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Condition and Deterioration Rate of Precommercial Thinning Slash at False Island, Alaska

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Cover photograph by Eric Winter.

Abstract

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We examined slash from thinning treatments in a 21-year chronosequence of young-growth stands in southeast Alaska to determine the strength and persistence of slash effects on two key features of deer habitat quality: forage availability and deer mobility within thinned areas. We describe the main deterioration processes and their dynamics over time. We measured wood density of slash of various ages and present a model to estimate changes in wood density over time. This report also discusses factors that contribute to initial slash loading, slash deterioration, and effects on deer habitat.

Keywords: Thinning, Sitka spruce, western hemlock, southeast Alaska, slash, decomposition, wildlife habitat, Sitka black-tailed deer.

Summary

In southeast Alaska, precommercial thinning enhances timber values and promotes the growth of understory plants that provide forage for wildlife such as Sitka black-tailed deer (*Odocoileus hemionus sitkensis*). The dead stems and branches of cut trees, however, can impede deer access to the thinned stand and may reduce development of understory plants through shading or physically occupying growing sites, potentially reducing benefits to wildlife. We observed the condition of slash from thinning treatments in a chronosequence of young-growth stands near False Island, Alaska, to determine how long thinning slash could reduce deer habitat quality. Our observations suggest that precommercial thinning slash can impede deer movement until about 9 years after thinning. A key deterioration process is the decay of side branches that are suspending the cut stems above the forest floor. As the branches decay, they break and allow the cut stems to settle to the forest floor. Between 9 and 13 years after thinning, slash shades some growing sites but also creates small refugia where plants can grow protected from browsing deer. After about 13 years, dead stems are still decaying and recognizable, but they have fully settled to the forest floor, where they occupy some growing space but no longer impede deer access. We measured wood density of slash in stands thinned in different years to estimate actual deterioration rates and loss of carbon. Decay rates of western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.) stem wood were similar, losing approximately 32 percent of wood density after 9 to 13 years and 40 percent 24 years after thinning. This report also discusses factors that contribute to initial slash loading, slash deterioration, and effects on deer habitat: stand age at thinning, site productivity, spacing, and annual snow accumulation.

Contents

Introduction

Understory vascular plants provide forage for deer and other animals, contribute to biological diversity, and are used for subsistence by residents of southeast Alaska. Consequently, promoting diverse and abundant understory plant communities is often an objective of thinning treatments in dense, light-limited, young-growth forests. Precommercial thinning can leave large amounts of slash (foliage, branches, and stems) covering the ground between residual trees. The chief concerns with heavy slash loading relate to resources other than timber. However, the benefits of reducing crown cover to promote understory development by thinning or pruning may be reduced as long as heavy slash accumulations shade or physically occupy growing sites. Also, the benefits of increased forage production may be unavailable to deer and other animals if slash impedes their movement through the stand. Because of these concerns, slash treatment (piling, lopping, scattering, etc.) is often recommended when thinning is prescribed in stands having high value to wildlife.

Unfortunately, adding slash treatments can more than double the per-acre cost of thinning and pruning. If funds are limited, this will reduce the number of acres that can be treated, leading managers to question whether the greater benefit comes from treating more acres and tolerating the presence of slash for some time or from treating fewer acres and immediately reaping the benefits of reduced crown cover, increased forage availability, and ease of passage for large animals. In weighing these alternatives, managers are hampered by the absence of information on the persistence of slash. We have little data on how long the slash significantly affects understory plant abundance and animal movement. In one study in southeast Alaska (Doerr and Sandberg 1986), most of the thinning slash had deteriorated 18 years after treatment and high levels of deer use were observed. The authors speculated that deer use may have been reduced by heavy slash accumulation immediately following thinning. Without better information on the early dynamics of slash deterioration, the relative benefits of thinning and slash treatment cannot be evaluated.

Slash has been shown to affect the movement of deer and other large herbivores. In Montana, elk (*Cervus elaphus nelsoni*), mule deer (*Odocoileus hemionus*), and white-tailed deer (*Odocoileus virginianus*) preferentially used clearcuts where slash did not impede their movement. In contrast, deer in ponderosa pine (*Pinus ponderosa* Lawson & C. Lawson) forests on Arizona's Kaibab Plateau were observed to prefer areas where logging slash was untreated, even though forbs were more abundant in areas where the slash was removed (Reynolds 1969). This preference was unexplained. Parker et al. (1984) developed a model of elk and deer energy expenditures for locomotion. Their model predicted that energy expenditures for moving through slash increased with the relative depth of slash (obstacle height in relation to animal height) and the obstacle density (number of obstacles encountered per unit of lineal distance). Jumping over obstacles greatly increased energy use, but animals could reduce that cost if they could walk around obstacles.

In several instances, slash has been shown to have a protective effect on tree seedlings and understory plants by preventing herbivory by deer. In Sweden, slash retention had no effect on total plant biomass that consisted mostly of grasses and sedges, but the growth of tree seedlings, shrubs, and herbs—as well as the total number of species—increased with slash retention (Berquist et al. 1999). Aspen regeneration and shrub cover were greater in South Dakota clearcuts where slash was retained, 19 years after cutting (Rumble et al. 1996). In Pennsylvania hardwoods, where intense deer herbivory is present, more regeneration was found in areas where slash was retained (Grisez 1960). In contrast, Bergquist and Örlander (1998) found that slash quantity was not correlated with deer browsing on conifer seedlings. Krueger and Peterson (2009) studied a gap 3 years after a major windthrow event and concluded the relatively light slash loading did not prevent browsing of herb-layer plants by deer.

From a purely scientific viewpoint, the ideal approach to the question of slash effects and persistence would be long-term, properly designed experimental studies that accounted for the diverse environmental and biological factors that that are known to affect slash decomposition and breakdown rates. Such studies would be worthwhile and, if broadened somewhat, could have applications beyond the immediate management questions—in modeling carbon storage, nutrient cycling, and site productivity, for example. It is likely, however, that useful findings from this sort of study would not be available to decisionmakers for a decade or more, so another approach was needed.

In southeast Alaska, thinning of young even-aged stands began roughly 30 years ago and continues through the present. We recognized that this population of thinned stands could be used in an observational retrospective study of slash decomposition rates, so we explored the concept with a limited sample of thinned stands. The primary objective of this project was to observe and report on the condition of slash and its likely interference with deer and other large mammal habitat enhancement goals in young-growth stands that had received thinning at different periods in the past near False Island, Alaska. This chronosequence approach also allowed us to address a secondary goal of quantifying the actual deterioration rate of individual slash pieces up to 24 years after thinning.

Methods

Team Observation for Consensus Building

An interdisciplinary team met the week of July 17, 2006, in the False Island area to make observations on slash in young-growth stands that had been precommercially thinned.[1] Participants included wildlife biologists, a fish biologist, a research forest pathologist, a silviculturist, and a research forest ecologist. The False Island area of Chichagof Island was selected because the Tongass National Forest's Sitka Ranger District had records on past thinning activities that allowed the team to view a series of accessible stands with a variety of thinning dates (time-since-thinning). A consensus-building approach was used in this project with the team making joint observations along this chronological sequence of past thinning. The team discussed observations on the condition of slash and abundance of understory while in these stands, and reached consensus on how slash appears to deteriorate through time to affect possible deer movement and understory vegetation development.

The most difficult task was judging the effect of slash on deer access. Objective rating of this was not possible within the constraints of this study. Access is likely to be affected not only by the amount and type of slash present, but also by how strongly a deer is motivated to access the site and the amount of effort it is willing to exert. Our subjective judgments on deer access were based on our collective ability to move through the slash and the assumption that deer would have a slightly easier time of it.

Sites

Thinned stands were located on the False Island road system located along Peril Strait on the southern portion of Chichagof Island, Alaska, at latitude 57° 31' N, longitude 135° 11' W. All were young even-aged stands that were naturally regenerated following clearcut harvesting. Thinning treatments ranged from 4.3-m to 5.5-m (14-ft to 18-ft) spacing 9 to 21 years before we made our observations. For a more recent thinning, 4 years prior, we accessed a stand near Lindenberg Harbor and the abandoned Todd cannery site 13 km southeast of False Island. In all cases, cut trees were left in place; our observations suggested that typical operational thinning had been implemented with no further treatment of piled, lopped, or scattered cut stems.

[1] All thinning of stands examined in this study was precommercial, i.e., done to reduce stocking and not to produce a product. From this point forward, use of the term "thinning" assumes that it was precommercial.

Deterioration Rate—Measured Changes in Slash Wood Density

A small team returned to False Island in September 2009 to make a more quantitative assessment of the rate of slash deterioration using the chronosequence of stands that represented time-since-thinning. Stemwood from thinning slash was collected in stands that represented 5 (Ocean Boulevard), 12 (stand 168), 17 (stand 582), and 24 (stand 529) years after thinning. Because a 5-year-old thinned stand was not available at False Island, we used larger trees cut 5 years prior at the Ocean Boulevard site, but sampled wood pieces closer to the tops of these cut stems to represent the same diameter classes as pieces taken from smaller cut stems at other sites (see below). In addition, live trees from an unthinned stand in the same age class were felled and wood pieces collected as described below to represent initial wood density, or time zero.

Four cut stems each for western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and Sitka spruce (*Picea sitchensis* (Bong.) Carrière) were sampled at each site. Three pieces of each cut stem, approximately 10 cm (nearly 4 in) long, were removed by hand sawing: one piece 1 m from the base, one from the mid-stem, and one near the top. These pieces averaged approximately 12 cm (5 in), 7 cm (3 in), and 3 cm (1 in) in diameter, respectively. Plastic bags were placed under some of the more decayed pieces to recover any parts of the wood pieces that would have been lost to fragmentation during the hand sawing. Six measurements were made on each piece of wood to the nearest millimeter: two diameters each for the top and bottom, and two lengths. After calculating top and bottom areas and length for these pieces, volumes were then derived by the formula for the frustum of a cone (Husch et al. 1972):

$$V = L(A_b + (A_b A_t)^{0.5} + A_t)/3 \tag{1}$$

Where

V = volume (cm^3)

L = length (cm)

A_b = area of bottom end (cm^2)

A_t = area of top end (cm^2)

Wood pieces were oven-dried to a constant weight at 50 °C and then weighed. Existing wood density of slash, which can be used to estimate deterioration through time, was determined from measurements of weight and volume by the formula below. Density values (expressed as g/cm^3) were averaged for the bottom, top, and middle sections to create a mean stemwood density for each cut tree.

$$D = W/V \tag{2}$$

Where

D = dry weight density (g/cm^3)

W = oven-dry weight (g)

V = volume (cm^3).

Analysis and estimation of decay rates were conducted with the nonlinear regression procedure (NLIN) in SAS (SAS 2009).[2] A two-phase exponential decay function was chosen because the rate of wood decay typically tapers off through time as substrate quality is reduced (Harmon and Sexton 1996).

$$y = b_1 e^{-k_1 t} + b_2 e^{-k_2 t} \quad (3)$$

Where

b_1, b_2 = coefficients for components 1 and 2

k_1, k_2 = decomposition rate constants for components 1 and 2

e = natural logarithm (2.7183)

t = time, in years

Results

The following observations, made by the team at each young-growth stand visited, are arranged in a chronology by time since thinning.

Stand 413 Near Lindenberg Harbor, 4 Years After Thinning

This stand was thinned at age 27 years to 4.9- by 4.9-m (16- by16-ft) spacing as part of experiment 3 of the Tongass-Wide Young-Growth Study (TWYGS) (McClellan 2008). In addition to the thinning, parts of the unit were pruned, with either 25 or 50 percent of the leave trees pruned. All three treatment areas were examined (figs. 1 and 2). The pruned branches increased the amount of small-diameter slash present. Four years after treatment, slash did not appear to be decayed, bark and twigs were still attached, and side branches kept the cut stems propped up. Within-stand variability in productivity had a major effect on slash loading and understory presence. In the lower productivity areas, slash stem diameters and slash loads were smaller. Overlapping slash stems between leave trees were 0.9 to 1.24 m (3 to 4.1 ft) deep in many places, and the slash likely impeded deer access to the site. Oval-leaf blueberry (*Vaccinium ovalifolium* Sm.), red huckleberry (*Vaccinium parvifolium* Sm.), and salmonberry (*Rubus spectabilis* Pursh) stems were growing through some of the slash piles and their presence was probably the result of lighter slash loads and greater understory abundance under the more open pretreatment canopy. In contrast, in the more productive portion of the stand, slash was 1.8 m (6 ft) or more in depth with larger diameter cut stems. The general lack of understory likely resulted from heavy slash loads and a legacy of the sparse understory that existed prior to treatment under the dense pretreatment canopy.

[2] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Michael H. McClellan

Figure 1—Slash and shrubs in a less productive area within stand 413, 4 years after thinning and pruning 50 percent of the leave trees.

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Figure 2—Heavy slash in a more productive part of stand 413, 4 years after thinning and pruning 50 percent of the leave trees.

Stand 168, 9 Years After Thinning

This stand was thinned at age 29 years to 4.3- by 4.3-m (14 by 14-ft) spacing. Slash was still suspended by side branches, which appeared firm and were not breaking. Stems had some external wood decay but were still sound inside. After 9 years, slash was still occupying growing space and limiting deer access to much of the stand (fig. 3). Ferns, red elderberry (*Sambucus racemosa* L. var. *racemosa*), devilsclub (*Oplopanax horridus* (Sm.) Miq.), and oval-leaf blueberry were the dominant understory plants. The limited understory response was likely attributable to both slash occupying growing sites and shade from the overstory canopy. The team concluded that the canopy would likely close before the slash deteriorated sufficiently and that this stand should have been thinned earlier to maintain a more abundant understory and create less slash.

Stand 143, 10 Years After Thinning

This stand was thinned to 5.5- by 5.5-m (18 by 18-ft) spacing at age 20 years. The stand is in a productive riparian flood plain and is dominated by Sitka spruce with red alder (*Alnus rubra* Bong.) present throughout (fig. 4). The slash loading from thinning appeared light given the wide spacing—probably owing to the size of the

Michael H. McClellan

Figure 3—Stand 168, 9 years after thinning.


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Figure 4—Stand 143, 10 years after thinning.

young conifers at the time of thinning and the lower pretreatment stocking as compared to more upland settings. Lower stocking of conifers appeared to result from the limited number of favorable microsites for conifer establishment and to the presence of numerous red alder in the stand. Red alder were generally retained during the thinning treatment. Thinning slash was mainly on the ground, partially decayed with limbs intact but decaying, so there was little shading of understory and movement through the stand was not restricted. The understory was well developed with a number of species, including salmonberry.

Stand 522, 12 Years After Thinning, With an Unthinned Travel Corridor

This stand was thinned to 5.5- by 5.5-m (18 by 18-ft) spacing in 1994 at age 26 years. A portion of the stand was left unthinned to provide a travel corridor for deer. The slash was still impeding travel within some portions of the thinned areas, but many areas within the stand were accessible and the unthinned corridor had a well-used deer trail. The thinned area had a good understory of plants including oval-leaf blueberry, salmonberry, and devilsclub (fig. 5). Side lighting from the thinned portion allowed vegetation to develop within the margins of the unthinned corridor (fig. 6). There was evidence that deer were moving out into thinned areas with lower slash loading to browse.

Greg Killinger

Figure 5—Stand 522, 12 years after thinning, in the thinned part of the stand.

Michael H. McClellan

Figure 6—Stand 522, 12 years after thinning, in the unthinned travel corridor.

Stand 507, 13 Years After Thinning

This stand was thinned to 4.3- by 4.3-m (14- by 14-ft) spacing at age 20 years. Leave trees were mainly western hemlock with small numbers of red alder present (fig. 7). The slash load was moderate with most of the 2.5- to 10-cm diameter stems on the ground. Smaller stems were decayed and weakened, but the larger stems were decayed on the outside and sound inside. Primary branches were decayed and breaking, allowing most stems to have settled on the ground. Slash distribution was quite variable, with open areas as well as small piles. The understory was well developed, but there was concern that the canopy was beginning to close and the understory would soon be diminished by canopy shading. The team concluded that slash deterioration had progressed to the point where it no longer presented a problem of shading understory or limiting the mobility of deer.

Greg Killinger

Figure 7—Stand 507, 13 years after thinning.

Stand 230, 13 Years After Thinning

This stand was thinned to 5.5- by 5.5-m (18- by 18-ft) spacing at age 21 years. The slash was composed of 5- to 15-cm diameter stems. Primary branches of slash were decayed but mainly still attached. Cut stems were on the ground with the outside

Greg Killinger

Figure 8—Stand 230, 13 years after thinning.

2.5 to 5.0 cm decayed and inside wood appearing mainly sound. The understory was well developed with good species diversity (fig. 8). Slash had deteriorated and settled to the point where it was probably not limiting deer mobility or shading understory.

Stand 582, 14 Years After Thinning

This stand was thinned at age 14 years to 4.3- by 4.3-m (14- by 14-ft) spacing. Slash stem diameters ranged from 2.5 to 13 cm (1 to 5.2 in) and the stems were partially decayed and on the ground. Slash was distributed in a more patchy fashion than seen in other stands; this was probably caused by within-stand variation in site productivity (figs. 9 and 10). Deer movement would not be restricted between the piles of slash. Slash was still shading understory in places, but understory plants were evident around the slash. Stand heterogeneity created a range of slash accumulation, which was viewed positively by the team and could be mimicked by varying the nominal spacing in highly uniform stands.

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Figure 9—Stand 582, 14 years after thinning, in an area of relatively light slash accumulation.

Michael H. McClellan

Figure 10—Stand 582, 14 years after thinning, in an area of greater slash accumulation.

Stand 382, 16 Years After Gap Treatment

This stand developed after clearcutting in 1929. The 77-year-old stand was dominated by heavily fluted western hemlock and had very little understory vegetation. Gaps measuring 0.08 ha were cut when the stand was 61 years old to improve deer forage availability (fig. 11). The treatments were applied at an age far beyond the usual precommercial thinning age, so the slash pieces ranged up to 50-cm (19.7-in) diameter (fig. 12). Smaller diameter pieces were well decayed and the slash had largely settled to the ground, so movement through the treated area was relatively easy and few growing places were shaded. Despite the abundant light within the gaps, understory biomass appeared much lower than expected. The understory vegetation (fig. 13) showed evidence of heavy browsing by deer: herbs and half-shrubs were nearly absent, western hemlock seedlings were severely clipped and rarely over 0.3 to 0.6 m (1 to 2 ft) tall, and the only shrub that was thriving was rusty menziesia (*Menziesia ferruginea* Sm.), whose twigs are known to be eaten in only small amounts by deer (Hanley and McKendrick 1985). The intense herbivory observed can be explained by several factors. This stand is on a low-elevation south-facing slope, so deer would be expected to congregate in this area during the winter. Also, the untreated parts of the stand are extensive and in the stem-exclusion phase of development, with very little understory present. The vegetation in the gaps was the only good source of forage in the stand, so deer were naturally attracted to it.

Michael H. McClellan

Figure 11—Stand 382, 16 years after gap creation, looking across a gap into the untreated 77-year-old forest. Note the lack of understory vegetation in the untreated area.

Greg Killinger

Figure 12—Stand 382, 16 years after gap creation in a 77-year-old stand. Note that trees felled in this treatment are larger than those in a typical precommercial thinning.

Michael H. McClellan

Figure 13—Heavily browsed western hemlock seedlings in a gap cut in stand 382.

Stand 528, 21 Years After Thinning

This stand was thinned at age 17 years to 4.3- by 4.3-m (14- by 14-ft) spacing. The slash was on the ground, no longer suspended, with decaying moss-covered stems. It would not limit movement of deer or create much shading for understory. Crowns have closed since this stand was thinned. There is little remaining understory cover in parts of the stand. Dead stems of rusty menziesia and salmonberry (fig. 14) are evidence of shady conditions created from canopy closure. The Sitka Ranger District has several other treatments in this stand. In 2003, the district installed 30-m-diameter gaps where all trees were cut, girdled, or pruned.[3] Understory vegetation within the gaps responded well to these treatments (figs. 15 and 16).

Greg Killinger

Figure 14—Stand 528, 21 years after thinning with no further treatment. Note the dead stems of understory shrubs.

[3] Mechanical girdling kills the tree by cutting through the bark and cambium around the circumference of the stem. Two cuts are usually made and the bark may be optionally removed between the cuts.

Michael H. McClellan

Figure 15—A 3-year-old gap created by cutting in stand 528, 21 years after thinning.

Michael H. McClellan

Figure 16—A 3-year-old gap created by girdling in stand 528, 21 years after thinning. Note the minimal amount of slash on the ground.

Stand 529, 21 Years After Thinning

This stand was thinned to 4.3- by4.3-m (14- by 14-ft) spacing at age 17 years. The remaining slash was in the form of small-diameter stems (2.5 to 10 cm [1 to 4 in]), on the ground, which broke easily. The small stumps from thinning were rotten. The canopy has closed since thinning and little understory was present at the time of our observations (fig. 17). Self-pruning did not occur, so there were many dead branches retained on leave trees.

Michael H. McClellan

Figure 17—Stand 529, 21 years after thinning. Note the lack of understory plants and the small-diameter stumps from cut trees.

Changes in Wood Density of Slash

The original wood density of cut stems averaged 0.44 g/cm^3 with western hemlock having slightly higher initial density (0.46 g/cm^3) than Sitka spruce (0.42 g/cm^3) (fig. 18). These values are very close to published specific gravity values, which are the same as g/cm^3 at room temperature at sea level, for these two species, which are 0.45 and 0.40, respectively (Forest Products Laboratory 1987). Our density values are averages for live trees from the three stem sections taken from near the bottom, middle, and top of stems. Interestingly, the wood collected from near the tops of tree stems had slightly higher mean density than wood lower in stems (fig. 19).

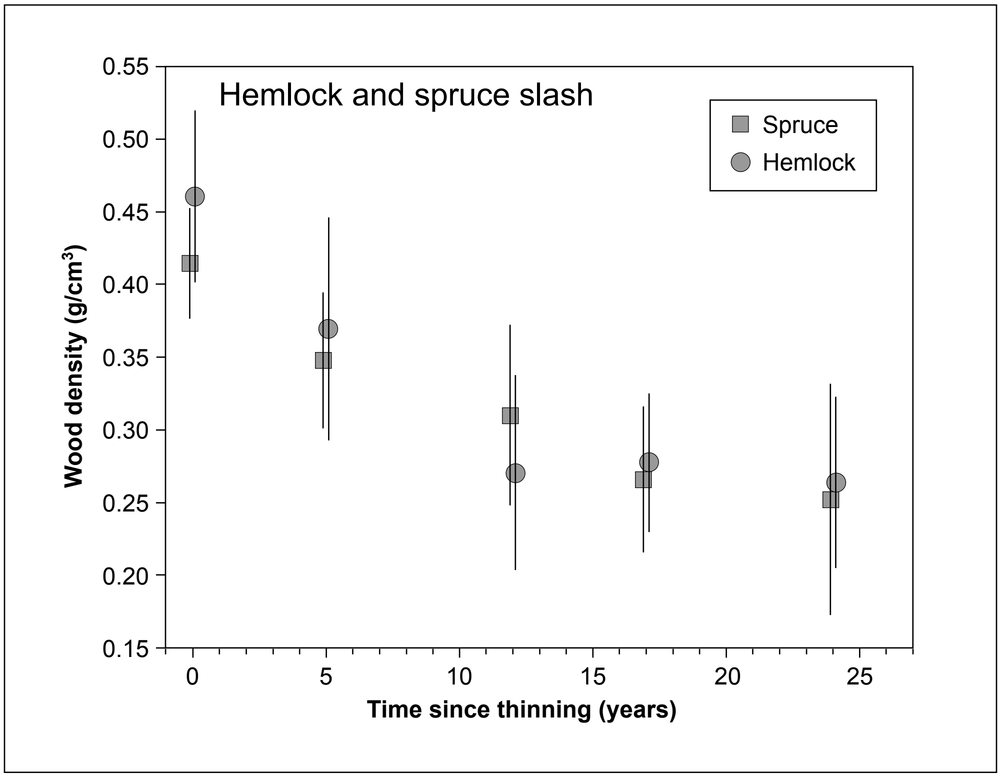

Figure 18—Mean wood density in young-growth thinning slash for western hemlock and Sitka spruce 0 to 24 years after thinning at False Island, Alaska. Error bars represent ±1 standard error.

Figure 19—Mean wood density in young-growth thinning slash of three diameter classes (from bottom, middle, and tops of stems) 24 years after thinning at False Island, Alaska. Error bars represent ±1 standard error.

Changes in wood density after thinning followed a nonlinear pattern for the two species and for different wood piece sizes (figs. 18 and 19). Hemlock wood and smaller pieces (stem tops) had higher mean densities than spruce or wood sections in the middle and lower stems, but these were not significant differences.

Because our sampling did not detect differences in initial density or deterioration rates between tree species or among piece sizes, we combined them to produce one model of the rate of deterioration of cut western hemlock and Sitka spruce young-growth tree stems. The resulting model was a two-phase exponential decay function ($p < 0.0001$):

$$D = 0.1794e^{-0.1344t} + 0.2570e^{-0.000725t} \quad (4)$$

Where

D = wood density

e = natural logarithm (2.7183)

t = time, in years

Wood density from cut tree stems after 24 years was 0.260 g/cm^3, representing a loss of about 40 percent from the initial wood density (fig. 20).

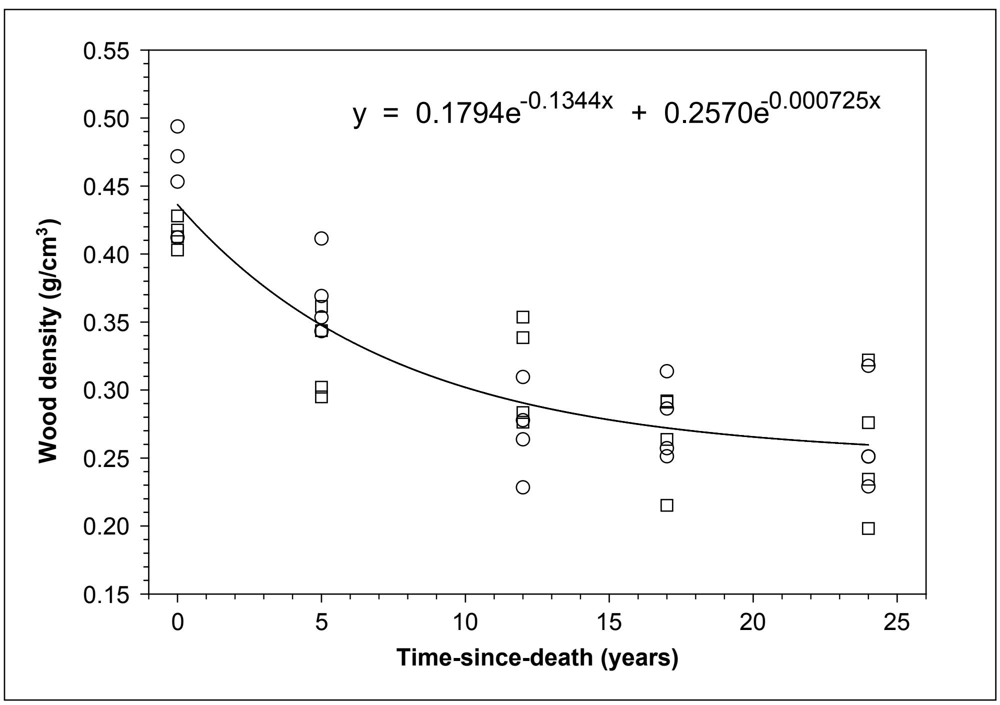

Figure 20—Mean wood density of western hemlock (circles) and Sitka spruce (squares) dead tree stems by time since thinning near False Island, Alaska. Values are mean wood density per tree stem from sample pieces taken at the lower, mid, and upper stem. Resulting equation is a two-phase exponential decay rate ($p < 0.0001$) where y = wood density (g/cm^3), x = years since death, and e = the base of the natural logarithm (2.7183).

Discussion

Initial slash loading appeared to be determined by the stand age at time of thinning, site productivity, and the intensity of silvicultural treatments. Older and more productive stands contained more standing volume and generated more slash during thinning. As the intensity (spacing) of thinning increased, slash loading was observed to increase. We observed the greatest slash loading in a stand that was both thinned and pruned at age 27 years. The large tree size, high volume, and intensity of treatment yielded deep and continuous slash loads in productive parts of the stand (see fig. 2).

Most of the stands we observed had a lot of within-stand variability of slash loading. We attributed most of this to within-stand variations in productivity, not to variations in thinning intensity. We found that within stands with uniform age and thinning prescriptions, the amount of thinning slash was far greater in the productive areas than in less productive areas. In the riparian stand we visited, we concluded that two factors contributed to the highly variable slash loading: the distribution of favorable microsites for conifer regeneration and the presence of red alder, which was not cut during thinning. After observing abundant understory plants growing under heavy concentrations of slash, we concluded that slash piles may have value in protecting plants from herbivory as they develop. By impeding deer access, the slash could allow perennial understory plants to develop robust root systems and gather resources while protected from herbivory.

We observed two treatment options that appeared successful in older, more productive stands where thinning would be expected to generate heavy slash loads. Leaving a portion of a stand unthinned is sometimes done to provide a travel corridor for deer, to ease movement between landscape elements, and improve connectivity. We found evidence of heavy use of travel corridors, but also found two added benefits. The unthinned areas received side lighting from the thinned areas, allowing greater understory development within the unthinned corridor. We also found evidence that deer were moving from the corridors into thinned areas with lower slash loading in order to browse. The second treatment option is girdling, rather than cutting trees to be thinned (see fig. 16). The objective of girdling is to kill the tree and have it remain standing, so that it deteriorates slowly rather than immediately delivering a large amount of slash to the forest floor. We examined a 3-year-old gap that was created by girdling and there was a good understory response and very little slash within the gap. One treatment option that is unlikely to be used in the future is bucking the slash into shorter pieces to get them to lie down. Two bucking treatments are being tested in the TWYGS study, but slash treatment is very expensive and thinning contractors are extremely reluctant to bid on contracts that include bucking or other postthinning slash treatments. In the past, it has been difficult for contractors to accurately predict the time and effort required to complete slash treatments, so there is considerable risk of underbidding.[4]

Immediately after operational thinning of young-growth stands, overlapping suspended slash stems appeared to present a serious issue for both deer mobility and shading of understory plants. These conditions persisted for roughly 9 years at False Island. From about 9 to 13 years after thinning, deterioration of side branches allowed slash to settle to the ground, where it became less of a barrier to animal movement. Slash still shaded some of the understory, but it also protected some plants from herbivory, thus creating understory refugia. Slash had not completely deteriorated after 13 years and could still be recognized on the forest floor, but there was negligible impairment of deer mobility and forage availability by this stage.

Visual inspection of individual cut stems in these stands helped us understand a general pattern of deterioration for thinning slash in the False Island area (table 1). Fine branches were the first to deteriorate and after 9 years, they are gone. Bark sloughs off and is missing at about the same time. Initially, cut stems are propped up by their primary branches, creating tall, impenetrable layers. These side branches can be retained, at least as stubs, long after thinning; however, about 10 years after thinning, branches become decayed, lose so much strength that they break, and allow the main stems to be pushed to the ground under their own weight or that of snow. Thus, the deterioration of branches is a key feature involved in the progression of slash from complex, deep tangles to simpler, shallow arrays of larger stems. The larger cut stems decay more slowly, with more decay on the outside and less in the stem interiors, but once they are on the ground and their branches have mainly deteriorated, they do not appear to produce much shading to understory plants or mobility issues for deer. Visual inspections of the well-decayed stems in the older thinned stands suggest that most of the wood decay is by white-rot fungi, which degrade both cellulose and lignin. This is in contrast to most of the wood decay occurring in dead old-growth hemlock and spruce trees, which is by brown-rot fungi, primarily the red belt fungus (*Fomitopsis pinicola* (Swartz ex Fr.) Karst), which degrades cellulose but not lignin.

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[4] Spores, S. 2012. Personal communication. Silviculture program manager, Tongass National Forest, Federal Building, Ketchikan, AK 99901-6591.

Table 1—Visual condition of thinning slash 4 to 21 years after thinning at False Island, Alaska

Stand	Age at precommercial thinning	Years since thinning	Bark	Fine twigs	Branches	Stem diameter and condition
413	27	4	Fully retained	90 percent retained	Fully retained	2 to 10 cm on unproductive sites, 15 to 20 cm on productive sites, larger stems suspended, very little decay
168	29	9	Partially gone	Gone	Long primary branches retained	15 to 18 cm, partially suspended, outer 2 cm (sapwood) decayed, not breaking
143	20	10	Mostly gone	Gone	Primary retained but decayed and breaking	Faster decay at this site (a riparian forest), mainly on the ground
507	20	13	Mostly gone	Gone	Primary stubs retained, decayed and broken	2 to 10 cm, stems on ground, smaller stems decayed and breaking
230	21	13	Mostly gone	Gone	Primary retained but decayed	5 to 15 cm, stems on the ground, small stems thoroughly decayed, larger ones decayed on outside 2 to 5 cm and sound inside
582	14	14	Mostly gone	Gone	Primary retained but decayed	2 to 13 cm, outer 5 cm of wood decayed, sound in middle
382	61	16	Partially gone	Gone	Long primary branches retained	5 to 50 cm, small stems decaying breaking, larger ones with decay in outer wood, including *F. pinicola*
528	17	20	Gone	Gone	Only primary stubs remain	10 cm, on the ground, partially decayed (both white and brown rots), breaking
529	17	21	Gone	Gone	Mainly gone	2 to 8 cm, stems on the ground, moss covered, decay penetrating, but middle sound

Note: This information is not available for stand 522.

Dynamics of Slash Deterioration and Crown Closure

The habitat benefits of thinning appear to be reduced by slash for a period of 9 years or so. Once the thinning slash has deteriorated to the point that deer have unimpeded access to the stand, the full benefits of understory enhancement are realized. At some point, however, the crown growth will lead to canopy closure and subsequent losses of understory plants due to shading. The length of this “window of opportunity” between slash deterioration and canopy closure seems to be controlled by site productivity, intensity of thinning, and timing of thinning. In general, more productive sites will reach canopy closure sooner than less productive sites. Figures 21 and 22 illustrate the effects of thinning timing and intensity—thinning at younger stand ages and thinning to wider spacing should lead to delayed canopy closure. Properly executed girdling treatments will decrease slash accumulation, so for any given spacing, girdling should create a longer period of forage availability.

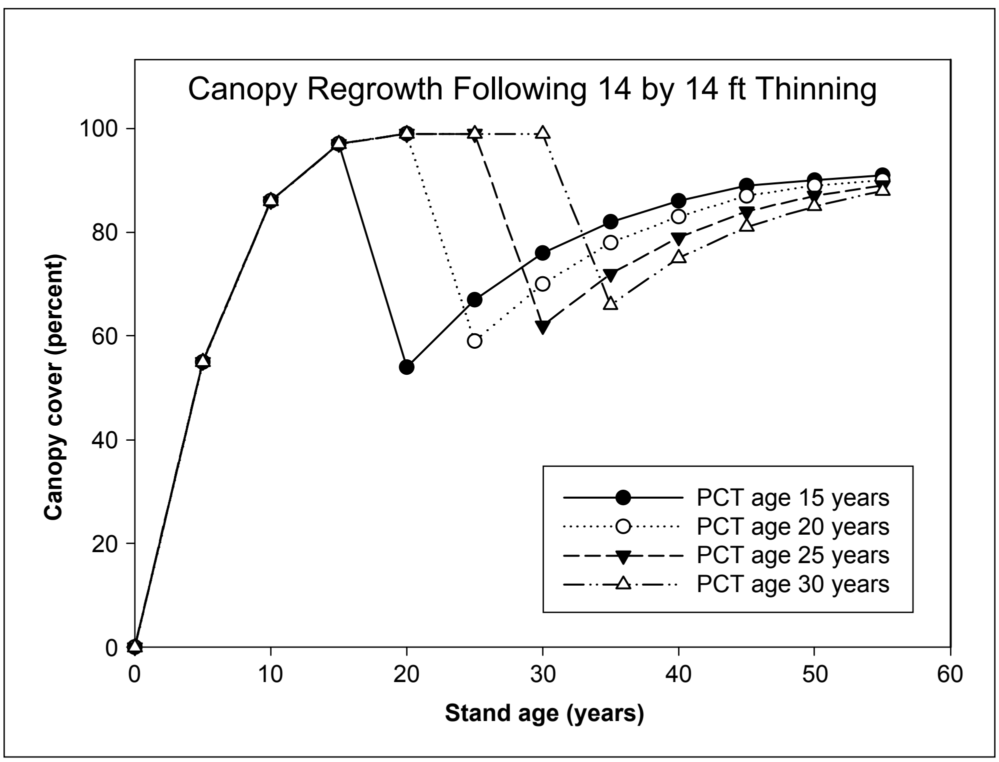

Figure 21—Predicted canopy cover following thinning to a 4.3- by 4.3-m (14- by14-ft) spacing at four different stand ages. These predicted results are from a FVS-SEAPROG “bare ground” run for a productive site.

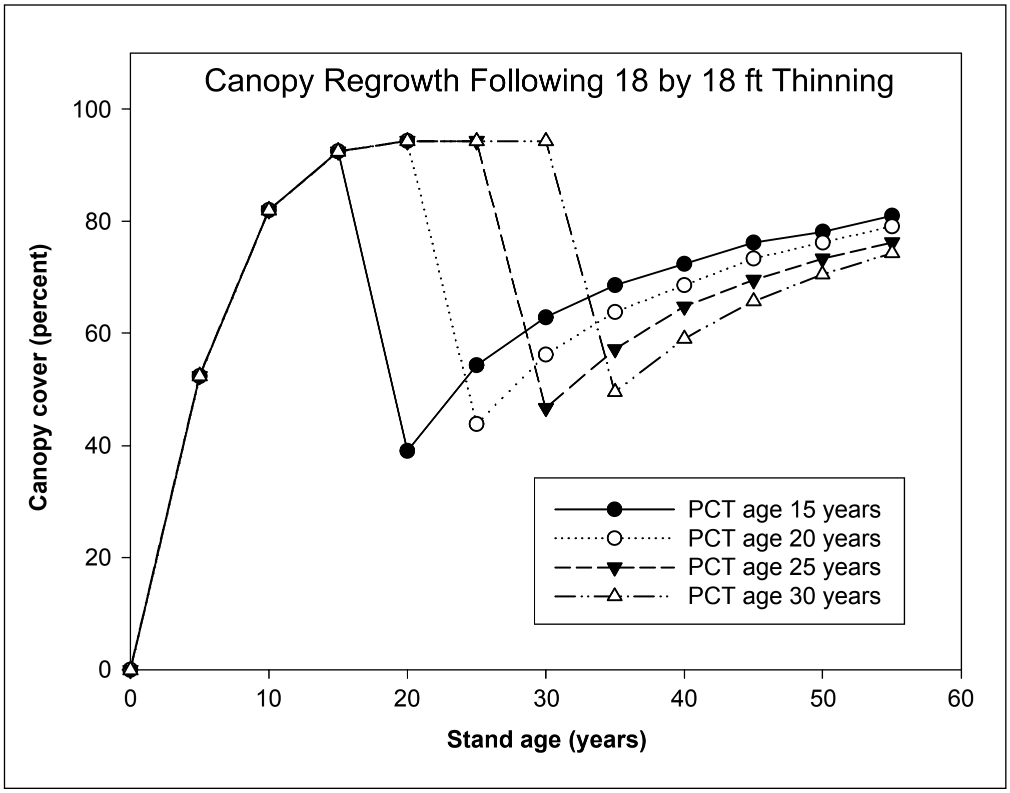

Figure 22—Predicted canopy cover following thinning to a 5.5- by 5.5-m (18- by 18-ft) spacing at four different stand ages. These predicted results are from a FVS-SEAPROG "bare ground" run for a productive site.

Changes in Wood Density

The wood density variation with height that we observed was similar to that found by Farr (1973) in a survey of 20 even-aged stands in southeast Alaska. The lack of effect on decomposition rates observed in these stands owing to tree species and stem diameter was unexpected, but could be explained by the relatively small diameter range of the stem sections. Saprophytic wood decay of dead trees tends to occur first on the surface of wood and progresses toward the center of stems. We would expect to find different decay rates by stem diameter, especially slower decay rates in larger pieces, if we had sampled a greater range of sizes beyond the typical 12 cm (5 in) thinned stems.

The two-phase exponential decay function is typical for wood decay (Minderman 1968) and can be explained by a rapid early phase of deterioration when the wood substrate quality is high, followed by a slower deterioration phase in the poorer wood substrate. Note that at time zero, the decay function is simply the sum of the two decay coefficients, which sum to the initial wood density, 0.44 g/cm^3.

Modeling the rate of decomposition revealed that the wood was initially composed of 41 percent (0.1794 g/cm^3) fast-decomposing material and 59 percent (0.2570 g/cm^3) more resistant to decomposition. After 24 years, 40 percent of the carbon is lost from the slash. Along with assessing the impact of slash on deer habitat, these results are useful to incorporate into carbon flux models. Once density is known, carbon content can be assumed to be close to 50 percent of wood, whether sound or decayed (Sollins et al. 1987).

Applicability of Results

Our observations were confined to a relatively limited part of southeast Alaska, so it is reasonable to ask whether the results and conclusions of this study apply to southeast Alaska as a whole. Three factors affecting deterioration rates would be expected to vary across southeast Alaska: temperature, moisture, and snowpack.

Decomposition is an enzyme-mediated process and, as such, its rate increases with temperature once temperatures exceed 0 to 5 °C. Optimum temperatures for wood decomposition are between 25 and 30 °C, and wood-decomposing organisms are unable to grow above 40 °C. Within the Tongass, we can expect temperatures to be lower than the optimum and to vary with latitude, elevation, aspect, and proximity to the outer coast, glaciers and interior passes. North-south differences could be large: southeast Alaska spans about 5° of latitude and work in Finland showed a 40 percent increase in conifer litter decomposition over an 8° decrease of latitude (Mikola 1960).

In some studies, wood decomposition occurred only when moisture contents were between 30 and 120 percent of the dry weight. In southeast Alaska, the frequent precipitation during the warmest months indicates that moisture is unlikely to be limiting, except possibly in the smallest diameter pieces during rare extended periods of dry summer weather.

Heavier snowpacks are likely to compress slash over time and reduce the overall depth. On the other hand, dense slash or shrubs can suspend snow above the forest floor and increase the effective burial depth of forage plants (Hanley et al. 2012), as well as make travel more difficult. Where snow cover persists into late spring, slash decomposition rates may be depressed. Southeast Alaska experiences large variations in climate over relatively short distances and weather monitoring stations are few and far apart, so it is unlikely we will have good data on snowpack persistence. Local managers, however, often have a good sense of where “snow holes” exist on their districts and their insights will be useful.

Future research would be needed to judge the applicability of these results to more southern locations in southeast Alaska. One possibility would be to repeat this study on Prince of Wales Island, which has a long history of precommercial thinning. Another opportunity lies in the TWYGS study.[5] In TWYGS experiments 2, 3, and 4, slash depth and cover are estimated on each understory vegetation sample quadrat. Over time, repeated measurements on the TWYGS sites will yield good information on slash loading and deterioration related to a range of silvicultural treatments.

Conclusions

Based on our observations at False Island, discussions with silviculturists and wildlife biologists, and observations elsewhere in southeast Alaska, we have concluded with the following list of observations (4 and 6) and hypotheses (1, 2, 3, 5, and 7):

(1) Initial slash loading is a function of stand age at time of thinning, microsite productivity, and the intensity of treatment. Older and highly productive stands contain more standing volume that is converted to slash during thinning. Slash loads increase with wider spacing, and pruning adds additional slash.

(2) Very few thinned stands will have uniform loading of slash. Within-stand variations in productivity or availability of favorable microsites (as in riparian stands) will lead to heavy concentrations of slash in some areas and small amounts of slash in others. Concentrations of slash may have value in protecting plants from herbivory as they develop.

(3) Where heavy slash is expected—as in thinning productive older stands—deer access to stands can be improved by leaving unthinned travel corridors or by using girdling rather than cutting as a means of killing trees. Slash treatments, such as cutting trees into smaller lengths, are unlikely to be done owing to resistance from thinning contractors.

(4) In the stands we observed, slash was likely to impede deer movement until about 9 years after thinning. From 9 to 13 years, slash no longer affected deer mobility, but some shading of understory occurred. Initial slash loading and winter snow accumulation could affect this timing.

[5] McClellan, M.H.; De Santo, Toni L. [N.d.]. Tongass-Wide Young-Growth Studies: study plan and establishment report. Manuscript in preparation.

(5) Thinning creates a "window of opportunity" that lasts from the time that thinning slash ceases to impede deer movement through the stand to the time the overstory canopy closes again and the understory dies off. The length of this window can be controlled by the timing and intensity of thinning, or by subsequent treatments.
(6) Tree species and diameter of stem wood had little effect on decomposition rates observed in these stands. Modeling the rate of decomposition revealed that the wood was initially composed of 41 percent fast-decomposing material and 59 percent material more resistant to decomposition. After 24 years, 40 percent of the carbon is lost from the slash.
(7) The landscape context is critical to predicting the potential wildlife benefits of silvicultural treatments. Heavy slash loads in a few stands may be of little consequence in a landscape with abundant available forage. Conversely, small-scale treatments set in landscapes with limited forage may create overly intense herbivory and destruction of the understory. Thoughtful placement and timing of thinning treatments can provide forage dispersed across the landscape by considering the location of sites during the "window of opportunity" when deer have access and forage is still available.

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English Equivalents

When you know:	Multiply by:	To find:
Centimeters (cm)	0.394	Inches
Meters (m)	3.28	Feet
Meters	1.094	Yards
Kilometers (km)	0.6215	Miles
Hectares (ha)	2.47	Acres
Square meters per hectare (m^2/ha)	4.37	Square feet per acre
Grams (g)	0.0352	Ounces
Grams	0.0022	Pounds
Grams per cubic centimeter (g/cm^3)	62.43	Pounds per square foot
Degrees Celsius (°C)	1.8 °C + 32	Degrees Fahrenheit

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