fully recovered their pre-attack stand basal area. Four stands, ranging in mortality at time of attack from 68 to 100%, had poor basal area recovery. Growth release on surviving trees exhibited species and size variability. Release of surviving lodgepole pine trees was often dramatic. Recruitment of new regeneration post-beetle attack was often, but not always, delayed by 5-10 years. Densities of post-beetle regeneration were often high in 2007. Based on age of understory trees in 2007, there was little advance regeneration in these forests at the time of the beetle attack.

Introduction

This project was originally titled "Evaluation of regeneration delay, release of advance regeneration, future growth rates, and stand dynamics after a 40-50 year old MPB attack in sub-boreal forests around Takla Lake". A significant Mountain Pine Beetle (MPB) attack occurred in the Takla Lake area of northern central BC in the early 1960s. We visited the area with good maps showing large areas of attack produced by the Forest Insect and Disease (FIDS) surveyors of the Canadian Forest Service. We found an intact sub-boreal spruce forest dominated by spruce and subalpine fir. We could not find a clear MPB signal. We found areas with lots of logs on the ground but found it difficult to identify the specific disturbance - some were more recent than the 1960s and species of down trees were not always necessarily pine. This observation, in itself, is revealing about the ability of forests to recover after an MPB attack.

The Flathead region of south eastern BC had a major MPB attack between 1978 and 1982. The MPB signal was very clear in this area and the epidemic location was well documented. Cored trees showed consistent growth releases associated with the timing of the attack. The study was mover to the Flathead region to better meet the objectives of our retrospective MPB study.

Methods

Site selection

Sampling was on mesic site types in stands where lodgepole pine was the leading canopy species. Lodgepole pine mortality was identified and only areas with MPB mortality were sampled. Sample sites areas had variability in species composition and attack intensity.

Field sampling

The protocols call for the establishment of 5 plots within a stand. Random transects were established and plots were spaced 50 m apart. At plot centre, we used two plots sizes, a 7.99m radius plot (for recording tree species and diameters) and a smaller 3.99m radius plot. Within the smaller plot an increment core was taken from all trees larger than 7.5cm at dbh. All smaller trees were destructively sampled to obtain growth data and age.

Laboratory sampling

Seedlings and saplings were cut at the root collar and cross-sections were sanded. Tree rings were visually counted under the microscope to determine number of years since germination and years with possible release events were recorded. In the samples where the age of the samples exceeded in at least ten years the date of the estimated year of the outbreak for that site, ring widths of the ten previous and subsequent years since the outbreak were measured.

Tree cores were mounted and sanded following standard dendrochronological methods (Stokes and Smiley 1968). Cores were visually cross-dated and ring-width series were measured on a Velmex bench to the nearest 0.001 mm. Ring-width series cores were statistically cross-dated using previously existing master chronologies (Daniels et al. 2007) using the program COFECHA (Holmes 1986). Ring-width series that did not cross-dated statistically and presented low correlation coefficient values were visually cross-dated.

Analysis

Master ring-width chronologies were developed for each site by standardization using the program ARSTAN (Cook 1985). Standardization is a process that removes the long-term variations from a time series of measured tree-ring properties by dividing the actual measurements by those predicted from a statistically derived equation. For this study, standardization was performed by fitting the observed data to a horizontal line passing through the mean ring width of the series. This method has been suggested to facilitate detection of past outbreak events better than other standardization models. Species-specific master chronologies were developed for each site. The purpose here was to combine all trees by species in master chronologies to represent average tree growth at each site. The chronologies were later used to study the behaviour of the surviving overstory trees as a consequence of the outbreak.

In order to study the individual growth response of the surviving trees after the MPB attack, we calculated percent-growth change according to the technique of Nowacki and Abrams (1997). Percent-growth change (GC) for a year is equal to $(M_2-M_1)/M_{1,}$ where M_1 equals the average growth over the prior 10 years and M_2 equals the average growth over the subsequent 10 years. It represents positive (releases), negative (suppression) and no significant changes. A 10-yr span for radial-growth averaging was selected since it tends to average out short-term growth responses related to climate, while capturing growth changes associated with canopy disturbance. Release (R) and suppression (S) events were identified for each tree based on the raw ring width measurements, and the criteria used were: high (H) releases (suppression) for > 100% GCH; medium (M) releases (suppression) for 50-100% GC, and low (L) release (suppression) for < 50% GC of increase (decrease) in radial growth. We recorded the years in which growth releases or suppression was initiated but also the series in which no significant release (suppression) was recorded after MPB attack (NS). Analyses were performed using simultaneously the ARSTAN (Cook 1985) and JOLTS (Holmes 1999) programs. For ARSTAN program we use the stand dynamics stuff option, which calculates only release events in raw series of tree-rings based in changes in percent-growth. We set running mean window of 10 years and percent-growth change following the criteria defined above. The JOLTS program was used to calculate not only releases but also suppression in radial growth. This program calculates the occurrence, coincidence and span of growth releases and suppressions finding the events according to the parameter “jolts”. The term is used to mean either releases or suppression according to the user’s choices for the program run. Again, we used a running mean window of 10 years and jolts factors for the change from pre- to post- jolts event related to the criteria expressed above (factors 1.05, 1.5, 2 related to >50%GC, 50-100%GC and >100%GC respectively).

Because the magnitude of release and suppression responses could be different between different size-class, we analyze the presence of any association between them at the time of MPB attack. We calculated the percent-growth change for a window of 10 years and for the year in which release or suppression were detected. Then, we correlated the value of percent-growth change with diameter of the tree at this time. We run this analysis for each species.

The resulting ages from seedlings and saplings were combined for each site in 5-year age classes to examine recruitment over time. The ring width measures of the subsample of regeneration older than ten years since the year of the outbreak were used to assess the growth response of the individuals after the outbreak. For this we calculated a ratio between the growth of the ten previous and the ten subsequent years since the attack date. A value greater than 1 will presume a positive growth response over the ten years after the outbreak while a value smaller than 1 may infer a negative response.

Results and discussion

Stand description and development

Table 1 presents average values for some stand statistics of the studied stands. Basal area at present shows a wider range of values compared to those before the attack. For most of the situations it represented a decrease in the amount, however there are sites at which the stocking was recovered (Sites 1, 10, 13, 20 and 21) and even exceeded pre-attack basal area (Sites 2 and 22).

Site	Year of Attack	Total BA 2007	Total BA Attack Year	Residual BA after Attack	Pl BA Dead at Attack	% Pl BA
1	1980	46.1	52.2	21.1	31.1	65.4
2	1979	51.0	48.6	23.4	25.2	78.7
3	1980	32.7	55.6	15.4	40.2	78.5
4	1980	26.5	57.7	11.8	45.8	89.2
5	1978	44.7	52.6	27.0	25.6	41.8
6	1979	35.3	49.5	18.6	30.8	64.7
7	1980	14.5	42.2	6.9	35.4	83.5
8	1980	40.7	56.6	16.4	40.2	80.5
9	1980	16.4	35.0	6.3	28.8	68.3
10	1980	51.5	54.1	30.6	23.5	65.7
11	1980	34.1	46.3	19.1	27.2	69.7
12	1979	29.8	43.5	12.3	31.2	71.6
13	1980	34.4	40.9	17.6	23.4	81.8
14	1980	35.2	58.4	20.7	37.7	62.2
15	1980	34.6	44.8	20.3	24.5	66.2
16	1979	4.0	30.7	0.0	30.7	99.9
17	1979	24.8	39.9	11.7	28.3	68.9
18	1980	19.8	29.9	11.4	18.5	61.9
19	1980	7.8	33.4	5.0	28.4	84.0
20	1980	50.1	50.4	25.0	25.4	51.2
21	1980	27.3	29.0	11.0	17.9	71.2
22	1979	44.3	43.7	25.2	18.5	51.1

Table 1: Stand descriptive characteristics for the the 22 studies sites.

Surviving overstory trees

Due to the range of MPB outbreak intensity and stand composition, the response of the surviving overstory trees was variable at both the species and stand level (Figures 1, 2 and 3). However, some general patterns appear to be apparent.

In general the surviving lodgepole pine trees exhibited a positive response after the attack in the following years (Figures 1, 2 and 3; Sites 3, 4, 9, 16, 17 and 21). On the other hand, there were stands where the remaining lodgepole pine trees had a poor growth following the outbreak.
By the same token, when present in the stands before the outbreak, species such as western larch (Sites 12, 13 and 19) and Douglas-fir (Site 6) showed a release response as a consequence of the high pine mortality.

Species with a more shade tolerant behaiviour exhbited dissimilar outcomes. While Interior spruce showed in most of the situations a growth release right after the outbreak (Sites 1, 3, 6, 15 and 17), balsam fir exhibited a less clear response (Sites 1, 8 and 14).

Figure 4 shows the percentage of growth responses of the surviving trees by species and sites across the existing ranges of diameters at the year of attack. Individual tree response after the MPB attack was variable over the range of diameters and no strong pattern of major releases (or suppression) related to a particular tree size was found. For all species, correlation values between diameter and percent-growth change were low and no significant (r values were Pl:0.06; Bl:0.29; Fd:-0.08; Sx:-0.12; Lw:-0.28). However, tree response seems to be more variable at lower size than at higher size in some species (except Bl). For example, for lodgepole pine extremely higher releases (>400%) after the outbreak were only registered in trees smaller than 20 cm of diameter at breast height (DBH). The same happened for interior spruce where higher releases (>200%) only occurred in trees smaller than 20 cm of DBH. Responses of the other species (western larch and Douglas-fir) were variable throughout tree size and only exhibited a weak pattern of higher releases at lower diameters. Finally, a reduction in radial growth after MPB attack did not show any pattern related to tree size. All sizes show some kind of suppression in all species analysed.

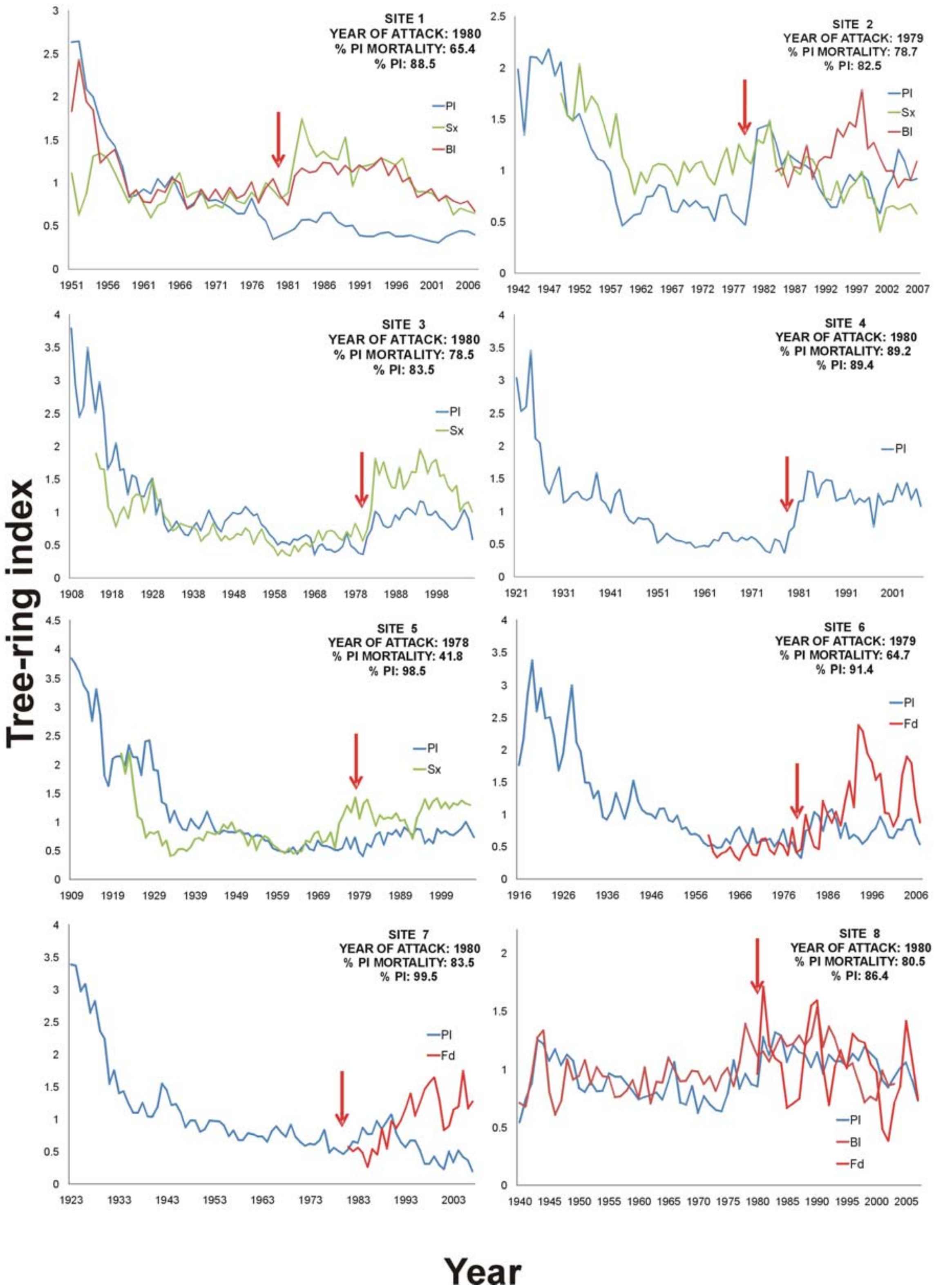

Figure 1: Ring-width mean chronologies by species for sites 1 to 8. Ring-width series were standarized using a horizontal line passing through the mean of each series. Red arrows indicate year of attack.

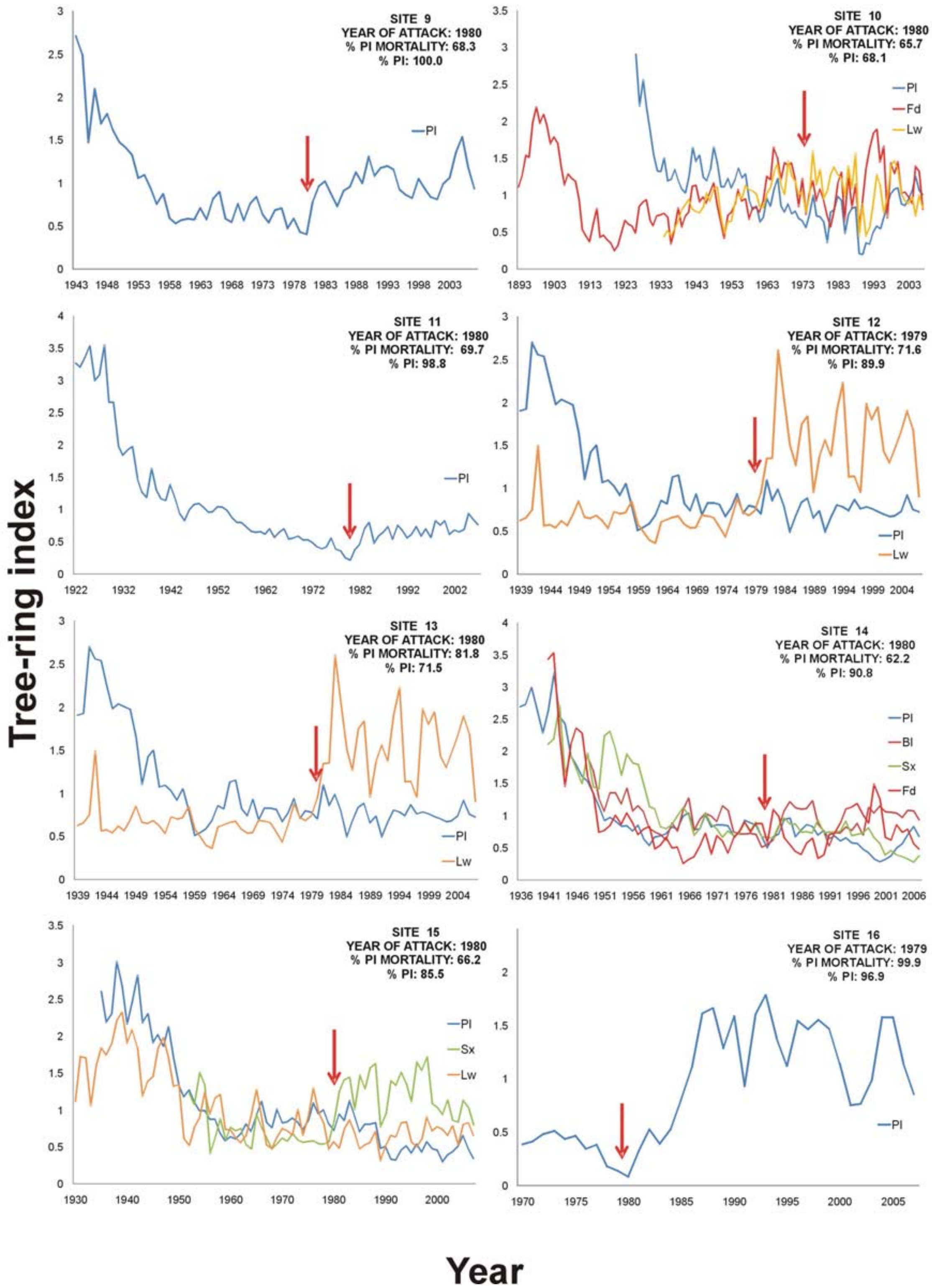

Figure 2: Ring-width mean chronologies by species for sites 9 to 16. Ring-width series were standarized using a horizontal line passing through the mean of each series. Red arrows indicate year of attack.

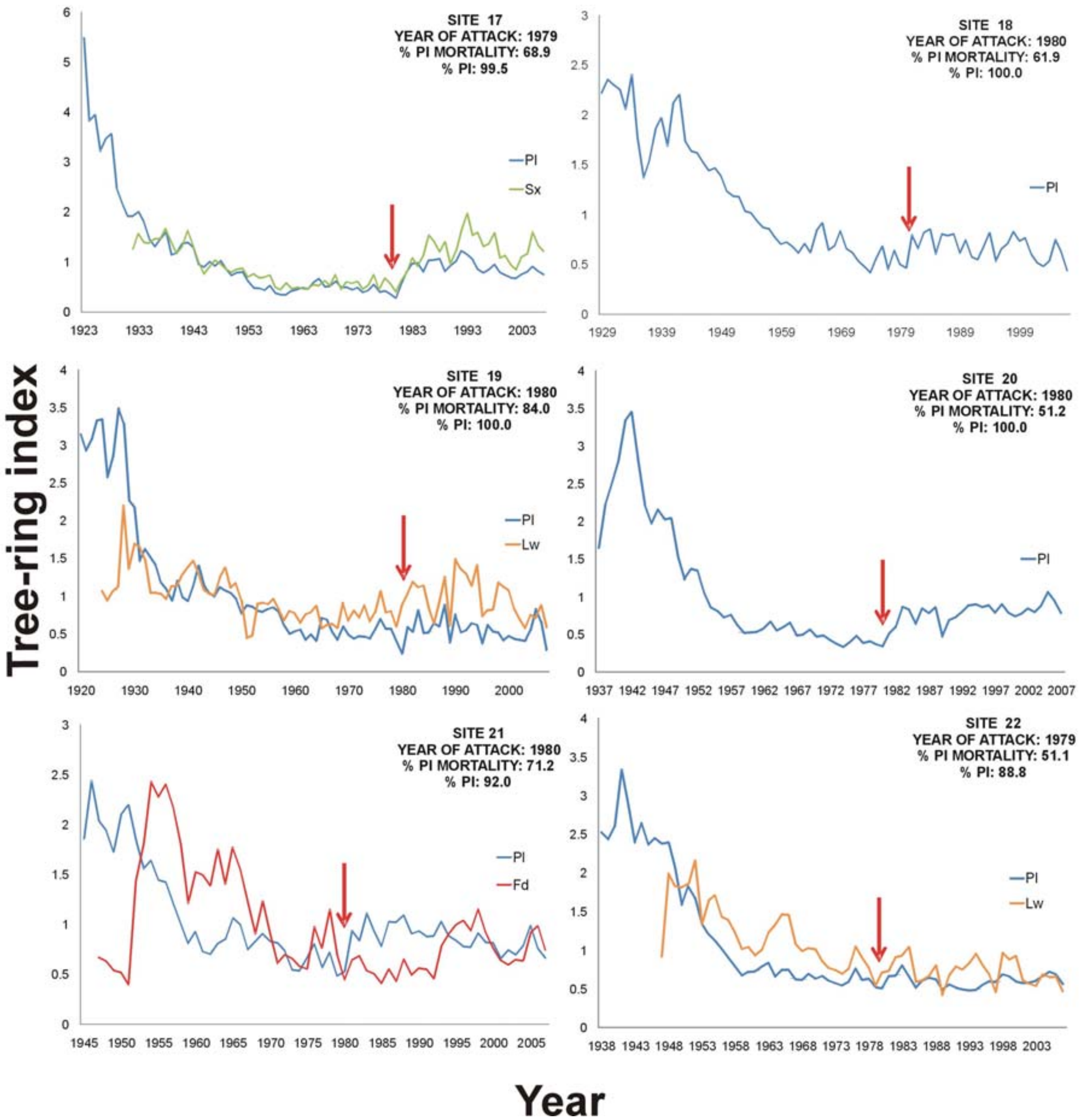

Figure 3: Ring-width mean chronologies by species for sites 19 to 22. Ring-width series were standarized using a horizontal line passing through the mean of each series. Red arrows indicate year of attack.

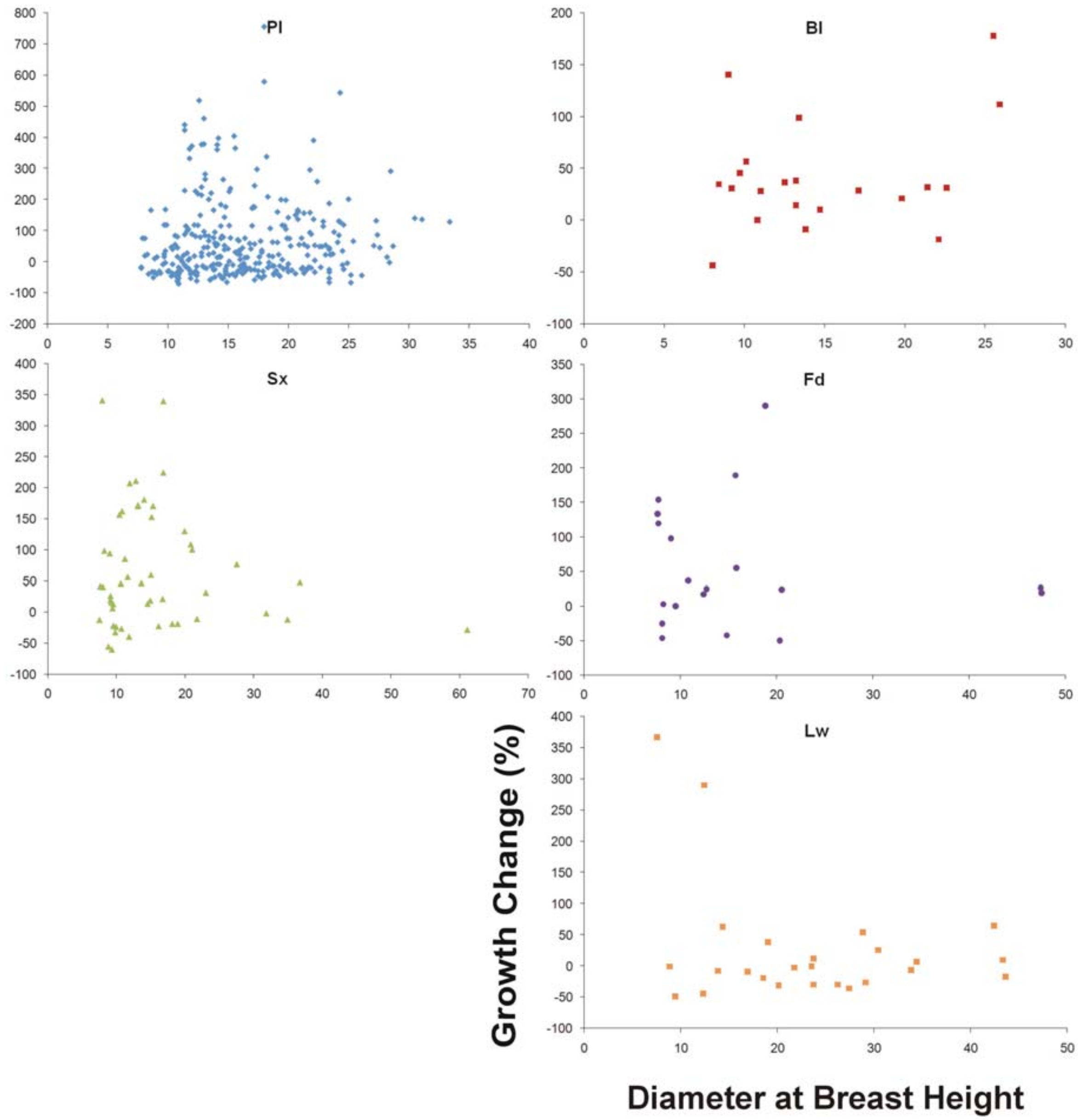

Figure 4: Percentage of growth responses of the surviving trees by species and sites for. Numbers in white indicate the total number of tress sampled at the site.

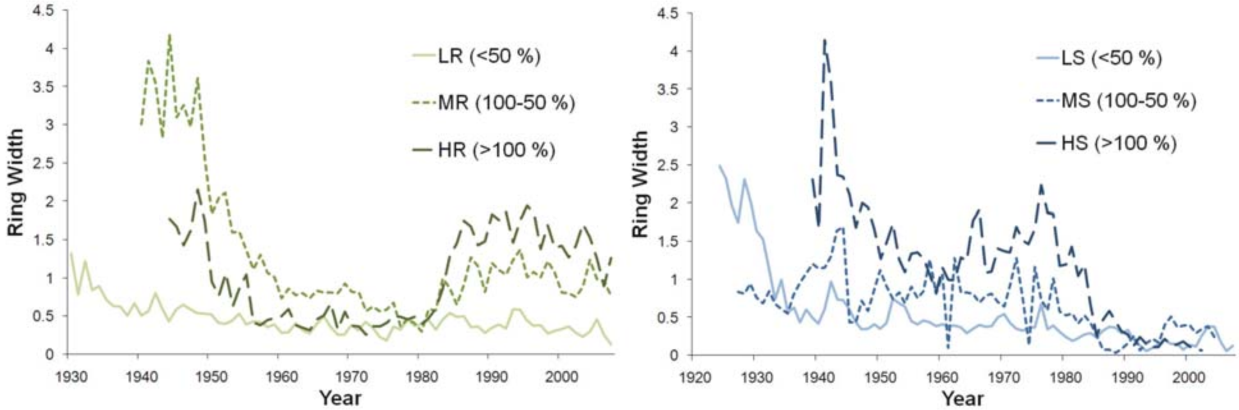

Figure 5: Individual ring width series for lodgepole pine trees showing different levels of release (left) and suppression (right) events. Year of attack was 1980.

Release (R) and suppression (S) events were identified for each tree and classified into six categories based on the magnitude of the response (Figure 5). Figure 6 shows the proportion of the different individual tree growth responses by species and site. Individual species have responded in different ways. Lodgepole pine trees showed different levels of release and suppression across all sites, however, the majority of the trees had a good positive growth change (HR and MR) at most sites. Douglas-fir and western larch trees exhibited, on the other hand, no or a poor performance after the attack with the exceptions of sites 12 (Lw) and 6 (Fd). Species such as balsam fir and interior spruce had a variable response.

The analysis by site also shows interesting results. While there were sites such as 10, 13, 14 and 15 where all species present exhibited a high proportion of suppressions, other sites such as 3, 4, 6 and 17 had a high proportion of releases. Trees from species present in site 22, on the other hand, showed no significant response.

When comparing the response of the lodgepole pine trees against the rest of tree species in the site, one could see contrasting situations. In sites 8 and 9 surviving lodgepole trees exhibited a good performance after the attack while trees from the other species did not. In contrary, in those sites where a higher proportion of lodgepole pine trees exhibited suppression patterns (1 and 10), trees from other species had, in general, a positive response.

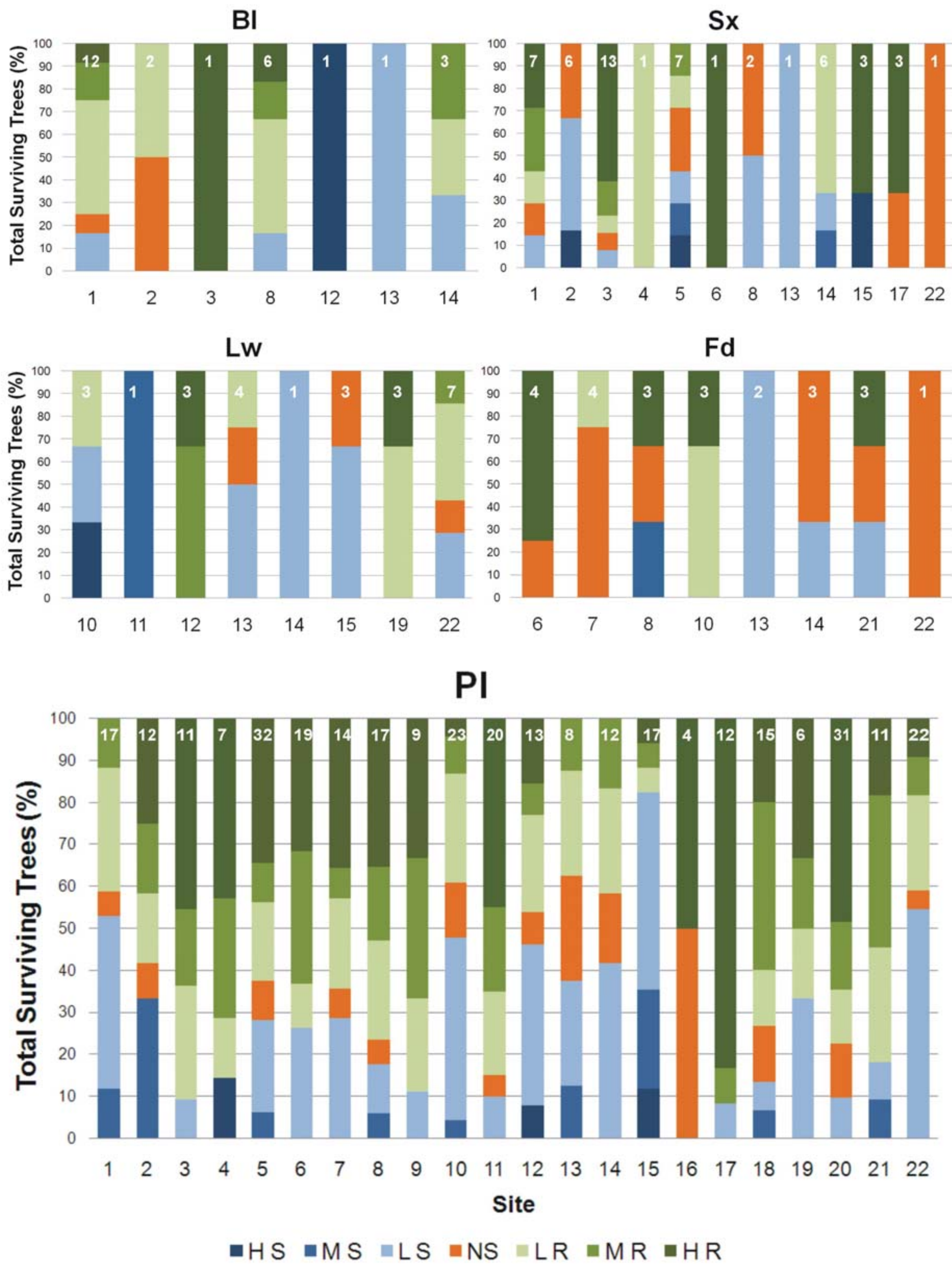

Figure 6: Percentage of growth responses of the surviving trees by species and sites. Numbers in white indicate the total number of tress sampled at the site.

Recruitment of regeneration post-beetle attack

Figures 6, 7 and 8 show regeneration recruitment over time expressed as 5-year tree age classes for the studied sites. For most stands the majority of the recruitment occurred after the outbreak with variable delay. There are some situations like Sites 4, 5, 10, 15 and 19 where the arrival of most of the trees happens in a period of five to ten years after the disturbance. For some others stands (Sites 1, 6, 7, 8, 9, 14 and 17) there seem to be a ten-year delay for the majority of the new trees. What seem to be common for most stands is that following the subsequent two decades after the outbreak there is an abrupt decrease in the recruitment.

It also appears that at the moment of the outbreak there was little advanced regeneration present in the stands. Although there are some stands with an important presence of trees established in the previous decades, these seem to correspond to small older trees from the overstory cohort. These could be both shade tolerant species such as interior spruce (Site 5) and balsam fir (Site 1) and suppressed lodgepole pine trees that survived the MPB attack.

Regarding the composition of the regeneration establishing after the outbreak, most trees correspond to shade tolerant species such as balsam fir for (Sites 1, 8, 13 and 14) and interior spruce (4, 9 and 17) or species with moderate shade tolerance such as Douglas-fir (Sites 6, 10, 16 and 18).

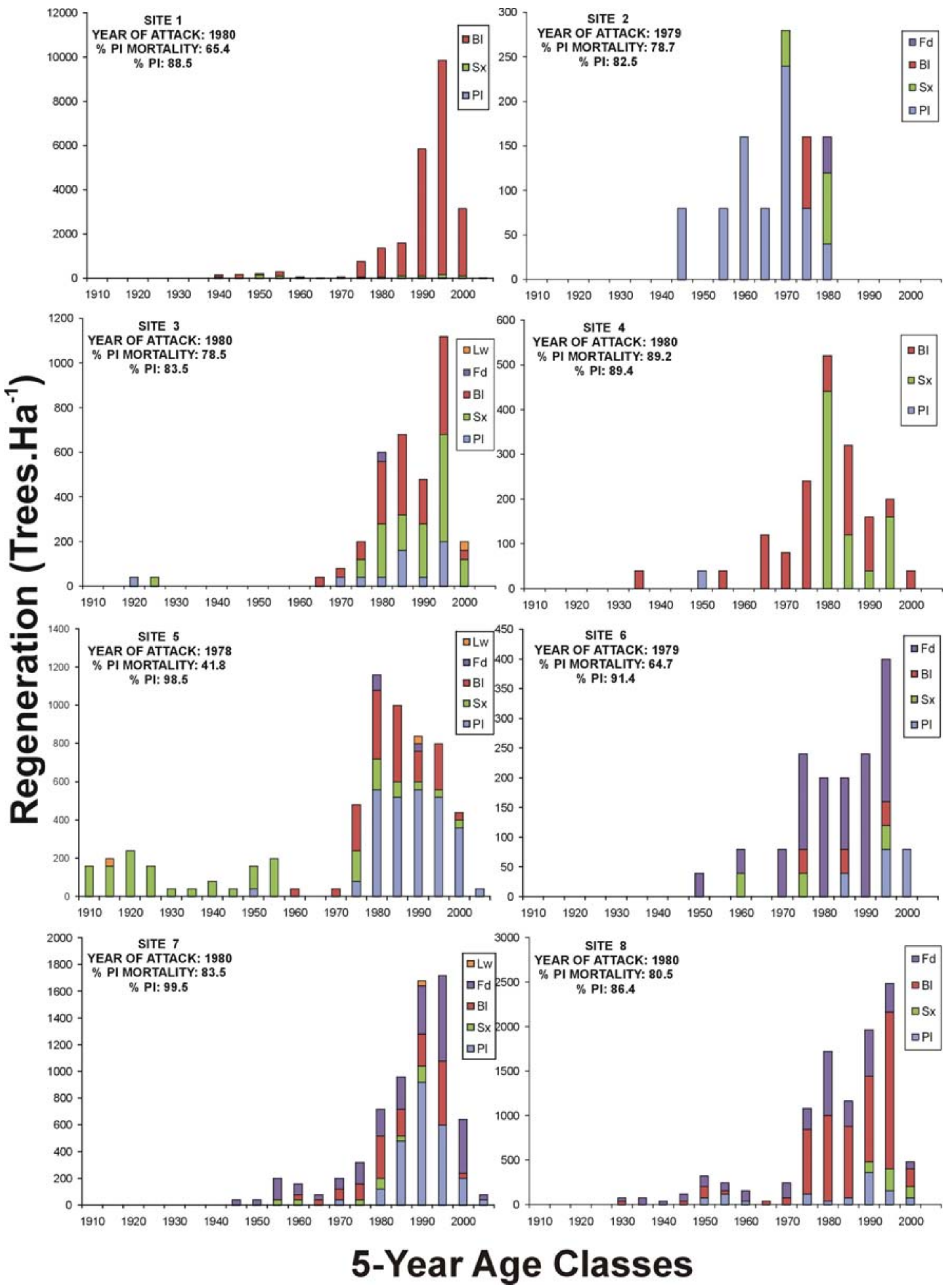

Figure 6: Regeneration recruitment per hectare by species in 5-year age classes for sites 1 to 8.

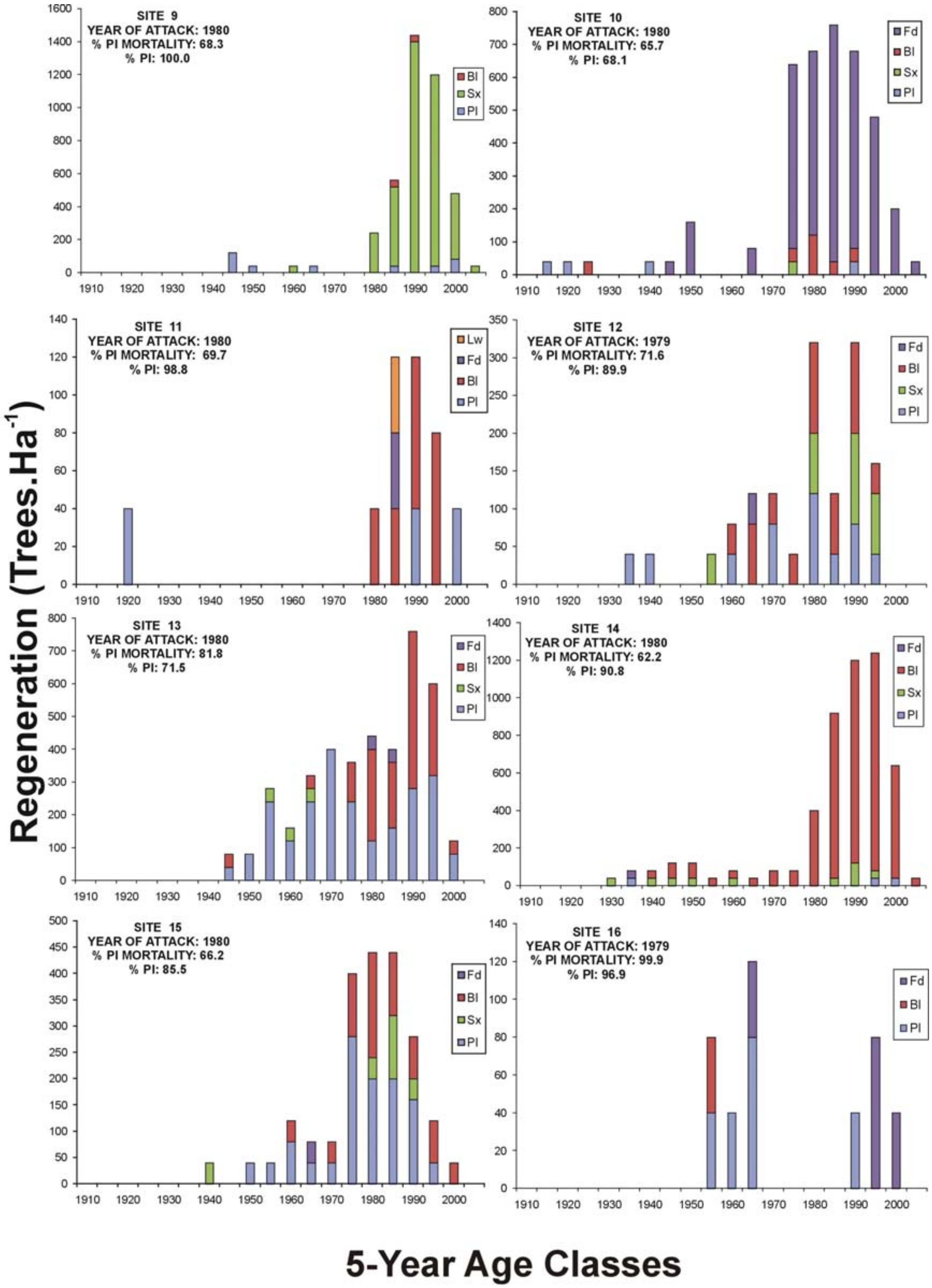

Figure 7: Regeneration recruitment per hectare by species in 5-year age classes for sites 9 to 16.

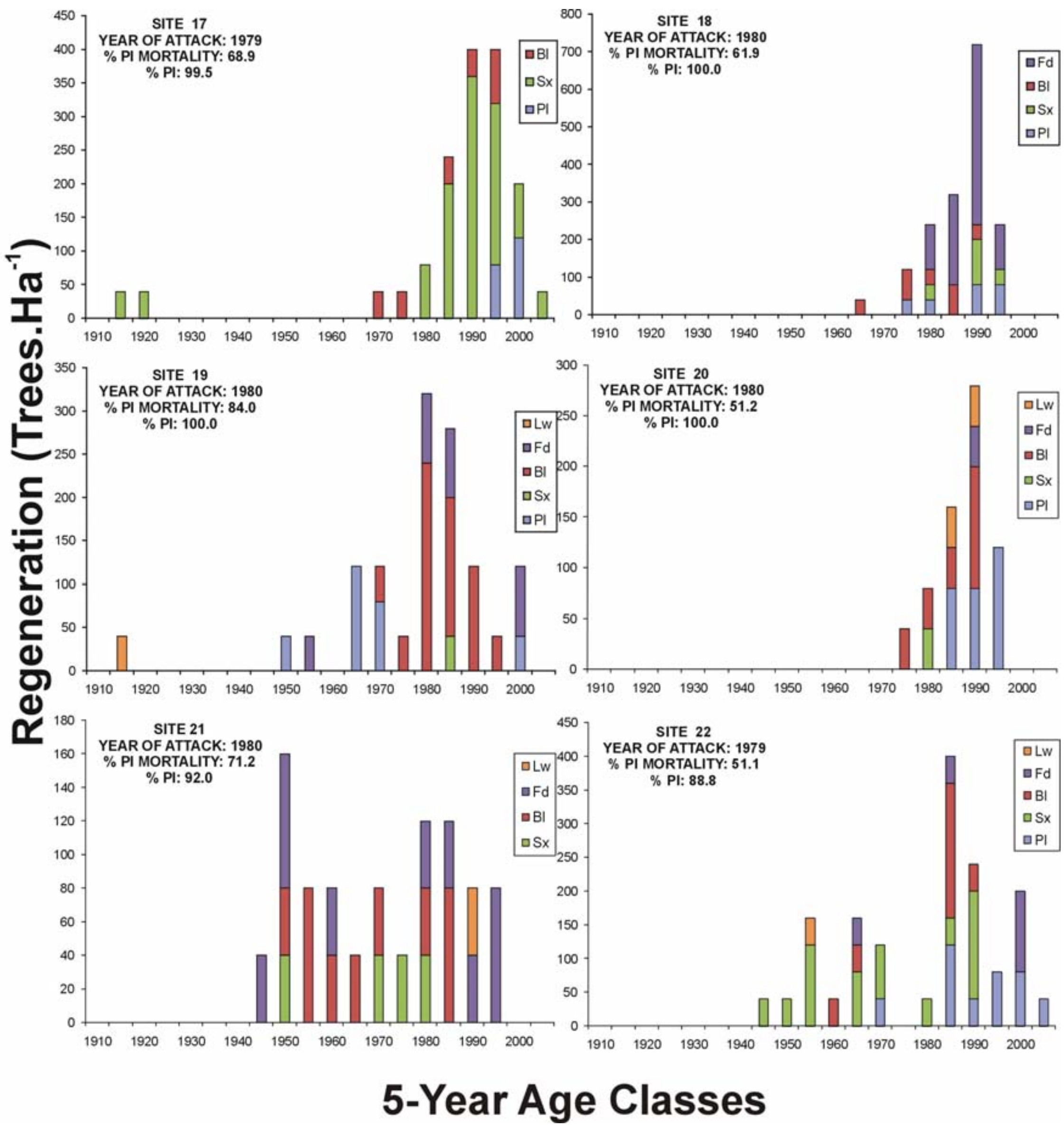

Figure 8: Regeneration recruitment per hectare by species in 5-year age classes for sites 17 to 22.

Understory response

We proposed to examine the understory response by comparing the average growth of the ten years before the outbreak with the average growth of the ten subsequent years. For that we calculated a growth ratio for the trees that were at least 10 years old at the moment of the disturbance and assume the following: a value greater than 1 will presume a positive growth response over the ten years after the outbreak while a value smaller than 1 may infer a negative response.

Most studied trees showed a positive growth response in the ten years following the outbreak independently of the species (Figure 9). In terms of absolute values all species had a similar response. There were stands such as Site 8 where all species exhibited the greatest release response.

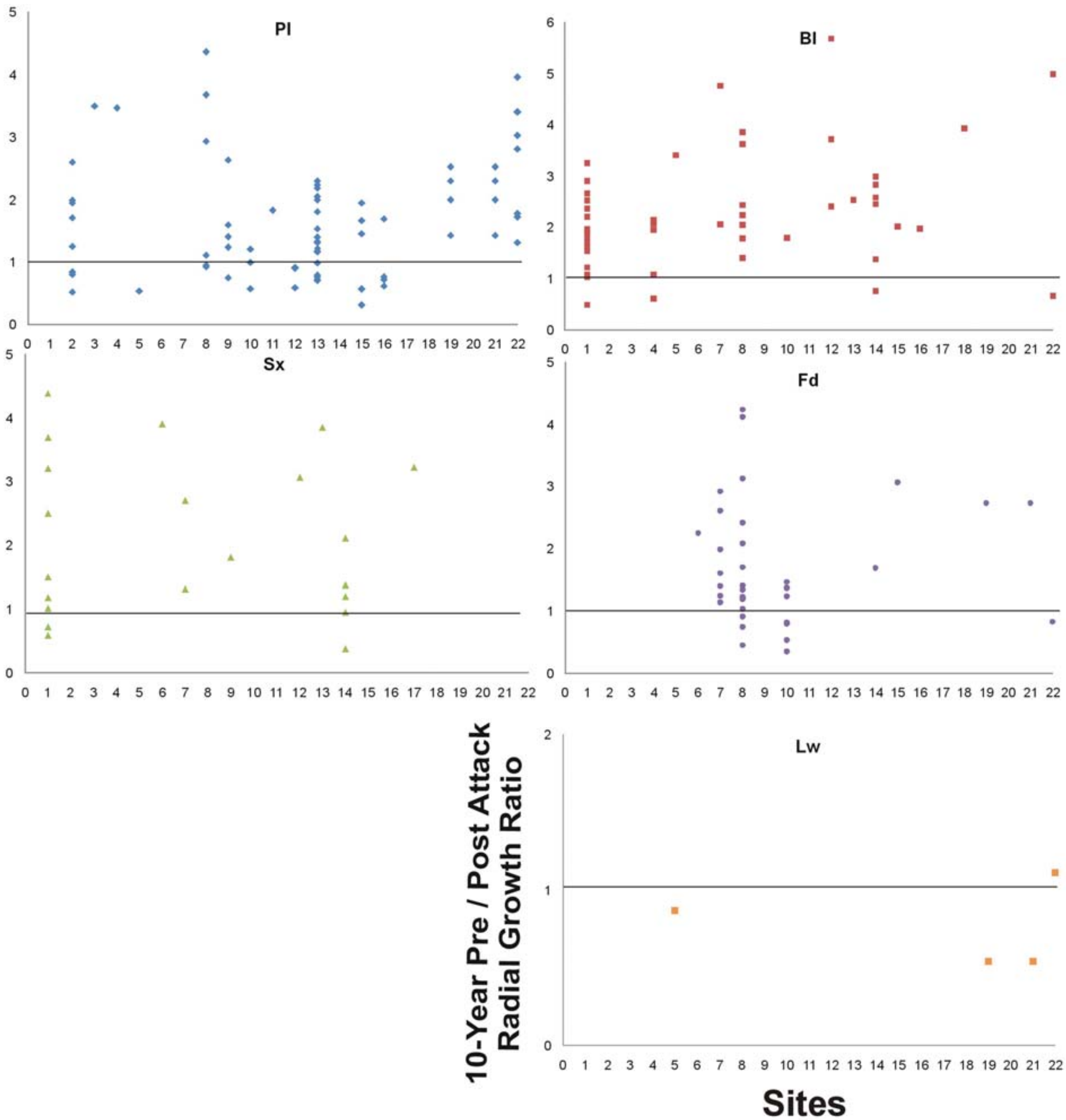

Figure 9: Regeneration response by species for the 22 studies site. Response was measured as a ratio of the average growth of the ten years before the outbreak and the average growth of the ten subsequent years.

Conclusion and Management Implications

- There seems to have been a high recruitment of individuals after the attack in those sites where the surviving overstory trees did not exhibit a good growth reponse (1, 5, 7, 8 and 14).
- Sites with low establishment corresponded to stands with vigourus overstory trees corresponding to either lodgepole pine or other shade intolerant species (12, 16 and 21). An interesting exception was site 2 where both regeneration establishment and overstory trees response was poor; this could explained by the high present amount of basal area (51 m^2 ha^{-1}).
- Regeneration establishment in general occurs with a delay of at least five to ten years corresponding to shade intolerant species such as interior spruce and balsam fir. With the exception of two sites where it ocurred as part of a mixed establishment, lodgepole pine did not establish as new individuals after the MPB attack.
- There seem to be at the moment of the outbreak little advanced regeneration established. However, when present, individuals from all species showed a good release response. In most cases we believe these trees correspond to small and suppressed trees from the same overstory cohort rather than seedlings established in the 15-20 years before the MPB attack. These results coincide with those of the surviving overstory trees. Although many stands exhibited a good growth response after the outbreak, results are variable. Responses varied depending on the number of surviving trees after the attack, proportion of trees killed and the species composition, the analyses show different results by species.
- Sites witch exhibited a high proportion of growth releases for the lodgepole pine trees (3, 4, 8, 9 and 17) were associated to stands with variable proportion of trees killed during the outbreak (28 to 45 m^2 $ha^{-1}$of BA) but with intermediate to low amounts of total residual basal area (6 to 15 m^2 ha^{-1}).
- There were stands where other species than pine had a good growth response independently on how lodgepole pine responded. Much of these responses were attributed to interior spruce.

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