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An Analysis of Douglas-fir Beetle Outbreak Occurrence as Related to Geology on the Idaho Panhandle National Forests

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Introduction

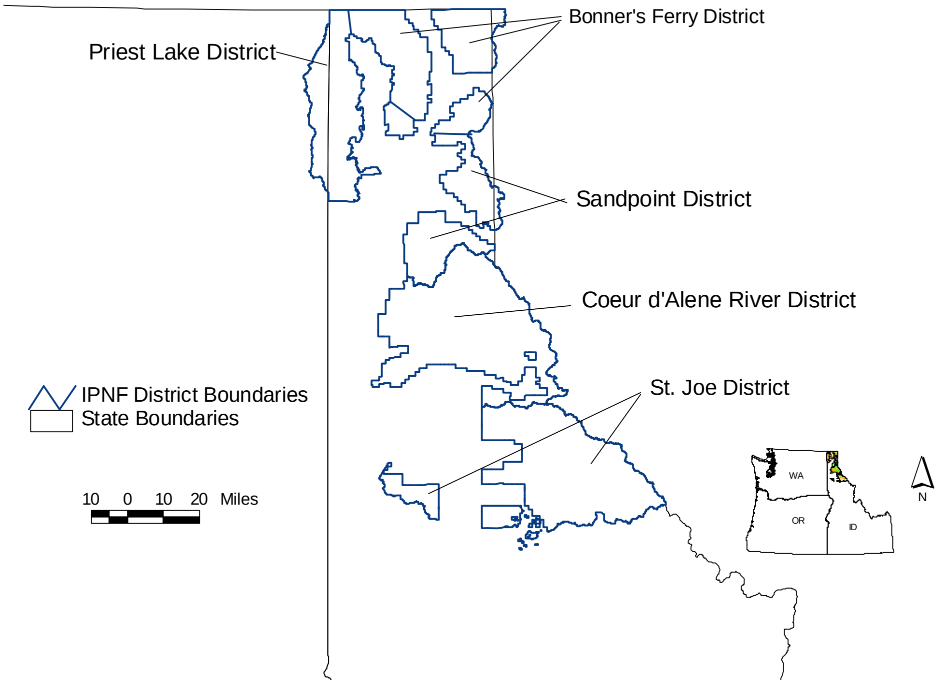
Douglas-fir (*Pseudotsuga menziesii*) is a native conifer species which is widely distributed throughout the inland northwest of the United States. This species occurs across a variety of site conditions, and may grow in pure stands or in combination with other tree species common to the area. Douglas-fir is one of the most important timber-producing species in the region.

A number of insects and diseases affect Douglas-fir stands in the region. Most are endemic to the area and experience natural cycles of buildup and decline. During the late 1990's, an endemic insect known as the Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopkins) began to increase to epidemic proportions throughout much of northern Idaho and northeastern Washington. This beetle burrows into the tree's bark and lays eggs. The adults and larvae then feed on the phloem, usually girdling and killing the tree (Hagle et al. 1987). During 1996 and 1997, an average of 51 ha/yr (125 ac) were affected by new Douglas-fir beetle attacks. By 1998 approximately 479 ha (1185 ac) were affected, and in 1999, aerial surveys indicated that 31,093 ha (76,830 ac) were impacted. These outbreaks caused great concern, due largely to the increased fire danger caused by huge areas of dead timber. Furthermore, as populations built, the beetles were able to spread further and faster than normal, affecting both public and private timberland in the region. The Panhandle National Forests initiated emergency salvage logging operations in the region, both to reduce fire risk and to reduce the risk of beetles spreading to adjacent private lands.

Recent findings in forest health research have indicated that the bedrock geology underlying forest stands may play an important role in forest nutrition, and consequently may affect tree susceptibility to insects and disease. While direct relationships between rocks and forest stand health have not yet been established, we believe that such relationships exist. In the current study, Forest Service workers in north Idaho and northeastern Washington noted a tendency for Douglas-fir beetle outbreaks to occur more frequently on certain rock types than others, even though adjacent stands on other rock types seemed otherwise very similar. This analysis utilizes Forest Service data on forest vegetative cover and Douglas-fir beetle distribution in combination with geologic data to assess whether beetles favored stands on certain rock types.

Data and Analysis

Geographic information system (GIS) layers were obtained from the Panhandle National Forest for five districts, including the Sandpoint, Bonner's Ferry, Priest River, Coeur d'Alene River, and the St. Joe Districts. The administrative boundaries for these areas are shown in Figure 1. The Forest Service provided two data sets. The first type of data was a vegetative cover layer consisting of individual stands, which met the criteria of being pole-size and larger timber, that occurred on habitat types having the highest probability of containing Douglas-fir (Zack, 2001). The second data type was comprised of a series of shape files showing areas affected by Douglas-fir beetle for 1996, 1997, 1998, and 1999. These shape files were digitized from aerial surveys conducted by the Forest Service's Forest Pest Management group.



Digital geology maps for the region were obtained from the United States Geological Survey (USGS) and the Idaho Geological Survey (IGS). The Sandpoint 1:250K quadrangle was merged with the Coeur d'Alene, Thompson Falls, Wallace, St. Maries and Headquarters 1:100K digital geology maps (Idaho Geological Survey 1996, Lewis and Derkey 1999, Lewis et al. 1999, Miller et al. 1999, Munts 2000). The geology maps were provided with detailed documentation describing each map unit. Some re-labeling of map units was necessary in order to maintain a consistent naming convention across all the different maps. One rock group known as the Belt Supergroup is prevalent in the inland northwest and in the analysis area. These are metasedimentary rocks dating from the Precambrian era. The formal nomenclature of these rocks is based on a hierarchy composed of groups, formations, and members (Lewis 2001, Lewis and Burmester 1999, Harrison and Campbell 1963). Within the analysis area, the formations that occurred were Prichard, Burke, Revett, St. Regis, Wallace, Striped Peak, and Libby. The Prichard and Wallace formations were further subdivided into upper and lower members. The Burke, Revett and St. Regis formations are often grouped together and called the Ravalli Group. In addition to these formal names, other lithology information for these formations was also available. For the Belt rocks, the most common lithologies were argillite, siltite and quartzite or some combination thereof. Other lithologies common within the area included glacial deposits and intrusive (granitic) rocks. Since the main topic of interest was whether the Douglas-fir beetle was more prevalent on Prichard formation rocks than on other rocks, we decided to retain the formal names for the Belt Supergroup of rocks. For other rocks in the analysis area, however, we used lithology descriptors. The categories selected for analysis were Prichard Formation, Wallace Formation, Ravalli Group (undivided), Libby Formation, Striped Peak Formation, glacial deposits, intrusive rocks, and other rocks. Map 1 in the Appendix shows the categorized geology layer and the distribution of Douglas-fir stands by size class, while Map 2 illustrates the Douglas-fir beetle outbreak areas for 1996 through 1999.

The geographic analyses were carried out in Arcview. The first analysis step consisted of intersecting the vegetative cover with the corrected digital geology. By intersecting these layers, we were able to preserve the individual stand size class information along with the geologic information for each polygon. Since the beetle outbreaks were digitized from aerial surveys, the outbreak polygons occasionally showed up as being outside the mapped locations of the Douglas-fir stands. This was expected; particularly as the data layers were created using varying methods and compiled at different scales. Therefore, the next analysis step was to clip the Douglas-fir beetle outbreak areas for 1996 through 1999 to the intersected Douglas-fir/ geology layer. This ensured that we only analyzed outbreaks for which we had stand size and geology information. Once this was completed, we created frequency tables for various combinations of size classes and geology by outbreak year. We exported the frequency tables to a spreadsheet in order to tabulate values. The outbreak areas for 1996 and 1997 were averaged since the affected areas for these years were so small compared to 1998 and 1999. To determine which classes to include in the study, beetle attack frequency was examined by stand size class. We only wanted to include stands that provided suitable habitat for Douglas-fir beetle. The distribution of selected stands was tabulated by rock type and these values were used as the expected distribution of Douglas-fir beetle under the null hypothesis of no rock type effect. Outbreaks were then tabulated by rock type, and Chi-square tests were performed using the outbreak distributions as the observed values, and the stand distributions as the expected values (Ott 1988). All frequency tables were created in ArcView and then exported to Excel worksheets for tabulation and Chi-square testing.

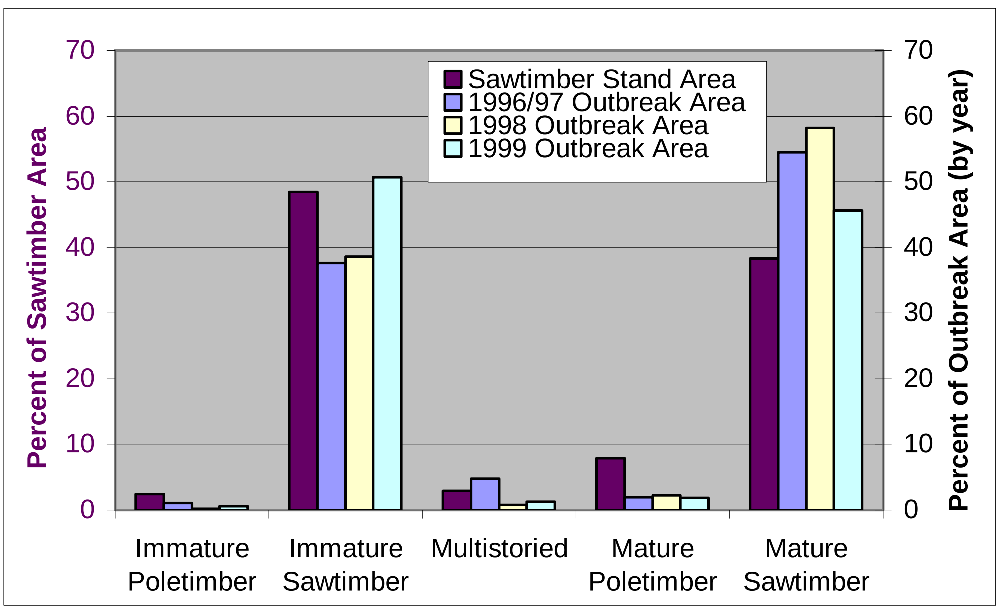
Results and Discussion

Size Class Analysis

As previously stated, only those stands that provided suitable Douglas-fir beetle habitat were included in the analysis. We requested that the Forest Service provide data for only those stands in habitat types likely to contain Douglas-fir, and of those stands, only those which were pole-size or larger. The resultant vegetative cover layer therefore included all stands likely to contain Douglas-fir, by habitat type and size class. Precise definitions of the various size classes is provided in the Appendix, but generally 'sawtimber' stands consisted mostly of trees 9 in diameter at breast height (dbh, measured 4 ½ ft above ground level), while 'poletimber' stands contained mostly trees which were smaller than 9 in dbh. Stand maturity refers to stage of development, such that mature stands were those where the growth stage has nearly reached the full potential of the site, while immature stands are still actively growing. Multistoried stands contain two or more tree size classes and often represent multi-aged stands. The Douglas-fir beetle normally prefers trees 12 in dbh, which likely occur in sawtimber stands, and perhaps in some multistoried stands as well (Hagle et al. 1987). Stand area and yearly outbreak areas by size class were tabulated to detect any preference shifts as beetle populations increased over the study period. The results are shown in Figure 2.

Figure 2 illustrates that most of the analysis area was in mature and immature sawtimber, with 38% and 49% of the stand area in those size classes, respectively. Douglas-fir beetle would most likely attack larger tree size classes and this expectation is confirmed in Figure 2 since most Douglas-fir beetle attacks occurred in larger size classes. In mature sawtimber, the beetle attacks occurred at rates proportionately higher than the amount of stand area in that size class during all years, indicating a beetle preference for mature sawtimber. For the immature sawtimber class, outbreak rates were proportionately lower from 1996 through 1998, but by 1999 the beetle-affected area was proportionately greater than the amount of land area in immature sawtimber. This result probably means that by 1999, the beetle populations had increased to such high levels that the immature sawtimber stands became desirable. A very small percentage of the analysis area was in multistoried stands, and no preferences by the beetles were detected by year in this class. In the poletimber size classes, the proportion of beetle-attacked area was proportionately lower than the amount of Douglas-fir stands in those size classes for all years. Based on this result, we excluded poletimber and multistoried stands from the study, and the remaining analyses were performed only on mature and immature sawtimber stands in the Panhandle National Forest.

Figure 2: Percent of stand area by size class, and percent of outbreak area by size class and year, in north Idaho and northeast Washington.



Geology

In order to detect beetle preferences for stands growing on particular rock types, we first tabulated the total hectares of study stands by rock type. We then tabulated the hectares of outbreaks by rock type, for each year of the study. If there were no preference for stands on particular rock types, then beetle outbreaks would occur in about the same proportion across all rock types. For example, if 20% of the stand area occurs on Prichard rock types, then 20% of the outbreaks in any particular year should also occur on that same rock type. The tabulated results by land area are shown in Table 1. This information is also represented as percentages of the total area for each category in Figure 3.

Table 1. Land area in sawtimber stands and areas of sawtimber stands affected by Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopkins) from 1996 through 1999, by rock type, for the Panhandle National Forests in north Idaho and northeast Washington.

Rock Type	Sawtimber Stands		Affected area 1996-97 (average)		Affected area 1998		Affected area 1999	
	Hectares	*Acres*	Hectares	*Acres*	Hectares	*Acres*	Hectares	*Acres*
Glacial Deposits	50,023	*123,608*	5	*13*	17	*42*	717	*1,771*
Intrusive Rocks	59,299	*146,529*	9	*23*	20	*49*	2,758	*6,814*
Libby formation	7758	*19,171*	0	*0*	0	*0*	213	*526*
Prichard formation	83,340	*205,932*	16	*39*	193	*476*	9,569	*23,644*
Ravalli group, undivided	55,895	*138,117*	1	*3*	4	*9*	6,710	*16,581*
Striped Peak formation	42,063	*103,938*	2	*6*	4	*11*	1,502	*3,713*
Wallace formation	131,944	*326,035*	16	*39*	227	*561*	9,398	*23,222*
Other Rocks	14,519	*35,877*	1	*2*	15	*37*	227	*560*
TOTAL AREA	444,843	*1,099,206*	51	*125*	479	*1,185*	31,093	*76,830*

Figure 3: Percent of land area in sawtimber stands, and percent of Douglas-fir beetle outbreak areas by rock type and year, in north Idaho and northeast Washington.

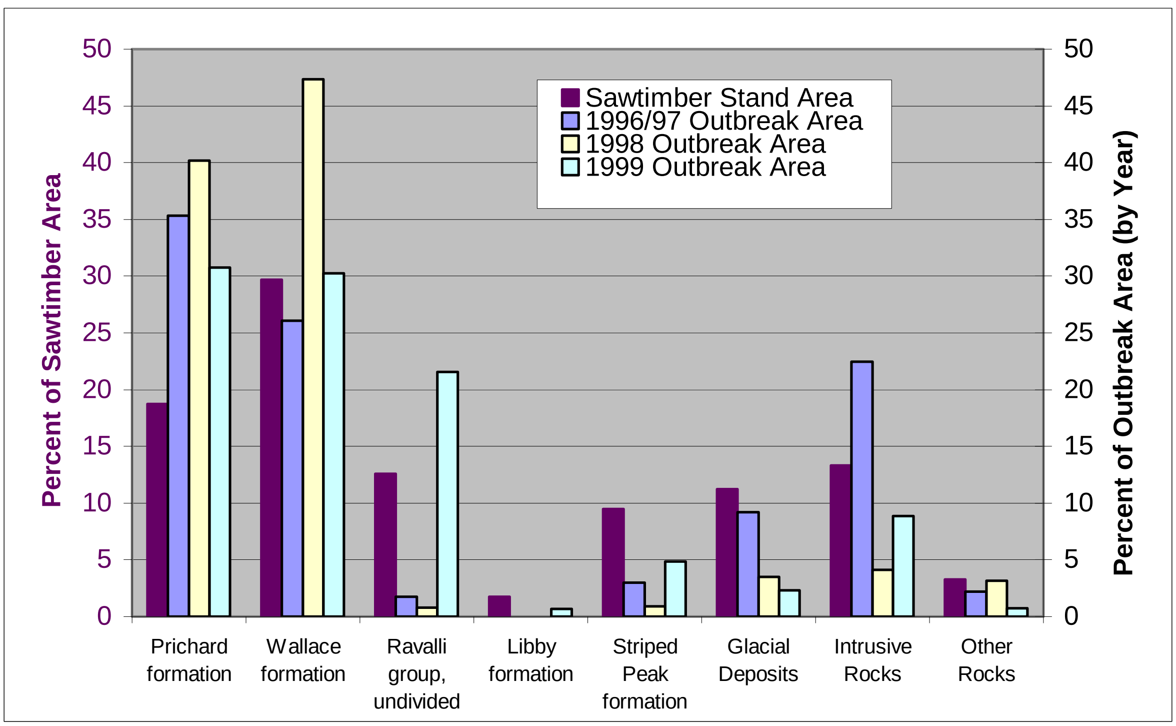


Figure 3 shows that for all years, the Prichard formation was heavily affected by Douglas-fir beetle relative to the amount of stand area on Prichard. Wallace showed high outbreak rates for 1998 and 1999, while the Ravalli Group was heavily affected in 1999. Libby, Striped Peak and glacial tills all showed beetle outbreak rates lower than expected. Intrusive rocks had high outbreak rates in 1997. Stands in the 'Other Rocks' category were not heavily affected in any year. A Chi-square (χ^2) test on these values was performed using the formula:

$$\chi^2 = \Sigma((E - O)^2/E)$$

where: E= expected value and O=observed value. Results of the Chi-square analysis are shown in Table 2.

Table 2. Chi-square (χ^2) test for differences between expected values (percent stand area in each rock type) and observed values (percent outbreak area on each rock type), by year.

	1996-97 average outbreaks	1998 outbreaks	1999 outbreaks
Prichard formation	14.71	24.61	7.74
Wallace formation	0.43	10.54	0.01
Ravalli group, undivided	9.34	11.05	6.47
Libby formation	1.74	1.74	0.64
Striped Peak formation	4.42	7.74	2.26
Glacial Deposits	0.37	5.32	7.11
Intrusive Rocks	6.25	6.37	1.49
Other Rocks	0.35	0.00	1.97
χ^2	**37.62**	**67.39**	**27.69**
test statistic df=7, α=.05	14.07	14.07	14.07

The Chi-square test indicated that overall, the beetle outbreak areas were not distributed in proportion to the amount of stand area on the various rock types. This was true for all three time periods studied. Among the individual cells, both the 1996-97 and the 1998 outbreaks on Prichard were significantly greater than the amount of stand area on this rock type. Outbreaks on other rocks showed tendencies towards disproportionate distribution, though these tendencies were not significant in the Chi-square test. Individual rock categories are discussed below.

Prichard Formation

Figure 3 indicates that approximately 19% of the sawtimber stands in the Panhandle region occurred on the Prichard formation. In contrast, the Douglas-fir beetle infestations in all years occurred in much higher proportions on Prichard stands than on other rock types. In 1996-97, which were not considered outbreak years, an average of 35% of the area affected by Douglas-fir beetle occurred on the Prichard. In 1998, the first serious outbreak year, 40% of the affected areas were on Prichard. The Chi-square test indicated that the 1996-97 and the 1998 outbreaks on Prichard were both significantly higher than the proportion of stands on Prichard. In 1999, the year of the most widespread outbreaks, 30% of the affected area occurred on Prichard. This value was not significant in the Chi-square test, however it was still proportionately higher compared to the total area of sawtimber-sized stands on Prichard. We believe that the beetle populations had built up so much in the preceding years that the beetles were able to attack stands on previously less susceptible rock types.

Wallace Formation

The results in Figure 3 and Table 2 show that the Wallace formation was also affected at a rate disproportionate to the amount of Douglas-fir stand area on that rock type. While the non-epidemic 1996-97 outbreaks were low compared to the amount of stand area on Wallace, in 1998, 47 % of the beetle outbreak areas occurred on the 29% of stands located on Wallace formation rocks. Although the Chi-square analysis indicated that this was not a statistically significant overall difference, we decided to look at individual members of the Wallace formation in more detail. A summary of the land area in sawtimber and the beetle outbreak areas for members of the Wallace formation is shown in Table 3. Figure 4 represents these values as percentages of total area, for Wallace formation stands only.

Table 3. Land area in sawtimber stands on Wallace, and outbreak areas from 1996 through 1999, for members of the Wallace formation, for the Panhandle National Forests in north Idaho and northeast Washington.

Rock Type	Sawtimber Stands		Affected area 1996-97 (average)		Affected area 1998		Affected area 1999	
	Hectares	*Acres*	Hectares	*Acres*	Hectares	*Acres*	Hectares	*Acres*
Wallace, lower	79,296	*195,942*	13	*32*	185	*456*	6,041	*14,926*
Wallace, undivided	7,922	*19,576*	0	*1*	4	*10*	564	*1,394*
Wallace, upper	44,726	*110,517*	2	*6*	38	*95*	2,793	*6,902*
TOTAL AREA	131,944	*326,035*	16	*39*	227	*561*	9,398	*23,222*

Figure 4: Percent of stand area on Wallace Formation and percent of Douglas-fir beetle outbreaks on Wallace Formation stands by year, in north Idaho and northeast Washington.

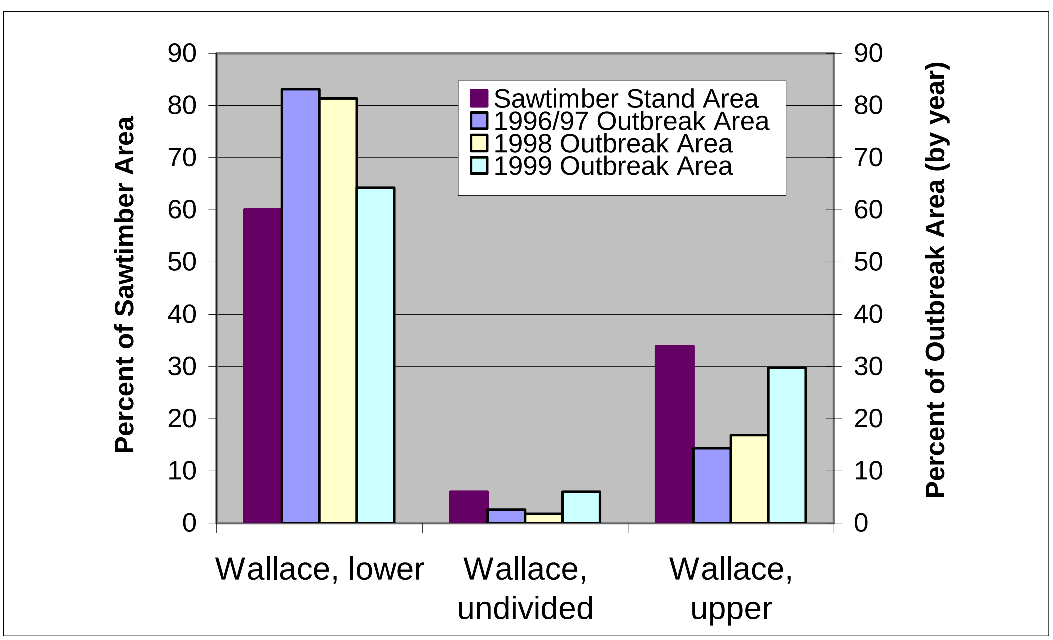


Figure 4 illustrates that 60% of the sawtimber stands on the Wallace formation occurred on the lower member of the Wallace. Approximately 34% of the Wallace sawtimber stands were on the upper Wallace, while the remaining 6% occurred on undivided Wallace formation, which means that these rocks were not distinguishable as upper or lower. While the majority of sawtimber did occur on lower Wallace, an even larger proportion of the Douglas-fir beetle outbreaks occurred on the lower Wallace in all years. During 1996-97 and 1998, 83% and 81% respectively of the outbreak areas occurred on lower Wallace. Conversely, only 14% and 17% of the outbreaks during the same years occurred on the upper Wallace stands. This suggests that the beetles preferred trees on the lower Wallace to stands on the upper Wallace. This conclusion was supported by the Chi-square analysis, shown in Table 4.

Table 4. **Chi-square test on Wallace Formation.** Chi-square (χ^2) test for differences between expected values (percent stand area on Wallace) and observed values (percent outbreak area on Wallace), by year.

	1996-97 average outbreaks	1998 outbreaks	1999 outbreaks
Wallace, lower	8.807	7.536	0.291
Wallace, undivided	1.959	2.993	0.000
Wallace, upper	11.305	8.568	0.514
χ^2	**22.071**	**19.097**	**0.805**
test statistic df=2, α=.05	5.991	5.991	5.991

The Chi-square test indicated that during 1996-97 and 1998, beetle outbreaks on the Wallace formation were significantly different from the distribution of stands on Wallace. Examination of individual cells showed an interesting phenomenon in terms of the lower versus the upper Wallace formation. On the lower Wallace, the proportion of 1996-97 and 1998 outbreaks were significantly greater than the proportion of stand area on lower Wallace. This indicated a preference for stands on lower Wallace. Furthermore, the occurrence of outbreaks on the upper Wallace during those same years was significantly lower than the proportion of stand area on upper Wallace, indicating that these stands were less desirable to the beetles. In all cases, the 1999 affected areas were not significantly different from the expected distributions. We believe that by 1999 the beetle populations were so large that preference was no longer being shown for stands on particular rock types.

Intrusive Rocks

Figure 3 also showed that sawtimber stands on intrusive rocks suffered a disproportionate amount of Douglas-fir beetle attacks during 1996-97. While total acreages during pre-outbreak years were relatively small, we decided to look at the intrusives in more detail. The intrusives category encompassed 55 individual rock units. Most of these rock units represented local plutons or other granitic structures (dikes, sills, etc.). By examining the percentages of sawtimber stands on each unit and comparing the beetle-affected areas for the three time periods in the same units, we determined that most of the disproportionate attacks were occurring on three rock units. These were the Galena Point Granodiorite, a pluton southwest of Priest Lake in north Idaho (Kgp); diabase sills and dikes associated with the Prichard formation in the Sandpoint and Bonner's Ferry districts (Ymi); and gabbroic and dioritic sills in the St. Joe district

(Tkgb). Land areas of sawtimber stands and beetle-affected areas on intrusive rocks in the analysis area are provided in Table 5 and Figure 5.

Table 5. Land area in sawtimber stands on intrusive rocks, and outbreak areas from 1996 through 1999 on intrusive rocks, north Idaho and northeast Washington.

Rock Type	Sawtimber Stands		Affected area 1996-97 (average)		Affected area 1998		Affected area 1999	
	Hectares	*Acres*	Hectares	*Acres*	Hectares	*Acres*	Hectares	*Acres*
Kgp	5,889	*14,552*	1	*2*	1	*2*	1,184	*2,925*
TKgb	1,190	*2,939*	1	*3*	8	*20*	42	*104*
Ymi	7,511	*18,558*	4	*9*	4	*10*	537	*1,328*
Other intrusives	44,710	*110,480*	3	*8*	7	*17*	994	*2,457*
TOTAL AREA	59,299	*146,529*	9	*23*	20	*49*	2,758	*6,814*

Figure 4: Percent of land area in sawtimber and percent of Douglas-fir beetle outbreak areas from 1996 through 1999 on intrusive rocks, in north Idaho and northeast Washington. Kgp is Galena Point granodiorite, Tkgp are gabbroic and dioritic sills, Ymi are diabase sills and dikes associated with the Prichard formation.

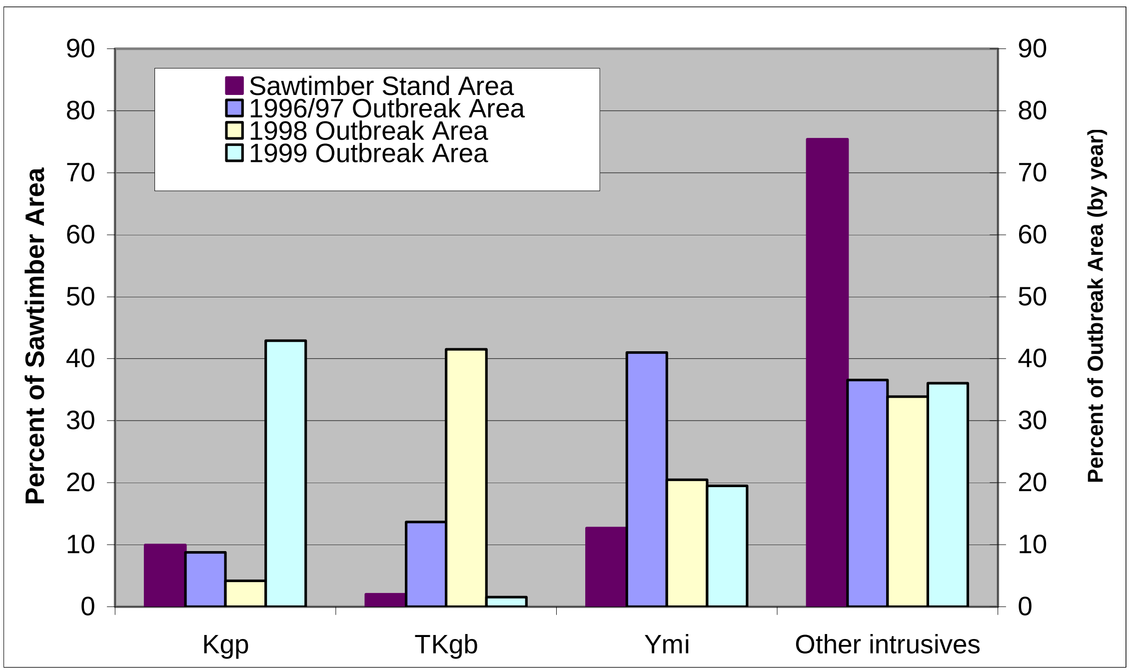


Figure 5 shows that in 1996-97, both of the units representing dikes and sills (Tkgb and Ymi) had high proportions of outbreaks relative to the amount of stand area on those rock types. While 13% of the outbreak area in 1996-97 occurred on Tkgb, 41% of the outbreak area occurred on Ymi. The stand areas occurring on these types were 2% and 12%, respectively. A Chi-square analysis was performed on these four intrusive rock categories, and results are shown in Table 5.

Table 5. Chi-square (χ^2) test for differences between expected values (percent stand area on intrusive rocks) and observed values (percent outbreak area on intrusive rocks), by year.

	1996-97 average outbreaks	1998 outbreaks	1999 outbreaks
Kgp	0.135	3.363	109.652
TKgb	67.949	778.124	0.116
Ymi	63.290	4.804	3.669
Other intrusives	19.999	22.874	20.519
χ^2	151.373	809.165	133.957
test statistic df=3, α=.05	7.815	7.815	7.815

The Chi-square test shows that the 1996-97 outbreaks on both TKgb and Ymi were significantly greater than the corresponding proportion of stand area on those rock types. The Tkgb unit represents gabbroic and dioritic sills, while the Ymi represents diabase sills and dikes associated with the Prichard formation. All of these rocks are likely to contain high amounts of calcium, iron and/or magnesium, and relatively low amounts of potassium. They are also coarse-grained rocks, and likely to weather to coarse, gravelly soils with poor water-holding capacity and low CEC. So for these reasons, we might expect these rocks to be 'bad rocks' from a nutrient standpoint. However another possible explanation is related to the surrounding rocks. The Ymi unit is associated with and surrounded by Prichard formation rocks, and likewise lower Wallace surrounds the Tkgb formation. See Map 3, Figures (a) and (b) in the appendix for a closer view of the geology surrounding these units. The stands on these rocks may simply have been victims of spatial circumstance, as they were in direct proximity to stands that were highly likely to harbor Douglas-fir beetle populations.

The third intrusive rock, Kgp, was a granodiorite. Ten percent of all stands on intrusive rocks occurred on the Kgp rock type, and during 1996-97 and 1998, beetle outbreaks were proportionately low on this rock. However in 1999, 43% of the outbreaks on intrusive rocks were on this unit. The Chi-square test indicated that this was significantly greater than the proportion of stand areas on Kgp. Normally we expect granodiorites to be 'medium' rocks, particularly if they are biotite-bearing as this one is. And beetle outbreaks at these high rates did not hit most other granodiorite or biotite-bearing rocks in the study area, even during the peak outbreak in 1999. However, examination of the digital geology indicated that this rock is surrounded by Prichard formation (Map 3, Figure (a)). We believe that the high attack rates on this rock type occurred because beetle populations built up in the surrounding Prichard-based stands, and then subsequently attacked stands on the Galena Point granodiorite pluton.

Finally, the Chi-square analysis indicated that with these three rock types separated from the rest of the intrusive rocks, the remaining 75% of all sawtimber stands on intrusive rocks had significantly lower outbreaks during all years in the study period. This indicated that in normal years, stands on intrusive rocks that were not surrounded by Prichard or lower Wallace rocks were not likely to be targeted by Douglas-fir beetles. Even during the epidemic outbreaks in 1999, these other intrusives were attacked at significantly lower rates than expected compared to the amount of stand area they contain.

Other Belt Rocks

Among the other Belt rocks, the Libby and Striped Peak formations showed low beetle attack frequency. These rocks hosted 2% and 9%, respectively, of the stands studied. Douglas-fir beetle outbreaks affected these stands at very low rates, with 1% and 4% of the epidemic 1999 outbreaks occurring on these rocks. These differences were not significant in the Chi-square analysis. The Ravalli group, which occurred beneath 13% of the study area, showed very few outbreaks during 1996-97 and 1998 relative to the rock land area. However in 1999, outbreaks on the Ravalli group greatly increased to 22% of all outbreaks for that year, though the Chi-square test indicated that this was not statistically significant. As the Ravalli group is composed of three formations (Burke, St. Regis, Revett), we did examine these formations individually. We did not see any particular patterns or trends among the formations, though the Burke did show a higher percentage of outbreaks in both 1998 and 1999 as compared to the St. Regis, Revett and undivided Ravalli rock units. Examination of the geology and outbreak maps in GIS indicated that many of the Ravalli stands that were affected in 1999 occurred adjacent to Prichard stands. We believe that the Ravalli stands were attacked more heavily in 1999 due to the buildup of beetle populations in adjacent Prichard rocks during previous years.

Glacial Deposits and Other Rocks

Approximately 11% of the stands studied occurred on glacial deposits. Though the differences between stand occurrence and outbreak occurrences on glacial deposits were not significant in the Chi-square analysis, we did see a steady decrease in the proportion of outbreaks on glacial deposits during the entire study period. While the outbreaks in 1996-97 were proportional to the amount of stand area on glacial deposits, when outbreaks increased during 1998 and 1999, the beetles showed a marked preference towards stands on other rocks. This would indicate that stands on glacial till were undesirable to the Douglas-fir beetles, even when outbreaks increased to epidemic proportions and they appeared to be attacking previously less desirable stands.

Other rocks occurred under about 3% of the study area. Rocks in this category included carbonate rocks, metamorphic rocks, other (non-glacial) deposits, extrusive rocks and sedimentary rocks. While these rocks may also support stands that respond more or less favorably to beetle attacks, they were uncommon in the study area and a more detailed analysis was not possible. In the overall study area, rocks in this category did seem to be affected by beetles at rates that were about proportional to the amount of stand area on those rocks. There were no significant differences during any of the years studied.

Conclusions

Most of the Douglas-fir beetle attacks on the Panhandle National Forests occurred in sawtimber-sized stands. While the mature sawtimber was initially attacked at high rates, once populations built up in 1996-97 and 1998, immature sawtimber was also attacked.

Results of the geologic analysis supported the hypothesis that Douglas-fir stands on the Prichard formation were more likely to be attacked by Douglas-fir beetle than stands on other rock types. We also found that stands on the lower Wallace formation were more susceptible to beetle attacks. Among the intrusive rocks, stands on three geologic units (Galena Point granodiorite, gabbroic and dioritic sills, and diabase sills and dikes associated with the Prichard formation) showed higher susceptibility to beetles than stands on other intrusives. The dikes and sills in particular had characteristics that might lead us to classify them as bad rocks from a nutrient perspective. However, in all cases, the intrusive units were in close proximity with Prichard and/or lower Wallace, leading us to believe that beetle populations from those neighboring stands attacked these stands. Beetles affected stands on other intrusive rocks at much lower rates than proportional to their occurrence. Similarly, stands on glacial deposits appeared less desirable to beetles, as during all years of the study they were attacked at rates low in proportion to their occurrence. Stands on the Striped Peak and Libby formations also showed low outbreak rates. Stands on the Ravalli group did show high rates of attack in 1999, and closer inspection of the formations comprising the Ravalli group indicated that stands on the Burke formation showed high rates of attack in 1998 and 1999. However since these stands were in close proximity to Prichard stands, it is possible that beetles from the neighboring stands caused the outbreaks on Burke.

On all rock types, proportions of outbreaks in 1999 were not significantly different from the proportions of stand areas on those rock types. We believe that by 1999 the beetle populations were so great that they attacked nearly everywhere, including stands previously less desirable to them. Thus, the 1999 distributions of beetle-affected areas began to more closely approximate the actual stand areas on different rock types.

Management Implications

The Douglas-fir beetles appeared to prefer stands containing mostly mature sawtimber that were growing on Prichard or lower Wallace rock types. Since so many of the stands on the Panhandle which we identified as likely to contain Douglas-fir were in mature and immature sawtimber, AND so much of the area is on Prichard and lower Wallace rocks, the region was heavily predisposed to the outbreaks which occurred in the late 1990's. One possible strategy to avoid future outbreaks of this sort might be to intersperse some younger or multistoried stands throughout the area. A shift in species composition away from Douglas-fir might be appropriate in some circumstances. Douglas-fir will encroach on ponderosa pine stands in the absence of fire, so prescribed burning or other means of removal of the Douglas-fir on drier habitat types might be warranted. We recommend managing for species other than Douglas-fir on Prichard and lower Wallace rock types.

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APPENDIX: STAND SIZE CLASS DEFINITIONS FOR STANDS ON PANHANDLE NATIONAL FORESTS, REGION 1, NORTH IDAHO AND NORTHEAST WASHINGTON

R1 AMENDMENT 2409.2le-96-1 | 2409.2le,141.21-141.39
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141.32 - **Stand Size Class**. SIZE_CLASS_CODE (Mandatory field.) (4-character . alpha code)

A classification of forest lands based on live trees in the stockable portion of the stand. The basic stand size classification can be further defined using descriptive adjectives as shown under the acceptable code list.

Sawtimber Stands. Stands at least 10 percent stocked with growing stock trees 5 inches diameter breast height (dbh) and larger, in which the stocking of trees 9 inches dbh and larger is at least equal to the stocking of trees 5 to 8.9 inches dbh.

Poletimber Stands. Stands at least 10 percent stocked with growing stock trees 5 inches dbh and larger, in which the stocking of trees 5 to 8.9 inches dbh exceeds the stocking of trees 9 inches dbh and larger.

Seedling – Sapling Stands. Stands at least 10 percent stocked with growing stock trees of all sizes, in which the stand size class is not poletimber or sawtimber. Saplings are generally 1.0 to 4.9 inches dbh and seedlings are generally less than 1.0 inch dbh.

Nonstocked. Forest land less than 10 percent stocked with growing stock trees.

Code	Description
SAWT	Sawtimber
MHRS	Mature High Risk
MLRS	Mature Low Risk
IMSA	Immature
POLE	Poletimber
MHRP	Mature High Risk
MLRP	Mature Low Risk
IPOL	Immature Pole
SAPL	Saplings
OSAP	Overtopped with Brush
SEED	Seedlings
OSEE	Overtopped with Brush
MULS	Multisized - 2 age classes.
MULT	Multisized - 3 or more age classes.
NONS	Nonstocked
HGHB	High Brush Occupying Site
LOWB	Low Brush Occupying Site
SOD	Sod Occupying Site
DUFF	Duff Occupying Site
DEB	Debris Occupying Site
BARE	Bare Soil
NA	Not Applicable - Use when forest type is nonforest.

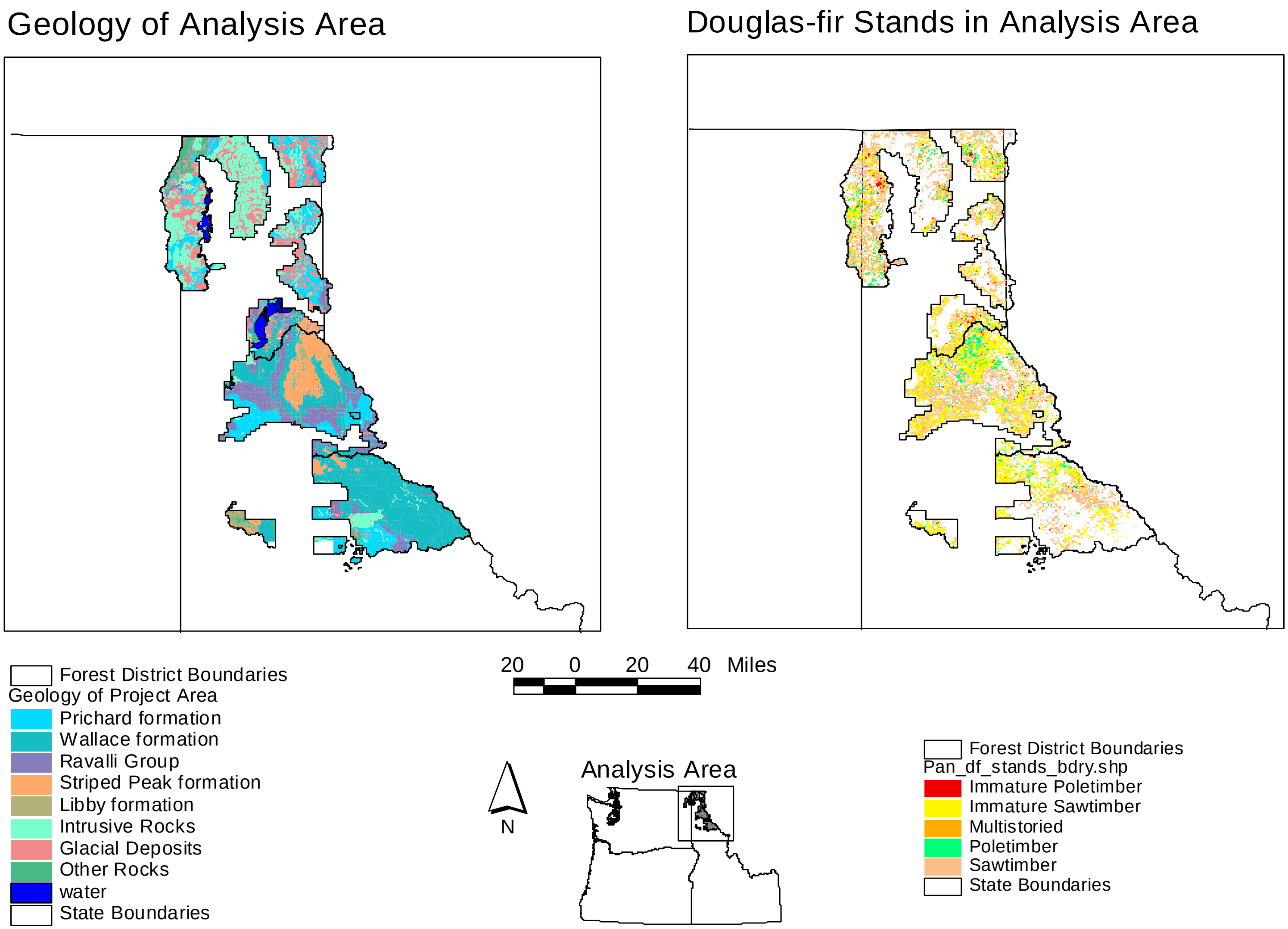
Stocking is the degree of occupancy of land by trees measured by basal area and/or number of trees.

Mature is defined as the stage at -which an even-aged stand has attained full development, particularly height and stand density. This usually occurs when a stand reaches 95 percent of culmination mean annual increment (CMAI).

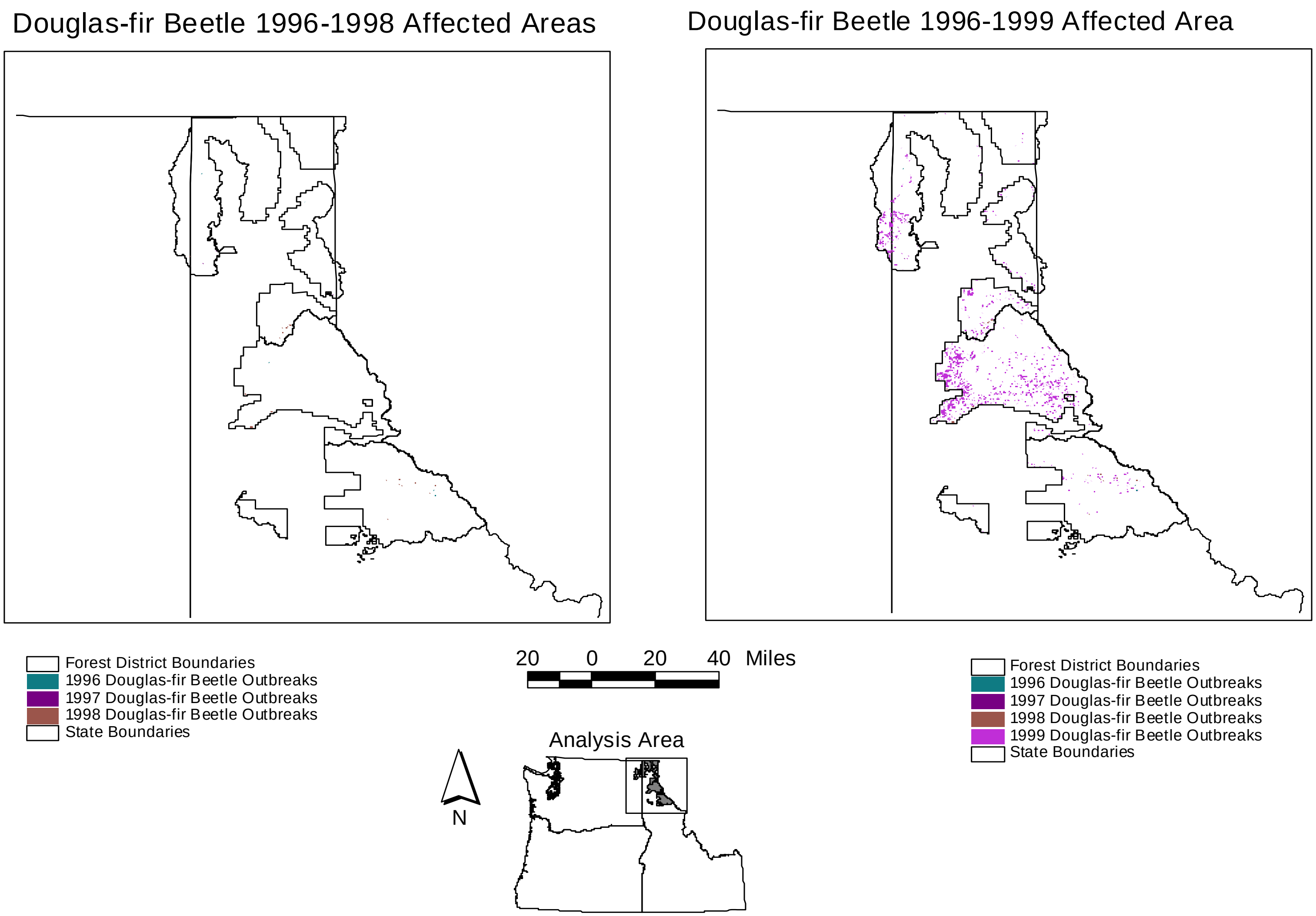
High risk is defined as generally the point in time when at least 40 percent of the stand, as measured by basal area, is affected by damaging disease or insects.

Multisized stands contain more than one age class (usually at least three age classes) intermingled intimately on the same area, and the difference in age between the oldest and youngest trees exceeds 20 percent of the length of the rotation. Use code MULS for stands containing two age classes. Use code MULT for stands containing at least three age classes.

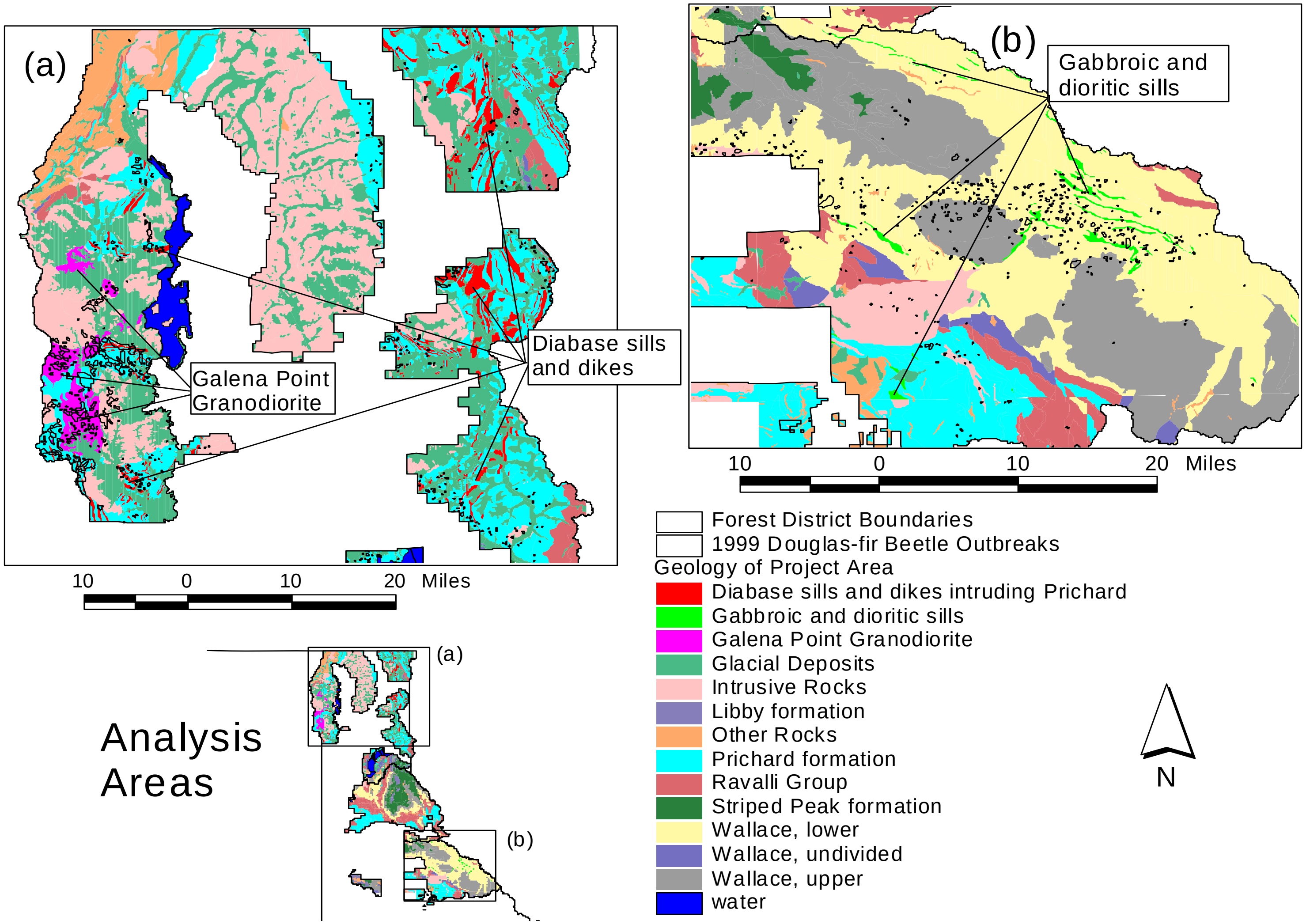
Stand size class year of origin, 2111, should be entered when the stand size class is either MULS or MULT.



Map Sheet 1: Geology of Panhandle administrative districts, and distribution of Douglas-fir stands within the districts.



Map Sheet 2: Distribution of new Douglas-fir beetle outbreaks between 1996 and 1999 on the Panhandle National Forests.



Map Sheet 3. Closeup views of three intrusive units which showed high susceptibility to attack by Douglas-fir beetle in north Idaho and northeastern Washington. Beetle outbreak area for 1999 is also shown.