Spruce Beetle Epidemic and Successional Aftermath in Glacier Bay

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Abstract. A spruce beetle (*Dendroctonus rufipennis* Kby.) epidemic that began in the mid-1970s and persisted to the 1990s caused significant Sitka spruce (*Picea sitchensis* (Bong.) Carr.) mortality in the Beardslee Islands and in a few neighboring mainland areas of lower Glacier Bay. Entomologists of the U.S. Forest Service installed vegetation plots in 1982 and have followed the progression of the outbreak and its influence on forest structure and plant succession for 20 years. Stagnant tree growth from low nutrient availability probably contributed to the spruce beetle epidemic. Tree death was heavy in some sites resulting in a large volume of dead wood and the formation of forest gaps, which are now occupied by tree seedlings, shrubs, and herbaceous plants. This secondary disturbance by spruce beetle appears to have accelerated succession in the direction of an old-growth forest condition as these forests now have a more complex structure than forests with a similar age structure unaffected by spruce beetle.

Introduction

Most of the work conducted on forest succession across the chronosequence of Glacier Bay National Park has focused on colonization of forbs, shrubs, and trees that eventually develop into a homogenous conifer forest composed of a relatively even-aged condition (Goldthwait, 1966; Bormann and Sidle, 1990; Fastie, 1995). However, the next transitional stage that represents the breakup of the even-age forest as it enters the more complex structure and composition of old-growth condition is not well understood in the Park, or anywhere else in coastal Alaska.

Until the mid-1970s much of the lower bay was occupied by relatively dense stands of Sitka spruce and western hemlock in the 120 to 140 year age class. The 'O' (organic) horizon in the soils associated with these stands had accumulated much of the nitrogen in these forests and consequently the spruce stands began to lose their foliar nitrogen in this age class (Bormann and Sidle, 1990). This foliar nitrogen decrease was strongly correlated to the slowing of height and radial growth (productivity) of trees and led to stagnation over the last 50 years in that study.

As a result of nutrient immobilization and resultant decreased tree vigor, extensive blow-down in the late 1970s and dry conditions in the early 1980s, spruce beetle became epidemic sometime before 1980. Aerial photographs taken in 1979 revealed spruce mortality on about 600 ha in the lower bay on Young and Strawberry Islands, and between Berg Bay and Ripple Cove. The infestation spread dramatically between 1982 and 1985 (the greatest epidemic years for spruce beetle), and by 1996 covered nearly 14,000 ha. Spruce mortality exceeded 75 percent of the stand in some areas. Spruce beetle mortality spread east of the original outbreak area, near Excursion Ridge, but has now subsided in the Park.

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The objective of this investigation was to document the role of spruce beetle and tree death on changes in forest vegetation composition and structure in beetle-impacted forests of lower Glacier Bay.

Methods

In 1982, 45 one-twelfth hectare plots were installed in the Sitakaday Narrows area of the Park to document the effect of a spruce beetle epidemic (Eglitis, 1987). In 1998, tree data were collected on every tagged live and dead tree that could be found (the tags on fallen dead trees could not always be found). In 2004, overstory tree data on the 1/12-ha plot was collected from the 21 plots near Berg Bay, Ripple Cove, and Lester Island. Plots originally were installed in locations that were dominated by Sitka spruce. Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) comprised only a small amount of the total basal area. As a measure of disturbance, the mean percentage of live basal area (from both live and dead basal area) on plots from five general locations was displayed graphically from 1977 to 1998.

Tree measurements (diameter at breast-height and tree height) and condition (beetle attacks, fungal fruiting bodies, and height-to-break) were noted. Spruce beetle was recorded as the cause of death if sufficient galleries could be found under the bark of dead trees; otherwise, trees were recorded as dead from unknown causes. Cores used in assessing tree growth were removed from trees at breast height with an increment borer, mounted, and sanded before ring counting with a dissecting microscope. The number of regenerating trees and cover estimates for 35 understory plant species found on the plots were recorded to determine vegetation richness and to give an interpretation on future successional trends. Seedlings of trees greater than one foot tall were counted by species on a randomly-chosen quarter-section of 27 plots in 1998 and on most of the plot area of 21 plots in 2004. Understory plant cover was estimated in nested 18×18-m plots in the 21 overstory plots measured in 2004 (described above). A GPS location was taken at each plot center and all trees that could be assigned a tag number were stem-mapped.

Results

Tree Growth Patterns

A pattern of early rapid and then declining radial growth rate occurred for Sitka spruce before 1920, as is typical of trees in this young-growth stage of development. Growth of Sitka spruce improved slightly between 1920 and 1940, after which it continued to decline (fig. 1), eventually slowing to just 0.5 mm/yr. By 1992, the radial growth of Sitka spruce was one-sixth of its radial growth in 1880. The smaller and younger western hemlock, however, revealed a pattern of rapid growth, indicating a release from the beetle-killed spruce. The western hemlock growth response probably was due to reduced competition for light and nutrients.

Tree Mortality and Basal Area Decrease

For all plots except Young Island, a relatively high proportion of the trees were still living in 1977. Young Island plots lost one-half of their Sitka spruce (fig. 2) and more than one-half of the basal area (cross-sectional area of tree stems) prior to 1982. Only 65 percent of the basal area of the Young Island plots remained by 1977. Lester Island plots lost more trees and basal area between 1982 and 1998 than plots at any of the other locations. Young and Lester Island plots had about the same average percentage of live trees in 1998, from one-third to one-half or less than plots at the other locations.

Deterioration of Dead Sitka Spruce

Stand structure and potential wildlife habitat in the form of dead standing trees were greatly altered by this intensive tree death. The wood of Sitka spruce is not particularly resistant to fungal wood decay, and tree boles deteriorated and broke in a predictable way after tree death. However, a higher percentage of trees that died during the peak years of beetle mortality broke from decay only a few years after dying. Trees that died after the peak years of mortality, without the presence of spruce beetle, stood longer. The average time between tree death and stem breakage for 50 percent of the Sitka spruce was 12 to 13 years. As boles continued to break from the top down they decreased to a height (taller for bigger diameter trees) where they remained stable for many years. The average projected time between tree death and the boles being on the ground for 50 percent of the Sitka spruce was 20 years. There also was a difference in dead tree cohorts and the presence of red belt fungus (*Fomitopsis pinicola* (Swartz ex. Fr.) Karst) conks, a common stem decay. The 1982 through 1984 dead tree cohort had a higher percentage of *F. pinicola* conks than the other dead-tree cohorts. The average projected time between tree death and visible conks of *F. pinicola* for 50 percent of the Sitka spruce was 18 years.

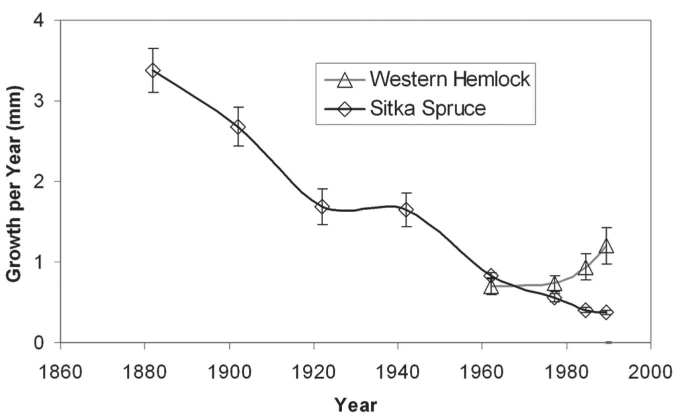

Figure 1. Mean radial growth of residual trees with 95-percent confidence limits (black bars) from 1,081 Sitka spruce and 59 western hemlock.

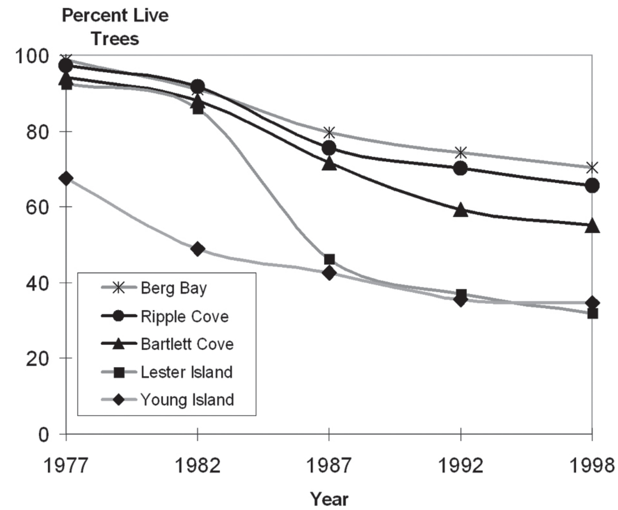

Figure 2. Average percentage of live trees (from live and dead basal area) at five locations from plot data in 1982, 1987, 1992, and 1998 and trees estimated to have died since 1977.

Tree Regeneration

The greatest and probably the earliest tree regeneration response was at the Yount Island site. Most of regeneration was Sitka spruce followed by red alder, except on Young Island where western hemlock was more prevalent than red alder. Among all plots, there were approximately 200–900 tree seedlings per hectare. Although there appears to be fewer Sitka spruce than western hemlock, every plot was fully stocked and the forest appears to be on a trajectory of returning to a closed-canopy condition dominated by conifers.

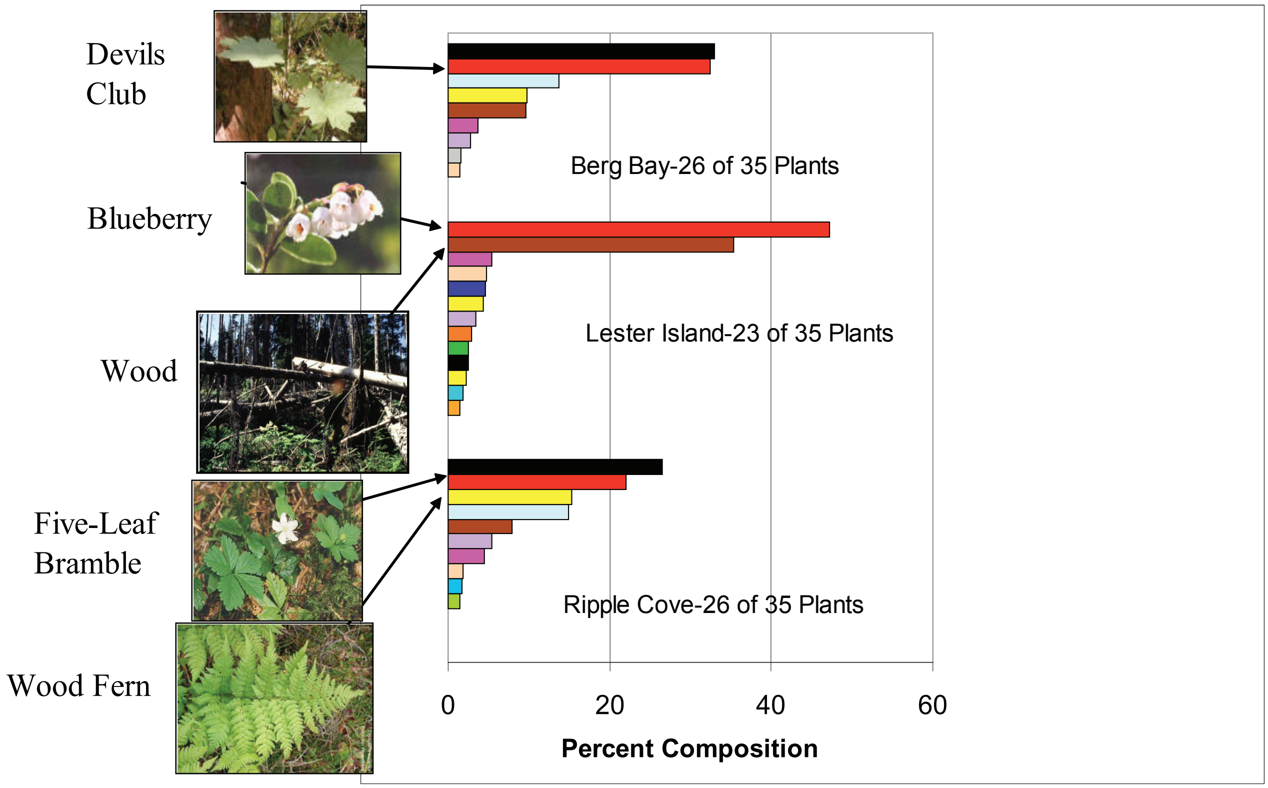

Figure 3. Cover estimates of understory vegetation and downed wood on 21 plots at Berg Bay, Lester Island, and Ripple Cove in 2004. Of the 35 species of plants measured on these plots, the 16 in order of percentage of composition was: devils club—*Oplopanax horridus*, blueberry—*Vaccinium alaskaense/ovalifolium*, down wood, five-leaf bramble—*Rubus pedatus*, wood fern—*Dryopteris expansa*, red alder—*Alnus rubra*, salmonberry—*Rubus spectabilis*, rosey twisted stalk—*Streptopus roseus*, bunchberry—*Cornus Canadensis*, heartleaf twayblade—*Listera cordata*, elderberry—*Sambucus racemosa* spp *pubens*, horsetail—*Equisetum arvense*, lady fern—*Athyrium filiz-femina*, single delight—*Moneses uniflora*, stiff clubmoss—*Lycopodium annotinum*, and wintergreen—*Pyrola asarifolia*.

Understory Forbs and Shrubs

Species dominance and diversity differed greatly among plots. Devil's club (*Oplopanax horridus* (Sm.) Miq.) and blueberry (*Vaccinium alaskaense/ovalifolium* Howell) were the most prevalent cover on the Berg Bay plots (fig. 3). Blueberry and downed wood comprised most of the cover on the Lester Island plots. Devil's club, blueberry, five-leaf bramble (Rubus pedatus Sm.), and wood fern (Dryopteris expansa (C. Presl.) provided most of the cover on plots in Ripple Cove. Lester Island had the least diversity of understory plants. Red alder, salmonberry (Rubus spectabilis Purch.), rosey twisted stalk (Streptopus roseus Michx.). bunchberry (Cornus canadensis L.), heartleaf twayblade (Listera cordata (L.) R. Br.), elderberry (Sambucus racemosa spp pubens Michx.), horsetail (Equisetum arvense L.), lady fern (Athyrium filiz-femina L.), single delight (Moneses uniflora (L.) Gray), stiff clubmoss (Lycopodium annotinum L.), and liverleaf wintergreen (Pyrola asarifolia Michx.) together made up 15 to 20 percent of the cover.

Discussion and Conclusions

Mature spruce forests often are attacked by spruce beetle in Alaska (Werner and others, 1977). Low tree vigor, as a result of the young soils having most of their nitrogen tied in the O horizon of the soils (out of reach to rooting spruce), contributed to the susceptibility of these forests to the spruce beetles.

The mortality of overstory Sitka spruce may result in several trajectories of succession. Deal (1999) demonstrated that a large number of cut trees (50 to 80 percent of the basal area removed) was required to change overstory species composition (in hemlock-dominated stands). On Lester and Young Islands approximately 60 percent of the trees died, with nearly all of that mortality as Sitka spruce. Many large Sitka spruce and western hemlock seedlings were on the earliest impacted Young Island plots; thus, the forest that eventually develops probably will be of mixed species. Although overstory western hemlock trees also will dominate some sites, there is a cohort of spruce regeneration that will occupy the midstory canopy on at least 50 percent of these sites.

More of the trees killed either before or after the bark beetle epidemic lacked obvious signs (i.e., conks) of stem decay than the trees killed during the epidemic. Spruce beetles possibly vectored the decay fungus *F. pinicola* to attacked trees (Petty and Shaw, 1986) during the epidemic, resulting in a faster fungal colonization of those trees. Trees killed during the height of the epidemic decayed faster, developed *F. pinicola* conks more quickly, and were deposited as the large woody component of the forest floor sooner than trees that died from other causes before or after the outbreak.

Management Implications

Tree death triggered by the bark beetle outbreak initiated a rapid process of transition in these homogeneous forests to a more biologically and structurally complex condition. The forests will continue to recover from the pulse of tree death by developing several tree age structures, multiple canopies, and a richer overstory and understory species composition not unlike the old-growth conditions seen in many older stands in coastal Alaska. Meanwhile, it will be interesting to observe whether or not younger spruce forests farther up bay will experience a similar secondary disturbance from spruce beetle as they reach the 120 to 140 year old age class. To what degree can information on disturbance and recovery in Glacier Bay be related with ecological processes outside of the park? With large areas of Southeast Alaska in an even-age condition following clearcutting in the later 1900s, it would be valuable to investigate other forests in this interesting dynamic transition stage to contrast disturbance factors and successional trajectories with those in the Park.

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