Chapter 5
Do bark beetles kill trees at Itasca State Park?

5.1 INTRODUCTION

Forest entomologists are mixed in their opinions of whether or not *Ips* bark beetles are a significant source of mortality for pine trees in the Great Lakes region. Most dying trees are infested by *Ips*, but this could be either because *Ips* cause the death of the tree or simply because *Ips* are efficient at locating and colonizing trees that are dying for other reasons. It has proven surprisingly difficult to distinguish between these two very different scenarios about the role of *Ips* in forest ecosystems. Which of these scenarios is true has important implications for forest management at Itasca State Park. If *Ips* infestations are restricted to trees that are destined to die with or without the presence of bark beetles, then the abundance of *Ips* has no consequences for the demography of pine forests at Itasca, and there is no compelling reason to monitor bark beetle populations, control them, or make any management decisions based upon the abundance of bark beetles. Alternatively, if *Ips* commonly attack and kill trees that are otherwise healthy, then bark beetles may deserve careful consideration in forest management decisions. This component of our research addressed the question of whether or not bark beetles kill trees at Itasca State Park. Our technical approach was to survey the population of red pines at Itasca for trees that were infested by bark beetles, monitor the fate of those trees, and evaluate whether the infested trees were in declining physiological condition prior to being infested by beetles. A variation on the central hypothesis was suggested by our observations in June of 1998 that many red pine trees exposed to the prescribed fires in April 1998 were under attack by bark beetles. This suggested the possibility that although *Ips* infestations may normally be restricted to trees that are otherwise dying, fire scorching may trigger beetle attacks in trees that are otherwise healthy. To test this possibility, we attempted to locate approximately equal numbers of infested trees for study that were and were not exposed to the prescribed fires of 1998.

5.2 METHODS

In September 1998, we spent three days searching for, and examining, live mature red pine trees that were presently under attack by bark beetles. Our search was conducted by slowly driving all of the roads within Itasca State Park, and examining the crowns of red pines that were visible from the road, and well lit by the sun so that we could discern color patterns within the crown. Thus our surveys only included a small fraction of the old growth red pine stands within the park (probably less than 5%). Trees with crowns exhibiting symptoms of beetle attack (branches with red, dying needles, intermixed with healthy branches) were examined visually at ground level and with binoculars to the crown for the presence of bark beetles. Infested trees contained bark beetles within the inner bark or had bark beetle galleries and exit holes; most also had extensive recent bark punctures from woodpecker foraging, and often had fungal fruiting bodies growing out of the infested regions of the bark. Infested trees were marked, mapped, and photographed. To evaluate the growth history of infested trees, we extracted tree cores from each infested tree and from the nearest similarly sized red pine. Char heights were recorded for any infested trees that were exposed to the prescribed burn in spring 1998. Cores were also taken from 120 other old growth red pine trees (10 codominant trees from each of 12 sites; see Chapter 2) to allow comparisons of growth in infested trees with growth patterns of trees in the park at large. Analyses of mounted and sanded cores were done using WinDENDRO software (Regent, V 6.0.4) to determine yearly growth.

Annual radial growth years of each infested tree was graphically compared to its nearby uninfested control tree for the 60 years of growth ending immediately prior to the beetle infestation. We tested the statistical hypotheses that infested trees were experiencing declining growth during the last 5 - 10 years relative to their uninfested controls, and that this decline was less evident among infested trees exposed to fire, by first calculating a difference between each pair of trees for each year of the growth record, which was standardized for historical differences in growth rates between tree pairs.

$$GD_{TY} = (GI_{TY}\text{-}GC_{TY}) - (GI_{35\text{-}84}\text{-}GC_{35\text{-}84}) \qquad \textbf{Eq. 5.1}$$

where GD_{TY} equals the standardized growth for infested tree T in year Y, GI_{TY} is the radial growth for infested tree T in year Y, GC_{TY} is the radial growth for control tree T in year Y, $GI_{35\text{-}84}$ is the average radial growth of all infested trees from 1935-1984 and $GC_{35\text{-}83}$ is the average radial growth of all control trees from 1935-1984. Equation 5.1 has the property that the average GD_{TY} across all trees equals 0 for the period from 1935 to 1984. 1935 to 1984 was chosen somewhat arbitrarily because it provided a 50 year estimate of tree growth that was likely to pre-date the start of physiological deterioration under most scenarios of growth decline that could predispose a tree to beetle infestations in 1998. Thus, under the hypothesis that beetles are preying on declining trees that are destined to die soon anyway, we would expect that GD_{TY} would tend to become increasingly negative during the 5-10 years prior to beetle infestation (as infested trees declined in their growth relative to the uninfested control trees). Pathogens, root dieback, senescence, and shifts in the water table are mechanisms that could produce a pattern of physiological decline over this time scale that lead to imminent tree death with or without the involvement of bark beetles. All of these mechanisms, and most others that we can imagine, would usually be evident as marked decreases in tree growth during the years prior to death.

A related hypothesis, although the implications are different for forest demography, is that bark beetles preferentially attack trees that are chronically slow growing. We tested this hypothesis by comparing the average growth rate of infested and uninfested trees during the pre-infestion time period from 1935-1984.

In September 1999, we revisited the infested trees that were marked in 1998, evaluated their condition, and photographed them. At this time, we also recorded the number of newly infested trees that we observed while searching approximately the same area as in 1998.

5.3 RESULTS AND DISCUSSION

Symptoms of infested trees. In 1998, we located 41 trees that were either currently infested by bark beetles or had been infested during the previous months. Trees that were infested by bark beetles were often evident at a distance from examination of their crown. Infested trees were characterized by the presence of branches with red, dying needles, intermixed with healthy branches (Fig. 5.1, left and middle). The dying branches are those whose vascular connection has been interrupted by beetles girdling the inner bark of part of the trunk. Upon closer examination, infested trees contained bark beetles or bark beetle galleries within the inner bark of the lower bole, had beetle frass and sawdust sprinkled around the base of the tree, and/or had bark beetle exit holes farther up the bole of the tree that were evident with binoculars; most infested trees also had extensive recent bark punctures from woodpecker foraging (usually Black-backed Three-toed Woodpeckers, *Picoides arcticus*, which appears to specialize in foraging on trees recently infested with bark beetles) and often had fungal fruiting bodies growing out of the infested regions of the bark. Fig. 5.1, right, shows a tree with a fading crown that was not infested by beetles. In this case, the crown deterioration was quite uniform, without the mosaic appearance of dying and healthy branches that is often produced by beetle infestations; this tree was probably afflicted with Diplodia blight (*Sphaeropsis sapinea*, = *S. ellisii* = *Diplodia pinea*.). Our surveys revealed only one or two mature red pine that appeared likely to die as result of Diplodia blight or any other pathogen. Our impression was that pathogens are a minor cause of mortality in mature trees compared to bark beetles.

All of the infested trees were of codominant crown size class (none were intermediate or suppressed). Infested trees were scattered throughout the areas of pine forest that we searched, although there were some areas where infestations were concentrated (Fig. 5.2). Thirteen of the infested trees were within the area burned in April 1998; char heights on these trees ranged from 0.2 to 5 m (mean ± SE = 1.83 ± 0.10 m). With more time, we could have certainly found many more infested trees, especially within the burned area, where many

For images see
http://www.dartmouth.edu/~mpayres/grants/Itasca/photos.htm

Fig. 5.1. Mature red pines at Itasca State Park that were under attack by *Ips* bark beetles during 1998 (left and middle). Note the presence of branches with red, dying needles intermixed with healthy branches. Contrast with the uniformly thinning crown of the tree on the right, which was not infested with bark beetles (possibly infested with Diplodia blight). The tree on the left, 704 in Table 5.1, was dead in 1999. The middle tree, 720 in Table 5.1, was sustaining continued attacks in 1999.

trees were attacked by bark beetles within the scorched area of the lower bole (see Chapter 6).

It was not always possible to identify the beetle species with certainty because often the infested areas of the bole were out of reach many meters above ground. However, it appeared that *Ips* spp. were the dominant bark beetles in the majority of infested trees. We found *Ips pini*, *I. grandicollis*, and *I. perroti* infesting live trees, suggesting that all three *Ips* species are sufficiently aggressive to impact tree survival (although the only *I. perroti* specimens were from fire-damaged trees). In many cases, we found two or more species of *Ips* intermingled within the same tree, suggesting that they may cooperate in mass attacks (and implying that increases in the abundance of one *Ips* species may sometimes benefit the reproductive success of other *Ips* species). The other bark beetles that we found infesting live red pines at Itasca were: *Dendroctonus valens* (common), and *Polygraphus rufipennis*, *Trypodendron lineatum*, and *Xyleborus dispar* (occasional). *D. valens* probably contributes to early attacks on many trees. The latter three species appeared to be secondary colonizers that generally depend upon the more aggressive species to first kill the host tree.

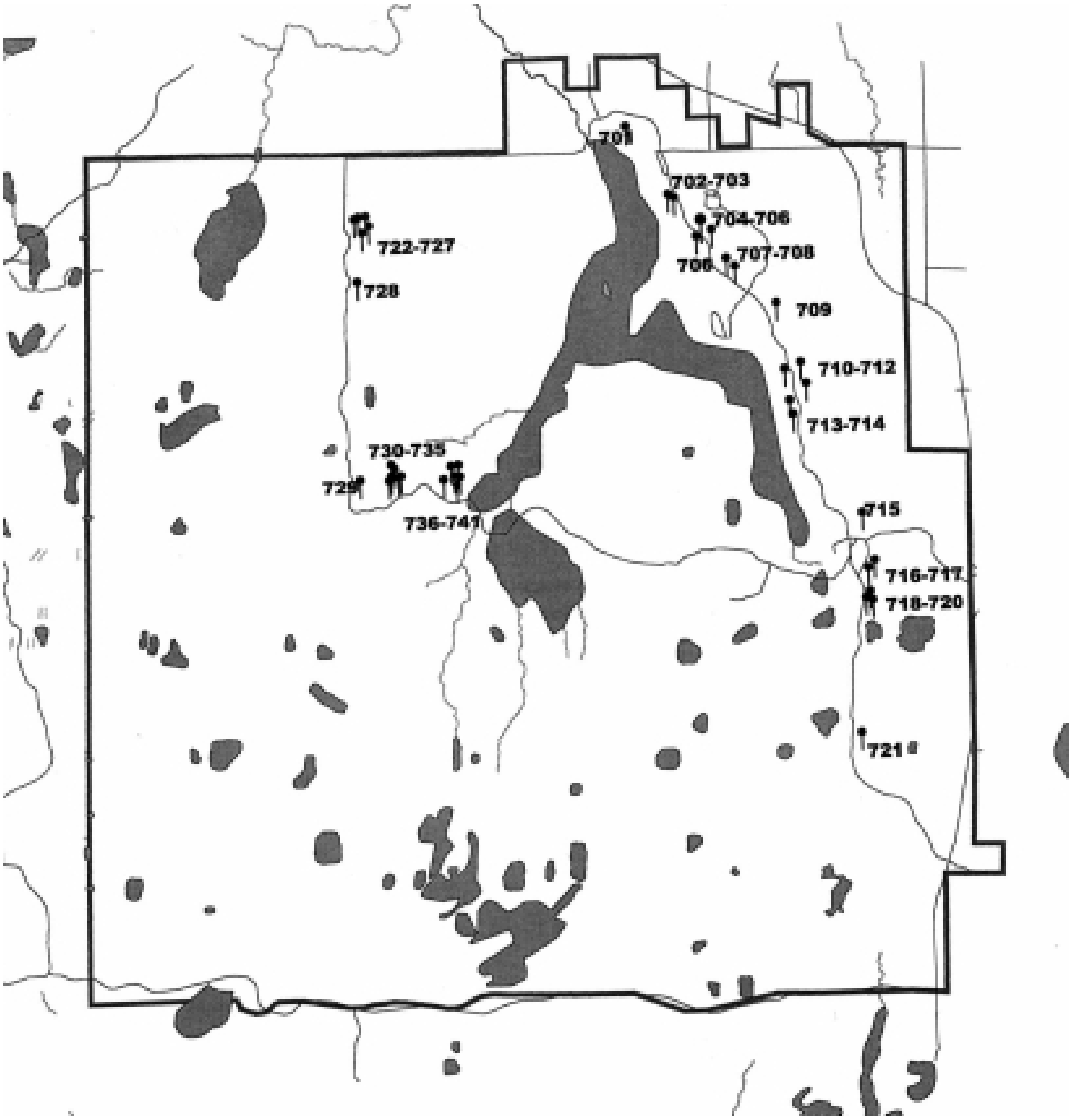

Fig. 5.2. Location of beetle-infested red pines that were marked and measured in 1998.

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Fig. 5.3. Red pines attacked by bark beetles at Itasca State Park. Photos are of the same trees taken in Setember 1998 (left) and September 1999 (right). Upper tree (713 in Table 5.1) was reduced to about 10% of its live crown by 1999, and will probably be dead by September 2000. Lower tree (724 in Table 5.1) sustained charring to 8 m on the trunk and was colonized within the scorched area by *Ips pini* during 1998. Copious resin flow restricted damage (see Chapter 6), but the tree was sustaining additional attacks in 1999. This tree may survive the attacks, but has been permanently girdled on a portion of the lower trunk, will develop a cat-faced scar if it survives long enough, and will more be susceptible to future fires (because of the loss of insulating bark and because the white pine next to it, which succumbed to the fire and subsequent attacks by bark beetles, will increase fuel loads during the next fire (Figs. 6.6 - 6.8).

Fate of infested trees. Of 41 mature red pines that were infested with beetles during 1998, 21 were dead by the end of the next growing season or were clearly going to be dead by the next year (Table 5.1). Of these, 18 appeared to have been killed by the beetles (Fig. 5.1) and three probably would have died from the fire damage alone. Of the 17 trees that were still alive, 6 of them were sustaining continuing beetle attacks in 1999, and 11 were apparently free of additional beetle attacks. In our judgment, some of the trees that were alive and no longer sustaining beetle attacks could survive for decades longer. However, all attacked trees sustained irrepairable damage to their vascular system, lost significant portions of their crown that had been supported by the damaged vascular tissue, and were in the process of losing portions of their bark, making them more vulnerable to pathogens, fire, windstorms, and future insect attacks (Fig. 5.3). Thus, beetle infestations led to rapid tree mortality in about 50% of the trees and increased the annual probability of mortality for the remainder.

In the process of revisiting infested trees that were marked in 1998, we identified 39 trees that became infested during 1999 - comparable to the 41 trees that we found in 1998. As in 1998, the newly infested trees were scattered throughout the park, but there were two notable concentrations of growing damage. In the vicinity of infested trees #707 and 708 (see Fig. 5.2), there were 11 mature red pines (out of a total of 15 in the immediate area) that were either recently dead or currently under insect attack. Examination of the main roots and lower boles of several of these currently infested trees showed no evidence of root pathogens or any problems with the root system. Bark beetles were the only apparent cause for tree mortality in this stand. (This site is immediately east of the park road at the sign “Douglas Lake Lodge, 3 miles”). The other obvious hot spot for beetle infestations was in the vicinity of infested trees #730-735 (see Fig. 5.2), which coincides with the red pine phytochemistry site #2, and is located just north of the park road, just beyond the advance sign for the largest white pine. Of approximately 200 trees at this site, there were 6 infested trees in 1998, seven more that became infested during 1999, and three more that were recently dead. There was no obvious cause for tree mortality at this site other than bark beetle infestations.

Previous growth vigor of infested trees. Of the 35 trees that were infested by bark beetles in 1998, none showed a pattern of declining growth in the years previous to the infestation (Fig. 5.4, Appendix 5). Overall, there were no systematic differences between infested trees and their paired control trees at any time during the 63 year growth record that was analyzed (Fig. 5.5). The average difference between the growth of infested and control trees was not significantly different from zero during any year from 1935 to 1997 (Fig. 5.5, upper). Neither was there any suggestion of a growth decline during the years immediately preceding beetle infestations in

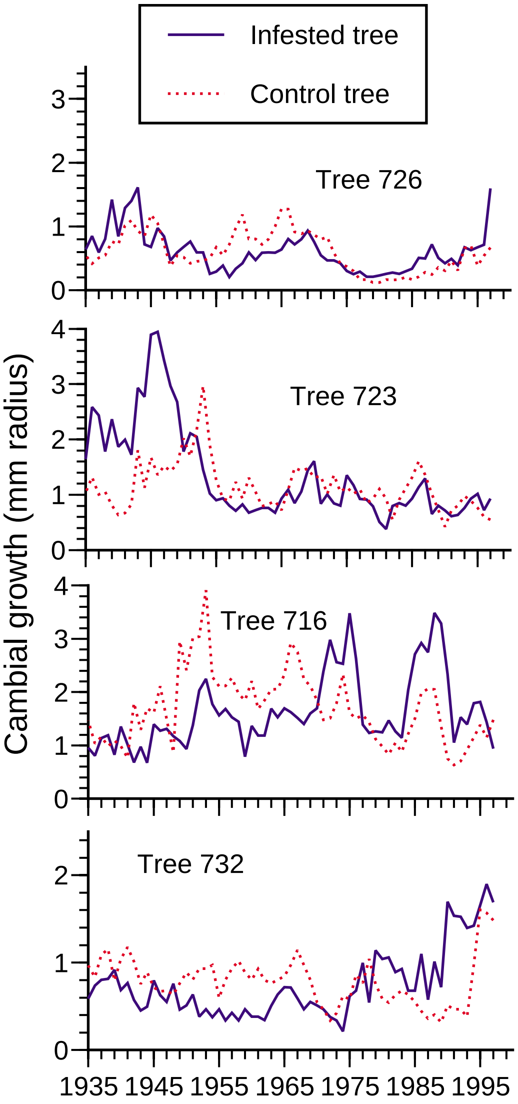

Fig. 5.4. Examples of growth rate comparisons between *Pinus resinosa* infested with *Ips* bark beetles in 1998 and paired non-infested control trees. None of 35 infested trees showed evidence of declining growth relative to the control tree in years prior to being infested by beetles. (See Appendix 4 for other trees)

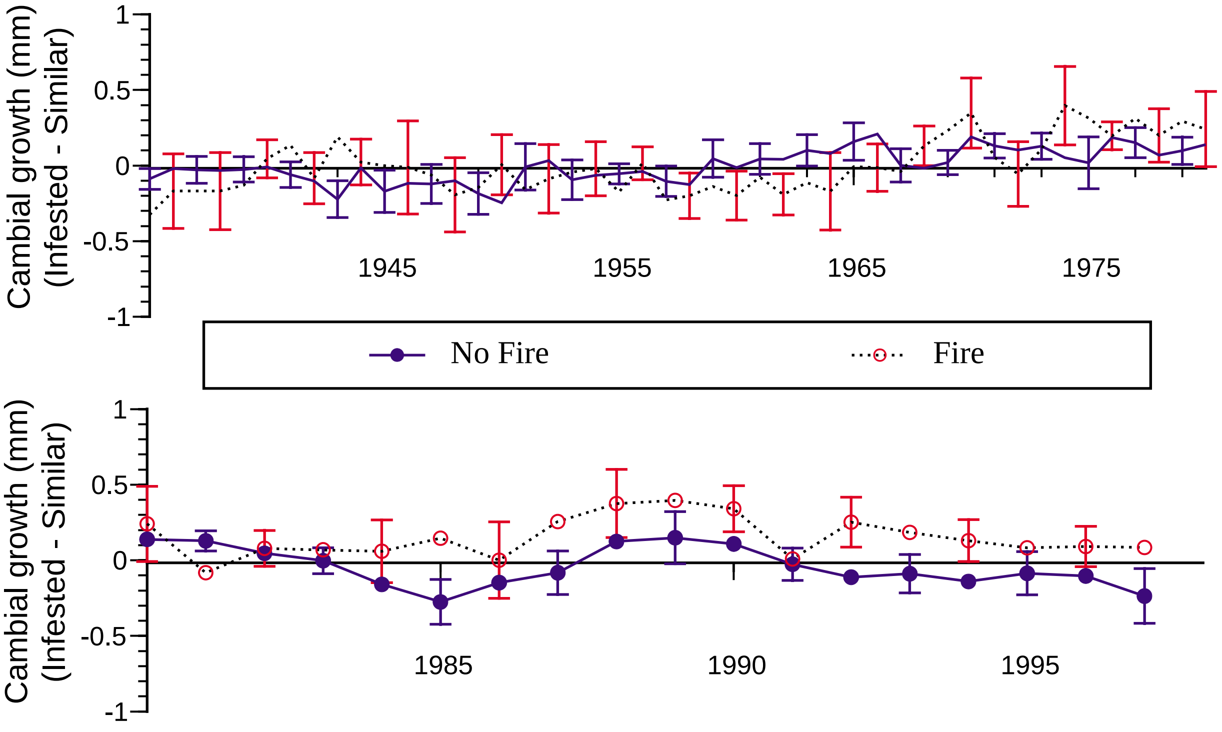

Figure 5.5. **Mean growth differences between *Pinus resinosa* infested with *Ips* spp. bark beetles in 1998 and their paired uninfested control trees from 1935-1980 (upper) and from 1980-1995 (lower)**

1998 (Fig. 5.5, lower; mean difference ± SE = 0.029 ± 0.026 mm / year; $T = 1.12$, $P = 0.26$). These patterns were the same for trees that were infested following fire scorching as for trees that were infested in the absence of fire.

Similarly, there was no evidence that bark beetles were tending to infest trees with chronically low growth rates. In fact, a comparison of the frequency distribution of growth rates for infested and uninfested trees showed that bark beetle infestations included some of the fastest growing trees in the park (Fig. 5.6; mean ± SE for infested vs uninfested trees from 1935 to 1984 = 1.09 ± 0.084 vs. 1.06 ± 0.041 mm / year, n = 35 and 121).

Conclusions. These data provide compelling evidence that *Ips* bark beetles commonly kill trees at Itasca. There was no suggestion of growth declines prior to beetle infestation in even one of the 35 infested trees for which we were able to reconstruct their growth history. Results also falsify the hypothesis that beetle infestations at Itasca are restricted to chronically slow-growing trees. Instead results indicate that *Ips* attacks are random with respect to tree growth. Even the most vigorously growing trees were subject to attack by bark beetles.

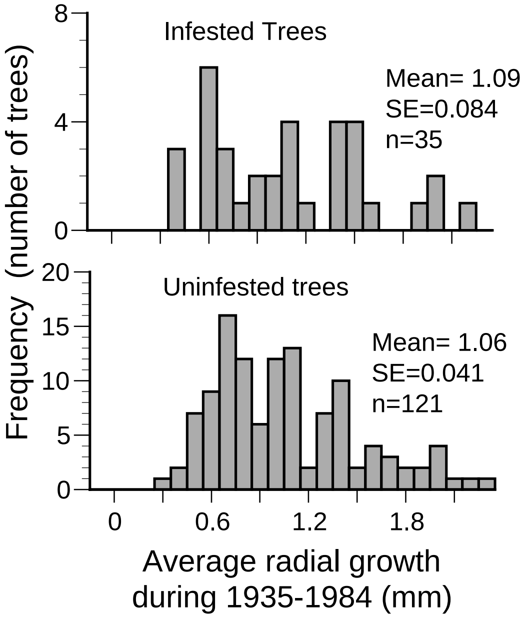

Fig. 5.6. Average growth rates during 50 years of trees subsequently infested by *Ips* in 1998 compared to those of uninfested trees.

Stalwart advocates of the hypothesis that *Ips* do not kill trees could still argue that there was some serious undiagnosed malady afflicting all of the infested trees in this study, which predisposed them to attack by beetles, and would have ensured that the trees would be dead within a few years anyway. However, virtually all of such potential maladies would be expected to produce a signal of reduced growth for at least a few years prior to infestation in at least a few trees out of 35. It seems most parsimonious to assume that many of the red pines infested by bark beetles at Itasca would otherwise live for decades longer.

We believe that we would find bark beetle infestations of living trees in almost any year at Itasca . The forests contain many standing dead trees at various stages of decay, indicating that tree mortality consistent with *Ips* infestations is common. We do not believe that the number of infested trees that we found were substantially elevated by the blowdowns during 1995-96. Our surveys were not specifically concentrated in stands that experienced blowdowns and many of the infested trees that we mapped were outside the immediate vicinity of any recent blowdowns. One notable exception was the cluster of infested trees mapped as 730-735 (Fig. 5.2), which were within 50 m of a substantial blowdown that probably produced tens of thousands of beetles during 1996-97. We guess that we would have found many more recently infested trees if we had specifically searched in the vicinity of similar blowdowns. It is noteworthy that *Ips* abundances were not at epidemic levels in 1998 or 1999, when most of our study trees became infested. In 25 3-trap arrays, mean captures of *Ips* did not exceed 145 beetles / site during any trapping period in 1997 or 47 beetles / site during 1998 (Chapter 3). Comparable sampling at our study sites in Wisconsin regularly capture a maximum of 50-100 beetles / site under apparently endemic conditions.

We estimate that our survey for beetle infestations included about 4000 trees. In both years, we found about 40 newly infested trees, suggesting that the annual probability of an individual tree becoming infested is about 1%. About half of the trees infested by beetles died in the short term, suggesting that the annual probability of a mature red pine dying from beetle infestations is about 0.5%. With an annual mortality rate of 0.5%, and no recruitment of trees, the Itasca population of red pines would be halved by beetle attacks in 139 years (Fig. 5.7). Of course, red pines also die from other causes such as windstorms, fires, pathogens, and lightning. If we guess that the background mortality rate from these other causes is 0.25% / year, and combine it with mortality from bark beetles, then it would require 93 years for the red pine population to be halved. This model still fails to account for the increased probability of future mortality that is a legacy of surviving past beetle infestations. Our data suggest that this increased risk is assumed by about 0.5% of the tree population per year. If we guess that the mortality rate of previously attacked trees increases to 5% per year, and hold the other estimates constant, then the tree population would be halved in 65 years. This halving time of 65 years can be contrasted to a hypothetical forest that lacks beetles (background mortality of 0.25% / year only), which would have a half life of 277 years. These calculations are simplistic in many respects, but they illustrate that the bark beetle attack rates we observed at Itasca during 1997-98 translate into important effects on the expected longevity of old growth red pine forests.

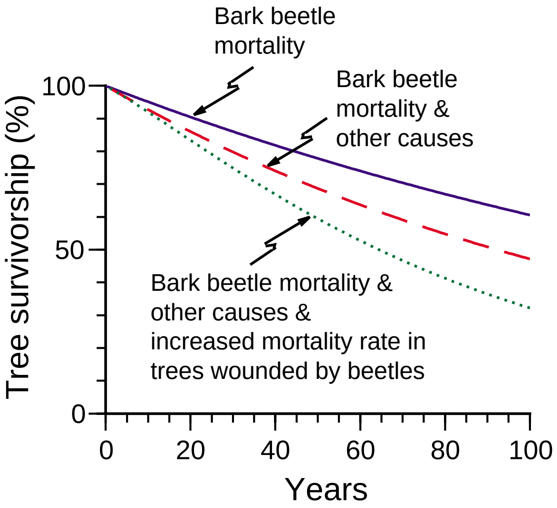

Fig. 5.7. Survivorship curves for a hypothetical population of red pines with a constant annual mortality rate of 5 trees / 1000 from bark beetles (estimated from our surveys at Itasca), or the same mortality rate from bark beetles plus a mortality rate of 2.5 trees / 1000 from other causes, or these same mortality rates plus an increase in mortality rates of trees previously wounded by bark beetles (to 50 trees / 1000). Under the latter scenario, which seems most realistic, the tree population would be reduced to half of its present size in 65 years.

Table 5.1. Summary of study trees infested by bark beetles that were marked and mapped in 1998.

Tree	DBH (cm)	Fire	Fate in 1999	Notes
701	49	no	Dead.	
702	68	no	Dead.	
703	56	no	Dead.	
704	71	no	Dead.	
705	75	no	Fully red crown. Dead by 2000.	
706	86	no	Attacks continue. 70% needle loss. Dead by 2000.	
707	85	no	No new attacks. 30% of crown lost.	
708	91	no	Attacks continue. Lower branches dead. Upper 30% of crown alive.	
709	95	no	No new attacks. Partly girdled.	
710	102	no	No new attacks. Girdled >50%.	
711	99	no	Dead.	
712	87	no	No new attacks. 70% needle loss. Death imminent.	
713	82	no	<10% green needles. Death imminent.	
714	87	no	No new attacks. Partly girdled	
715	62	no	Lower branches dead. Needles yellowing. Death imminent.	
716	81	no	Dead.	
717	47	no	No new attacks. Lower branches killed. Remaining crown OK.	
718	69	no	No new attacks. Half of crown dead. Girdled >50%.	
719	54	no	Dead except one branch at 10 m.	
720	76	no	New red branches. Continued attack.	
721	92	no	Dead.	
722	63	yes	No new attacks. Partly girdled. Thinning branches.	
723	86	yes	Dead.	Center burned out to > 4 m around; killed by fire, colonized by beetles
724	81	yes	New attacks. Incipient CFS*.	Scorched to 8 m
725	62	yes	New attacks. >70% girdled. 1 existing CFS*. Incipient CFS* on other side.	Scorched to 6 m; Old CFS* to 2 m
726	39	yes	New attacks. CFS* enlarging from 2 m, 25% circumference to 5 m, 50%.	Scorched to 3 m; beetle attacks expanding old CFS
727	74	yes	Lower crown dead.	Scorched to 4 m; beetle attacks expanding old CFS
728	78	yes	Dead.	Old CFS to 1.2 m; burned out trunk; killed by fire, colonized by beetles
729	?	no	Dead.	
730	72	no	New attacks. >50% girdled.	
731	65	no	<10% green. Functionally dead.	
732	99	yes	<10% green. Functionally dead.	Scorched to 3 m;
733	90	yes	No new attacks. 60% girdled.	Scorched to 70 cm
734	55	yes	Dead.	Scorched to 30 cm; old CFS* to 25 cm
735	52	yes	Dead. All needles red.	Scorched to 20 cm
736	64	yes	Dead.	

737		21		yes		No new attacks. >50% girdled.		
738		47		yes		No new attacks. >50% girdled.		Old CFS[*] to 2.5 m
739		61		yes		Dead.		
740		24		yes		Dead.		
741		23		yes		Dead.		Scorched to 5 m; old CFS[*] to 2 m

[*] CFS = cat-faced scar; see Chapter 6.