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# Decision Support for Managing Mixed Species Riparian Forests in Southeast Alaska

David V. D’Amore, S. Mark Nay, Rick Edwards, Scott H. Harris

## Authors

**David V. D'Amore** is a research soil scientist, **S. Mark Nay** (retired) was an ecologist, and **Rick Edwards** (retired) was an aquatic ecologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 11175 Auke Lake Way, Juneau, AK 99801. **Scott H. Harris** is Director of Conservation Research, Institute for Applied Ecology, 4950 SW Hout Street, Corvallis, OR 97333.

Cover photo: Chilkoot River near Haines, Alaska. Photo by Reinhard Tiburzy, stock.adobe.com.

# Abstract

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Riparian zones are important ecotones, integrating terrestrial and aquatic functions that support ecosystem productivity. A key ecological role of riparian zones is the production of large conifers that eventually enter the stream and provide important habitat complexity within the freshwater ecosystem. Many riparian zones in southeast Alaska were heavily disturbed during logging operations from 1950 to 1980, which depleted the large wood supply to streams.

Abundant conifer and red alder regeneration was common after harvest, replenishing a young population of trees, but the presence of red alder has been perceived to inhibit conifer stand development and large wood recruitment to streams. Therefore, alder thinning has been used to accelerate conifer growth and address the large wood deficit in streams. However, the trajectory of stand growth in these mixed species riparian stands is complex, and the response to alder or conifer thinning has not been thoroughly documented since riparian restoration projects have been implemented throughout southeast Alaska. Further, few protocols exist for evaluating the progress and success of restoration actions.

To address this need, we measured species abundance, tree density, light, and growth history on dominant landforms associated with varying stream geomorphological classes in 13 postharvest riparian stands. The presence of alder did not negatively affect conifer growth across a range of stand and landform conditions. Thinning conifers on terrace landforms increased the annual stand growth increment where conifers dominated. In the absence of thinning, equal stocking of alder and conifer did not affect conifer growth increment on terraces in mixed stands. We found that the density to tree size ratio (trees per hectare to quadratic mean diameter) is a useful metric to monitor the progress of stands toward desired late-seral conditions. These results indicate that mixed species stands do not impede conifer growth and provide valuable riparian nutrient inputs, improved light, and biological diversity.



**KEYWORDS:**

Forest stand development
Riparian restoration
Silviculture
Stream restoration
Young-growth

# Contents

# Introduction

## Riparian Ecological Background

A key nexus in watersheds is the riparian zone, which is generally identified as a zone of interaction between terrestrial and aquatic environments along riverine corridors (National Research Council 2002). Riparian areas have higher species diversity than surrounding upland areas and are shaped by disturbances and water fluctuations that create a distinct corridor along water bodies (Naiman and Décamps 1997). The riparian zone is critical in determining the timing, amount, and quality of chemical and physical inputs from the surrounding watershed, and it is fundamental to the maintenance of healthy stream ecosystem structure and function.

Riparian zone structure and function are major research and management concerns in the Northeast Pacific coastal margin because abundant anadromous salmon rely on functional riparian zones to maintain healthy spawning and rearing habitat (Van Alen 2020). Riparian zones regulate organic matter, light, sediment, water, dissolved organic carbon, nutrients, and wood; all of which are key components of healthy freshwater habitat (National Research Council 2002). Large wood derived from late-seral conifers is critical in retaining sediment and forming pools in streams (Murphy and Koski 1989).

Many studies and restoration efforts concentrate on large wood supply as an indicator of stream function (Fetherston et al. 1995, Gomi et al. 2006, Roni et al. 2008, Ross et al. 2019). The importance of large woody debris to aquatic habitats that support resident and anadromous fish has created an interest in quantifying stream structural attributes and how stream structural attributes respond to anthropogenic and natural disturbances that influence the recruitment of large wood into streams (Flitcroft et al. 2022).

## Soil Geomorphic Conditions in Southeast Alaskan Riparian Zones

The riparian zones in southeast Alaska are primarily composed of several alluvial landforms, including floodplains, alluvial fans, glacial outwash, and toeslopes. The U.S. Department of Agriculture, Forest Service classifies these landforms into stream channel process groups (hereafter, channel types), including floodplain (FP), alluvial fan (AF), moderate gradient mixed control (MM), and glacial outwash categories (Kelliher 2010). There is a distinct soil association on the floodplain landforms—a younger Entisol is common on the lower active floodplain, and an older Spodosol is common on the more stable terrace landform (D'Amore et al. 2011).

## Riparian Plant Associations

The natural disturbance history of the riparian zone promotes the development of distinct plant communities. Early successional species, such as red alder (*Alnus rubra*) (hereafter, alder), are common within the plant associations of the recently disturbed younger surface, while uncommon flood disturbance on the terrace leads to an abundance of conifers, including Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*). Disturbance favors the silvics of Sitka spruce, and this species dominates the plant associations on alluvial landforms (Capp et al. 1992). The understory plant community in lower areas with more frequent flooding includes salmonberry (*Rubus spectabilis*) and stink currant (*Ribes bracteosum*), with occasional devilsclub (*Oplopanax horridus*) and American skunk cabbage (*Lysichiton americanus*); better-drained areas have ovalleaf blueberry (*Vaccinium ovalifolium*) and rusty menziesia (*Menziesia ferruginea*) (DeMeo et al. 1992, Martin et al. 1995).

## Southeast Alaska Riparian Conditions

Southeast Alaska contains abundant healthy watersheds and is viewed as a salmon habitat refugium for the Northeast Pacific (Ruggerone et al. 2010). Past timber management in the region by large landowners, including the Tongass National Forest, tribal corporations, and the State of Alaska, has mostly been defined by selective cutting and clearcutting old-growth forests (Harris and Farr 1974). However, on the Tongass National Forest, about 14,000 ha of riparian forest have been harvested in 101 of 915 watersheds; more than 10 percent of the riparian area was harvested between 1950 and 1980 (USDA FS 2014).[1] This harvesting occurred before 1990, after which the Tongass Timber Reform Act (1990) protected streams with anadromous salmon. Riparian harvest

[1] U.S. Department of Agriculture, Forest Service [USDA FS]. 2014. Tongass young growth management strategy. On file with: USDA Forest Service, Pacific Northwest Research Station, 11175 Auke Lake Way, Juneau, AK 99801.

resulted in several thousand hectares of riparian forest stands that lack critical pool habitat because of reduced inputs of large woody debris (Bryant 1980).

Soil disturbance during the logging activity was common and led to different vegetation trajectories after harvest. The disturbance caused by tractor logging early in the logging history, between 1950 and 1970, resulted in three-times more soil disturbance than the subsequent cable logging from 1970 to 1990 (Landwehr et al. 2012).[2] Legacy pieces of large wood that remained in and adjacent to the streams were removed in an attempt to enhance spawning habitat before scientific evidence proved this to be detrimental to the stream complexity and successful rearing of salmon (Wohl 2014).

## Riparian Restoration Measures

The logging activity described above promoted the spread of early-successional red alder along tractor yarding pathways, skid trails, and roads (Deal 1997, Landwehr et al. 2012).[3] Subsequent stands in many logged alluvial landforms had abundant red alder and salmonberry thickets above sparse to moderate natural conifer regeneration in the understory. Because of potential for conifer growth suppression, regenerating riparian forest stands on the Tongass National Forest are commonly thinned to accelerate the return to desired late-successional or old-growth conditions, including increased quantity and diversity of understory plant communities, increased large woody debris recruitment, and enhanced nutrient cycling (Orlikowska et al. 2004, Pollock and Beechie 2014). However, there is limited information about stand growth and differentiation in alder-conifer stands, and stand recovery from disturbance across the range of riparian landforms has not been fully quantified.

We designed this study to provide key information about the recovery of young-growth, riparian forest stands on riparian landforms associated with different channel types. The traditional, yet previously untested assumption is that alder regeneration following harvest disturbance suppresses conifer growth and therefore increases the risk of extending the time before reaching desired future conditions in riparian zones. Therefore, we measured stand growth across a range of stand conditions in young-growth stands with varying mixtures of conifer and alder. We also evaluated the practice of conifer release, a treatment focused on cutting alders surrounding a conifer rather than thinning an entire stand or reach of the terrestrial riparian zone. Our goal was to inform future decisions regarding riparian stand management options in southeast Alaska by (1) establishing a decision support guide to quantify how the presence of alders influence conifer growth and (2) evaluating alder thinning as a restoration measure in riparian stands.

# Materials and Methods

## Regional Ecological Setting

We conducted the study across several islands of the Alexander Archipelago located in the Northeast Pacific coastal temperate rainforest of southeast Alaska. Accretion of geologic terranes through subduction and subsequent faulting and glacial epochs carved deep fjords and created U-shaped valleys along major stream drainages (Brock et al. 1996, Gehrels and Berg 1992). Subsequent uplift and erosion created a sequence of low-relief, alluvial terrace deposits lining the large valleys of the island archipelago with distinct soil geomorphologic sequences (D'Amore et al. 2011).

The region's abundant annual precipitation (average annual 30-year normal precipitation near the sites ranging from 2146 to 2538 mm), lack of a dry season, and mean average temperature of 4.7 °C at sea level (Alaska Climate Research Center 2025) promote the accumulation of biomass in large-stature conifers and extensive peatlands. In riparian stands, Sitka spruce and western hemlock compose the dominant forest cover in productive areas, enriched by western redcedar (*Thuja plicata*), Alaska cedar (*Callitropsis nootkatensis*), and deciduous red alder. The alluvial landforms are extremely productive for conifers given the ideal growing conditions and have some of the highest volume forest cover in the region (DeMeo et al. 1992, Martin et al. 1995).

[2] Landwehr, D.J.; Foss, J.V.; Silkworth, D.R. 2012. Soil quality monitoring on the Tongass National Forest. The Tongass' interpretation of the Region 10 soil quality standards. Part 2: summarizing 4 years of data collection. 39 p. Unpublished report. On file with: USDA Forest Service, Pacific Northwest Research Station, 11175 Auke Lake Way, Juneau, AK 99801.

[3] See footnote 2.

## Site Selection, Plot Design, and Tree Measurements for Experimental Observations

Riparian forest harvest was common early in the period of industrial logging in southeast Alaska, commencing around 1960 and becoming less common after 1980. Riparian forests were later protected from harvest with the passage of the Tongass Timber Reform Act (1990). Because riparian alluvial surfaces had some of the largest diameter trees, typically younger with fewer defects and of higher quality wood, they were prized in early harvest operations. The low gradient facilitated both ground-based and cable yarding operations that created severe surface disturbance.

We selected riparian sites that had similar harvest operations 37–68 years before our study and which represented the major alluvial channel types (Kelliher 2010, Paustian et al. 1992). These channel types represent groupings of channels that have similar stream geomorphologic and fluvial evolution. We selected 13 stream reaches for plot establishment and measurement during the summer when alders were leafed out. We chose stream reaches with channel types that had the most riparian harvest on the Tongass National Forest, including the categories moderate gradient mixed control, floodplain, and alluvial fan (USDA FS 2014).[4]

Each of these channel types is associated with specific landforms (Brock et al. 1996). Several landforms are found in a sequence, with floodplains adjacent to the stream channel, terraces extending outward from the floodplain, and toeslopes creating a transition from the valley floor to the hillslopes. The varying factors that led to the formation of these landforms influence the growth response of trees. To address this variability, we chose a plot design based on Marquardt et al. (2010), which is an alternative to traditional fixed-radius circular or fixed-area square plots used in previous riparian research studies in the region (Deal et al. 2004, Orlikowska et al. 2004). We delineated rectangular 5- by 40-m plots oriented perpendicular to the stream channel to best characterize the riparian stand complexity and variation of landforms along the stream reach (fig. 1). Each plot had eight

[4] See footnote 1.

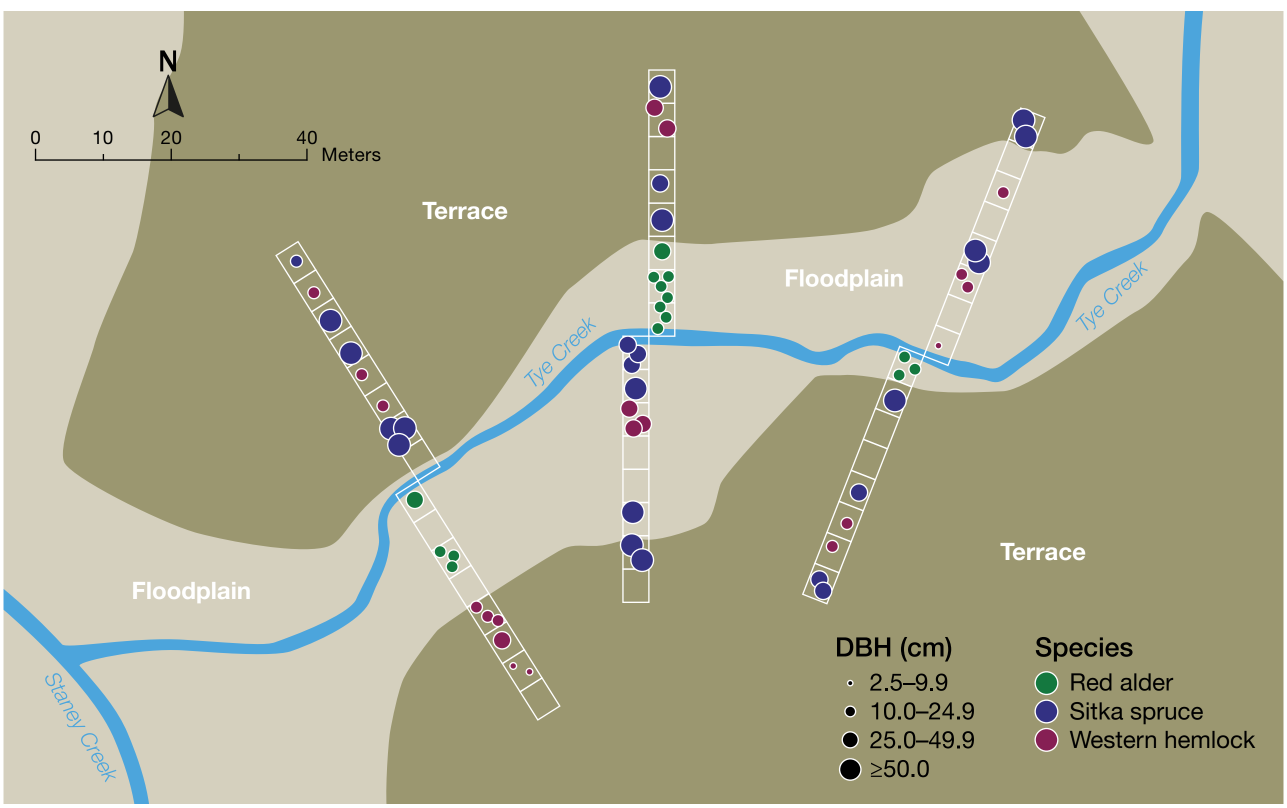


Figure 1—Plot design and arrangement along stream reaches across floodplain and terrace landforms at the Tye Creek sample site in southeast Alaska. Plots were divided into eight sectors and were perpendicular to the stream channel. Circles within the sectors represent species and diameters of trees at breast height (DBH) located at different spatial locations.

5-m-long sectors along the entire 40-m extent of the plot. We identified the channel reach by channel type, and we associated tree measurements with landforms found in each plot sector. We established a pair of plots at a random point within each 50 m of reach length. The plots were oriented perpendicular to the stream reach on each side of the channel (fig. 1). We established two or three pairs of plots, a total of four or six plots (depending on reach length), along each of 13 experimental stream reaches.

We affixed a fisheye lens to a digital camera, mounted the camera on a tripod at 1.3-m height, and took photos in the middle of the day. We used Gap Light Analyzer software (Frazer et al. 1999) to determine canopy cover from the photos. We identified all trees ≥2.5-cm diameter at breast height (DBH, i.e., 1.3 m) within the plot by species and measured canopy class and DBH. We measured the tree height (from the ground to the highest tip) of all trees within a plot or, in extremely dense stands, of a subset of trees within a plot equally distributed across canopy dominance classes. We used a Criterion laser to measure tree height to the nearest 0.1 m. We used all measured tree heights and DBHs to develop height-diameter relationships to estimate heights of trees that we did not measure. We calculated basal area from tree DBH and scaled it to a total area of 1 ha to estimate basal area for all tree species.

## Calculated Size-Density

We calculated the ratio of trees per hectare (TPH) to stand quadratic mean diameter (QMD) as a simple measure of stand density (see Curtis and Marshall 2000). The size-density ratio captures the combination of tree density and size used to represent stand diversity across the Tongass National Forest similar to the use of the size-density model developed by Caouette and DeGayner (2005). The size-density ratio provides a relative measure of the size distribution of trees within a stand. Higher size-density ratio indicates a higher stem density with fewer large-diameter trees. Lower size-density ratio indicates lower stem density with more large-diameter trees. We derived size-density ratios from data in Johnson et al. (2006)[5] for late-seral stands across a range of conditions in nonharvested riparian areas; these values served as reference conditions for the desired future size-density ratios.

## Basal Area Increment

We collected increment cores from conifers at 1.3-m height from 30 randomly chosen trees across codominant and dominant canopy classes at each site to measure ring-width intervals. We glued tree core samples to wooden mounts and sanded and scanned them using an Epson scanner. We then used WinDENDRO (Regent Instruments, Inc. 2025) for stem analysis to measure the ring-width intervals for the total core extent from bark to pith for individual trees. We calculated the basal area increment, which is the measurement of the annual change in cross-sectional area of a tree stem. Annual individual tree basal area increment (BAI) was calculated by converting the ring-width interval into annual BAI from ring width and DBH measurements using the following equation:

$$BAI_t = [\pi\,(D_t \div 2)^2] - [\pi\,(D_{t-1} \div 2)^2]$$

Where:

$BAI_t$ = basal area increment for year $t$ (mm$^2$)

$\pi$ = constant pi (about 3.14)

$D_t$ = diameter at breast height (mm) for year $t$

$D_{t-1}$ = diameter at breast height (mm) for year $t$–1

We calculated average annual stand BAI from annual individual tree BAIs across the cores taken from trees at each site.

## Conifer Release Measurements

We identified four riparian stands that had received conifer release treatments; they were located in Upper Harris River, Lower Harris River, Azalea Creek, and Camp Creek near Polk Inlet. Three of these stands were treated in 1999 to provide additional large wood along stream reaches on Prince of Wales Island. We established experimental plots in treated stands according to the protocol described above to gather information from increment cores of trees within these treatment areas. Our approach was to examine the growth of trees in the stand that had release treatments compared to trees in the stand that were not treated. We analyzed tree cores following the protocols described above to determine BAI for untreated trees (plot trees) and release treatment trees (release trees).

[5] Johnson, J.; Krosse, P.; Paustian, S.; Parks, R.D.; Paul, T.; Turner, R. 2006. Riparian young growth emphasis. Unpublished document. On file with: USDA Forest Service, Pacific Northwest Research Station, 11175 Auke Lake Way, Juneau, AK 99801.

# Results

## Composition, Density, and Size Distribution in Riparian Forests Across Landforms

The stand ages (years after harvest) ranged from 37–68 years at the time of measurement, which covered most of the historical riparian harvest period (table 1). All stands regenerated naturally and developed mixtures of conifer and alder basal area that ranged from 99 percent conifer to 61 percent alder; one stand had almost exclusively conifer, and in most stands, alder made up half or less of the total basal area (table 1). The total basal area calculated for all stream reaches increased with stand age and ranged from about 22 to 93 $m^2$/ha. Alder basal area was largest in stands with no record of precommercial thinning (table 1). The conifer stand density varied widely from 150 to 992 trees/ha (table 1), but there was no relationship between stand density and age. Size-density ratio trended lower with stand age, but the relationship between conifer QMD and stand density did not vary with the amount of alder in a stand.

Conifer basal area dominated the terrace and toeslope landforms, but conifers and red alders were more equally distributed on alluvial fans and floodplains. The average conifer size-density ratio was lower for alluvial fan and floodplain landforms than for terrace and toeslope landforms (table 2). Average conifer (73 percent) and alder (27 percent) basal areas between the medium floodplain (FPM) and small moderate gradient mixed control (MMS) channel types were strikingly similar.

Average total basal area, average conifer basal area, and average conifer QMD were higher on large floodplain (FPL) channel types than FPM and MMS channel types, but the average proportion of alder basal area on FPL channel types was higher (table 2). The lower average conifer size-density ratio on the FPL channels was driven by the average conifer QMD, as average densities were similar across channel types, but average conifer QMD was higher (table 2).

The stem density decreased from abundant small-diameter trees to less abundant larger diameter trees across all landforms illustrating the early successional diameter distribution in the stand (fig. 2). Small-diameter conifers were abundant on all landforms, though notably less abundant on floodplains compared to other landforms. Conifer stand density was higher on terraces than on other landforms within most diameter classes. Floodplain conifer diameter classes were the least variable. Alder diameter distributions differed from the conifer diameter distributions; the alder diameter distributions were bell-shaped and centered in the 20- to 30-cm diameter classes across all landforms (fig. 2). Alder density in the center of the distribution (20 to 30 cm) was highest on alluvial fan and toeslope landforms and lowest on terraces. Alders dominated the mid-sized (15 to 30 cm) diameter classes on the alluvial fans, whereas their distribution was more equal to conifers on floodplains (fig. 2). Conifer and alder height classes both tended toward normal bell-shaped distributions, illustrating a more rapid differentiation across conifer height classes than diameter classes within the stands. Alder height distributions had distinctive peaks in the 25-m height class on all landforms except on terraces (fig. 2). The lower alder density in this height class (25 m) on terraces also corresponded to a slightly higher conifer density compared to the other landforms.

## Stream Canopy Cover

Total percentage of canopy cover decreased with increasing alder basal area in riparian plots (fig. 3); the relationship was significant: $y = 81.98 + (-0.05 \times \text{alder basal area})$; $p < 0.01$. Total canopy cover decreased from 85 to 76 percent as alder basal area increased from 13 to 77 $m^2$/ha.

## Size-Density Model

The size-density ratio (TPH/QMD) of conifers along channel types at all sites ranged from 12.6 to 61.8 (table 1) and averaged 21 to 30 (table 2). The greatest variability in size-density ratio was found in the MMS channel type. The lowest size-density ratio occurred in a large floodplain (FPL) with 61 percent alder basal area (table 1). However, there were no clear associations between size-density ratio and channel type or amount of alder. The stand measurements did provide a range of stand conditions for comparison with late-seral size density (fig. 4). All the stands that we measured were in a narrow age range, so there was no clear pattern of stand differentiation toward the desired late-seral stand condition of a size-density ratio of about 10. There were two potential recovery trajectories from harvest where the stands followed either a linear or curvilinear progression toward late-seral conditions (fig. 4).

## Table 1—Site information for stream reaches in riparian forest stands sampled in southeast Alaska

| Site name | Channel type | Harvest date | PCT date | Total basal area | Conifer basal area[a] | Red alder basal area[b] | Conifer basal area | Red alder basal area | Conifer stand density | Conifer quadratic mean diameter | Conifer size-density ratio[c] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Year | | Square meters per hectare | | | Percent | | Trees per hectare | Centimeters | |
| Calvin Creek | MMS | 1971 | 1986 | 21.5 | 18.1 | 3.4 | 84 | 16 | 867 | 14.0 | 61.8 |
| Calvin Creek | FPM | 1971 | 1986 | 34.8 | 29.6 | 5.3 | 85 | 15 | 550 | 19.2 | 28.6 |
| Tye Creek | MMS | 1967 | 1984, 1988 | 28.9 | 24.7 | 4.2 | 85 | 15 | 383 | 17.7 | 21.7 |
| Hydra Creek | MMS | 1970 | 1986 | 27.2 | 27.0 | 0.2 | 99 | 1 | 992 | 17.6 | 56.4 |
| Orpheus Creek | MMS | 1973 | 1991 | 22.5 | 19.6 | 3.0 | 87 | 13 | 442 | 14.3 | 30.9 |
| Hanging Pipe Creek | MMS | 1967 | NR | 36.3 | 17.8 | 18.5 | 49 | 51 | 425 | 11.3 | 37.6 |
| Azalea Creek | MMS | 1960 | NR | 29.4 | 13.2 | 16.1 | 45 | 55 | 275 | 8.5 | 32.3 |
| Azalea Creek | FPM | 1960 | NR | 30.1 | 15.9 | 14.2 | 53 | 47 | 175 | 8.9 | 19.6 |
| Noxon Creek | FPL | 1965 | 2000 | 31.6 | 20.9 | 10.7 | 66 | 34 | 558 | 13.2 | 42.2 |
| Appleton Creek | FPL | 1965 | NR | 92.9 | 36.1 | 56.7 | 39 | 61 | 150 | 11.9 | 12.6 |
| Fish Creek | FPL | 1963 | 1990 | 37.4 | 29.0 | 8.4 | 78 | 22 | 242 | 11.7 | 20.7 |
| Coogan Creek | FPL | 1947 | NR | 56.0 | 44.7 | 11.2 | 80 | 20 | 500 | 15.3 | 32.7 |
| Maybeso Creek | FPM | 1962 | NR | 54.7 | 42.4 | 12.3 | 78 | 22 | 575 | 23.2 | 24.7 |

FPL = large floodplain, FPM = medium floodplain, MMS = small moderate gradient mixed control, NR = no record, PCT = precommercial thinning.

[a] Conifers include Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), and western redcedar (*Thuja plicata*).

[b] Red alder (*Alnus rubra*).

[c] The size-density ratio is the ratio of conifer stand density (trees per hectare) to conifer QMD (quadratic mean diameter).

Table 2—Average conifer and alder basal area and size-density ratio across all measured sectors by landform and channel type from riparian forests in southeast Alaska

| | Total basal area | Conifer basal area[a] | Red alder basal area[b] | Conifer basal area | Red alder basal area | Conifer stand density | Conifer quadratic mean diameter | Conifer size-density ratio[c] |
|---|---|---|---|---|---|---|---|---|
| **Landform** | SQUARE METERS PER HECTARE | | | PERCENT | | TREES PER HECTARE | CENTIMETERS | |
| Alluvial fan | 37.1 | 20.1 | 19.6 | 54 | 46 | 525 | 19.0 | 27.6 |
| Floodplain | 56.6 | 32.0 | 25.9 | 56 | 44 | 556 | 25.4 | 21.8 |
| Terrace | 44.9 | 34.4 | 11.0 | 77 | 23 | 693 | 23.6 | 29.4 |
| Toeslope | 34.0 | 24.8 | 9.6 | 73 | 27 | 632 | 21.2 | 29.9 |
| **Channel type** | | | | | | | | |
| FPM | 32.4 | 23.5 | 9.6 | 73 | 27 | 623 | 20.8 | 30.0 |
| FPL | 84.9 | 50.3 | 36.5 | 59 | 41 | 634 | 30.2 | 21.0 |
| MMS | 35.7 | 26.0 | 10.3 | 73 | 27 | 618 | 22.2 | 27.8 |

Values are averages across all the alluvial fan landforms and all the channel types, so there is some variation in the values along with the errors of the averages.

FPL = large floodplain, FPM = medium floodplain, MMS = small moderate gradient mixed control.

[a] Conifers include Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), and western redcedar (*Thuja plicata*).

[b] Red alder (*Alnus rubra*).

[c] The size-density ratio is the ratio of conifer stand density (trees per hectare) to conifer QMD (quadratic mean diameter).

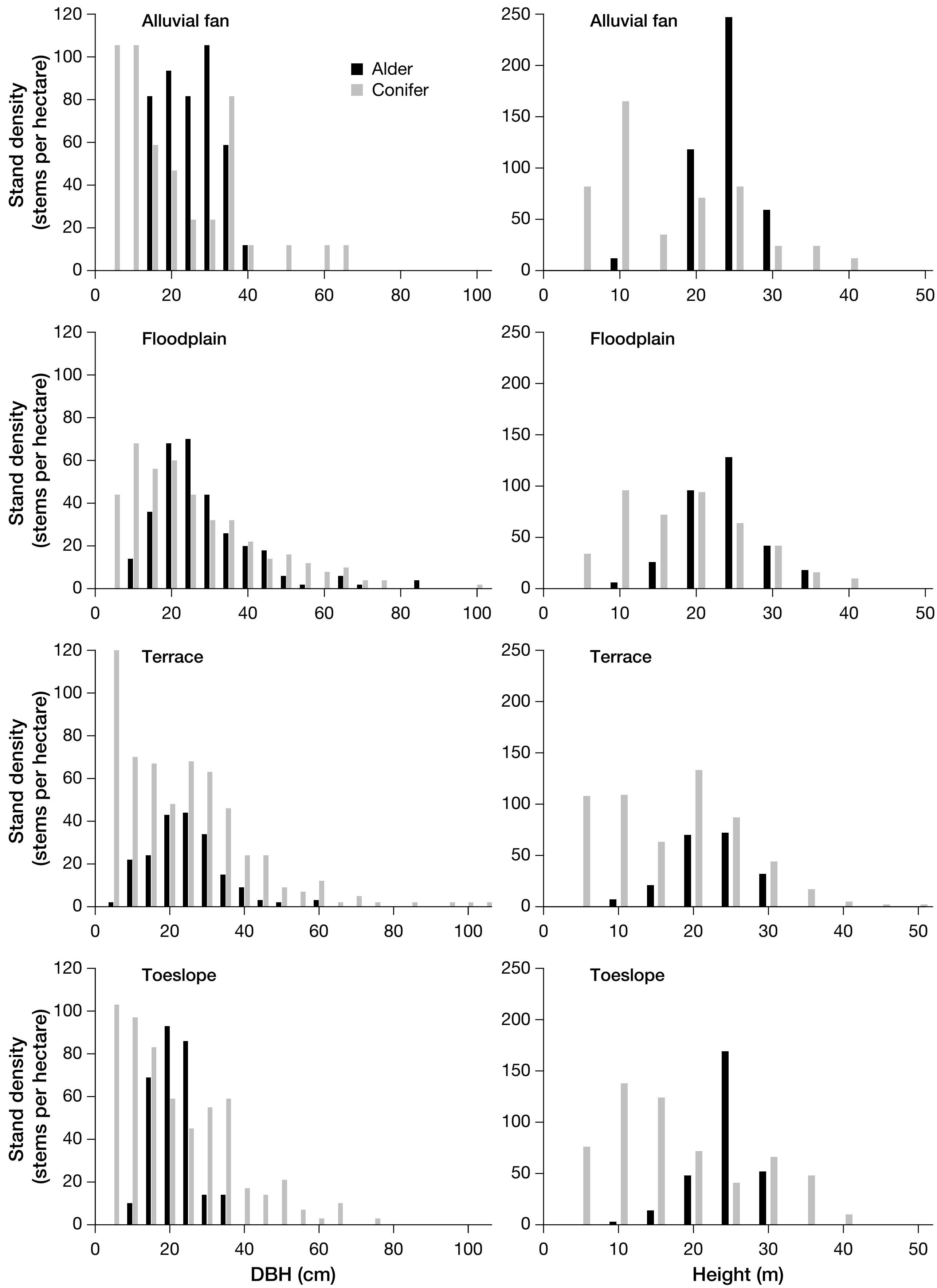


Figure 2—Conifer stand density by diameter at breast height (DBH) and height for four landforms in southeast Alaska. Conifers include Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), and western redcedar (*Thuja plicata*). Alder refers to red alder (*Alnus rubra*).

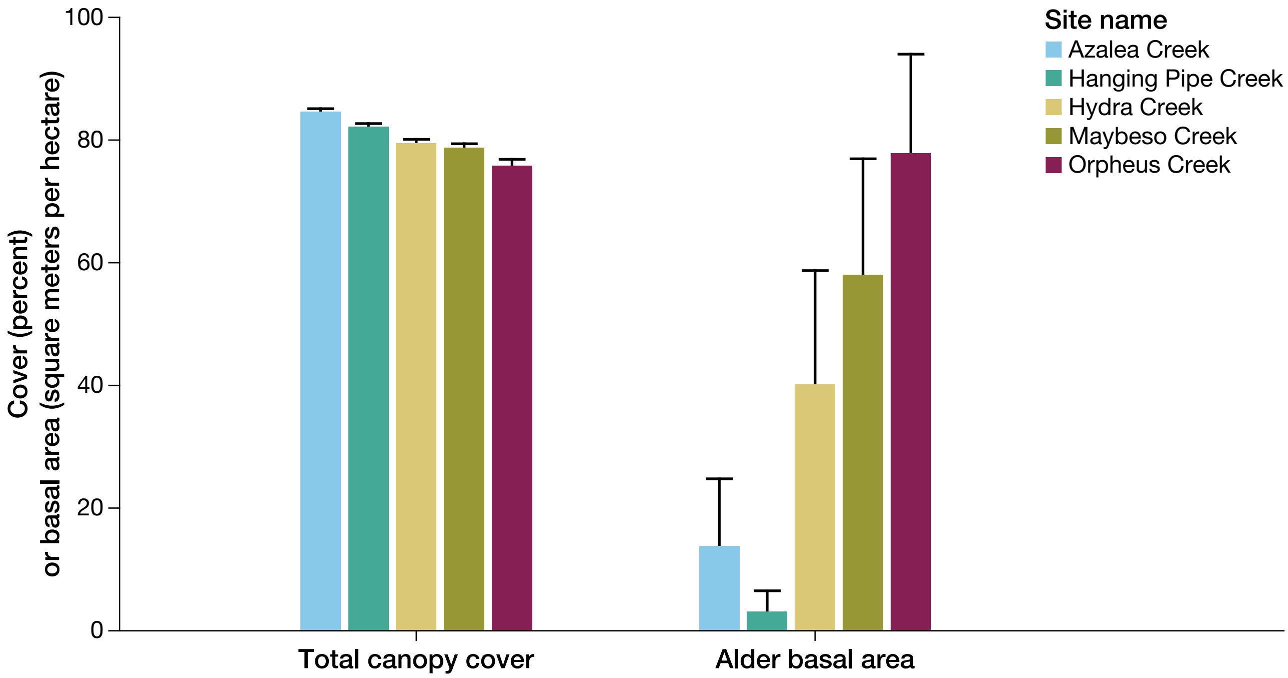


Figure 3—Relationship of total percentage of canopy cover to alder basal area in riparian stands in southeast Alaska. Canopy cover serves as an indicator of light transmittance in stands. Bars represent means, and whiskers are ± 1 standard error. Alder refers to red alder (*Alnus rubra*).

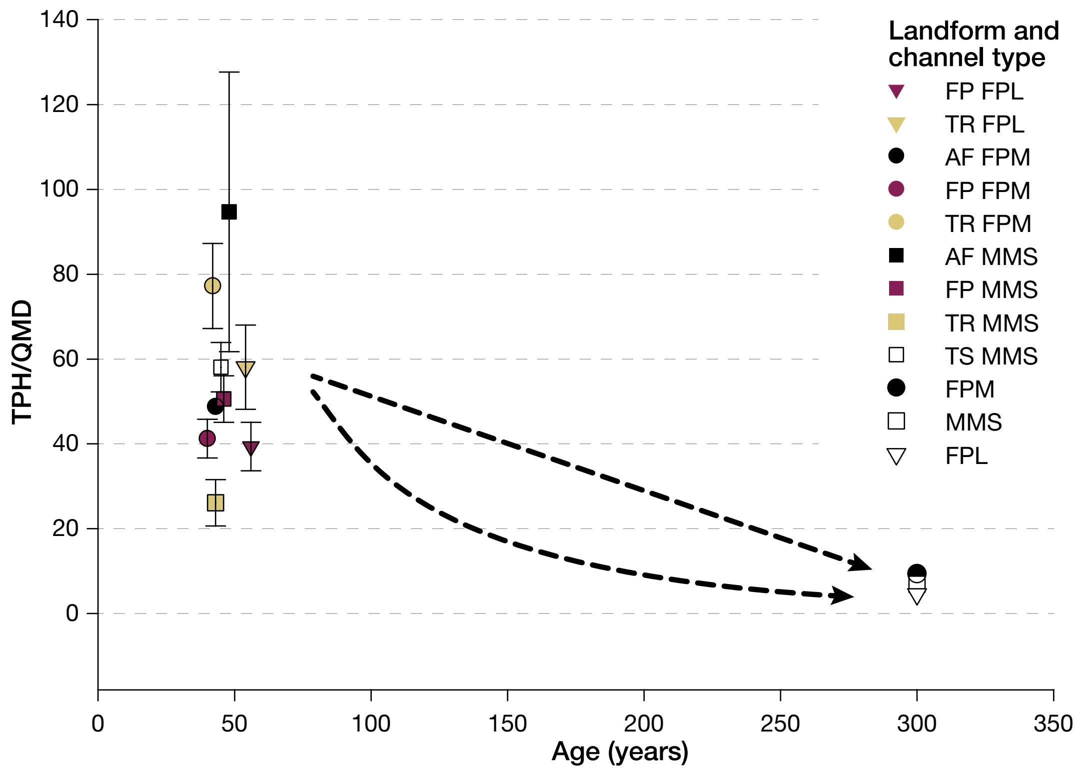


Figure 4—Size-density ratios calculated as trees per hectare (TPH)/quadratic mean diameter (QMD) by landform and channel type. Individual southeast Alaska riparian sites are identified by channel type. Values are averages, and whiskers are ± 1 standard error for TPH/QMD as a response to average stand age across all replicates of channel type and landform combinations. Size-density ratios at 300 years serve as a reference for late-seral conditions or desired future conditions (Johnson et al. 2006: see footnote 5) in reference sites along each channel type. Johnson et al. (2006) did not provide landform designations, so these values represent a combination of conditions in the future desired condition of riparian forest. Dashed lines represent two potential recovery trajectories: linear or curvilinear. AF = alluvial fan, FP = floodplain, FPL = large floodplain, FPM = medium floodplain, MMS = small moderate gradient mixed control, TR = terrace, TS = toeslope.

### Stand Basal Area Increment

Conifer stand BAI increased as stands recovered from harvest (fig. 5). However, the trajectory of the increase varied with both the presence of alder and precommercial thinning treatment. The Hydra Creek site (1 percent alder basal area) had a slight increase in stand BAI postharvest followed by an extended period with no notable change in stand BAI. The stand BAI at the Hydra Creek site increased after a thinning treatment and peaked at 4961 $mm^2$ 13 years after thinning (fig. 5a). Postharvest, the stand BAI increased steadily at the Calvin Creek site (15 percent alder basal area) but appeared to reach a period of slow increase until the thinning treatment when the increase in stand BAI accelerated and peaked at 3973 $mm^2$ 17 years after thinning (fig. 5b). The stand BAI at the Azalea Creek site (56 percent alder basal area) increased steadily postharvest without any thinning treatment and peaked at 3887 $mm^2$ 27 years after harvesting (fig. 5c). Overall, the stand BAI increased in all stands from values <500 $mm^2$ to an apparent asymptote around 4000 to 5000 $mm^2$. Preharvest stand BAI values are from residual trees that were present before harvest.

### Conifer Release

The experimental (untreated) plot trees comprised most of the total basal area in the conifer release sites, while the release trees made only small contributions to total basal area (fig. 6). The conifer release signal was clear at most sites, with a distinct upward trend in BAI after the treatment. The best response was at the Lower Harris River site, which had a substantial and sustained increase in BAI after the treatment. The basal area contribution from the release trees nearly matched the BAI of the plot trees by the end of the observations. The release trees at Camp Creek reached a higher BAI than the experimental plot trees soon after the treatment. The Camp Creek site had the lowest stand-level BAI, so even though there was a more modest gain in release tree BAI, it matched and exceeded the overall stand-level BAI. Both the Upper Harris River and Azalea Creek sites had evident responses to the treatment, and the release tree BAI was approaching that of the entire stand (fig. 6).

# Discussion

### Landform Influence on Riparian Stand Conditions

Landform influences riparian stand development by affecting the amount and duration of waterflow, sediment accumulation, and soil development. Although all landforms supported mixed species stands, the combination of fluvial and clearcut harvest disturbances increased alder presence more on floodplain and alluvial fan landforms than on toeslope and terrace landforms. The increased conifer abundance on the less disturbed surfaces is consistent with the habitat preferences of alder and observations in other riparian zones (Pabst and Spies 1999). Clearcut harvest in southeast Alaska is typically followed by prolific natural regeneration of conifers, which creates closed canopies within 15–25 years with numerous trees of uniform diameter and height (Alaback 1982, Deal and Farr 1994, Deal et al. 1991). Because of the lack of light, low structural diversity, and lower individual tree volume accumulation, conifer stands usually require a silvicultural thinning to improve stand health and biodiversity (USDA FS 2014).[6]

Where alder and conifer are both present in a stand, overall tree density is lower, individual conifers are larger (Deal 1997, Deal et al. 2004), and understory cover is higher (Hibbs and Bower 2001). These attributes of mixed species riparian stands facilitate a more direct recovery trajectory from clearcut harvest to stand structural diversification (Hanley and Hoel 1996) and a favorable distribution of large conifers within the upper canopy (Deal et al. 2004). Abundant alder on floodplain and alluvial fan landforms has a greater influence on conifer growth than on terrace and toeslope landforms.

In riparian forest stands, larger diameter trees are spaced more widely than in upland stands, which creates lower overall volume production but enhances growth of the largest trees (Deal et al. 2004). The most desirable condition for the growth of large-diameter conifers in riparian stands is equal stem densities of conifer and alder (Deal et al. 1997). The stands in this study all reached their maximum size-density ratio either through

[6] See footnote 1.

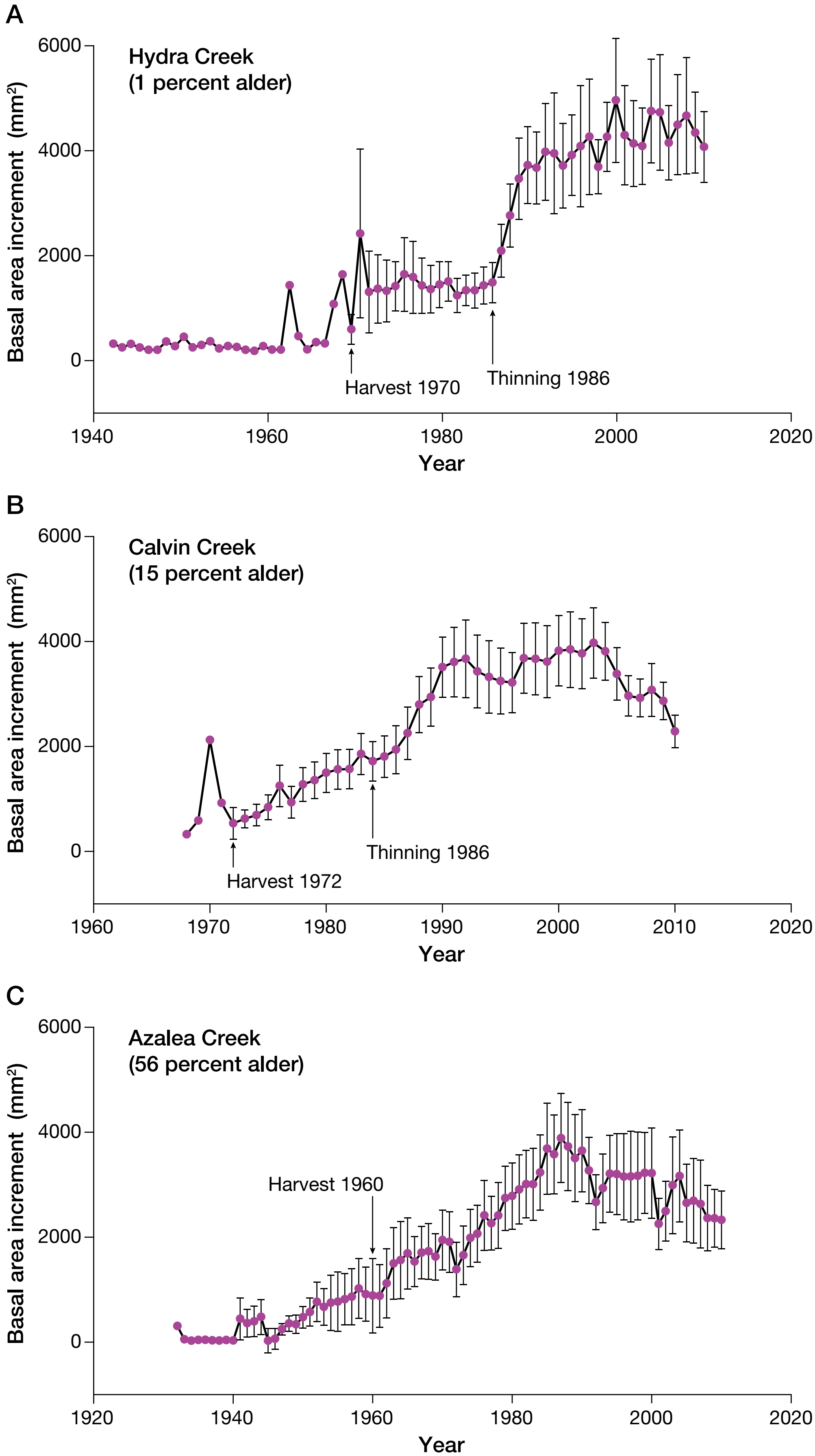


Figure 5—Conifer stand basal area increment for three sites across a gradient of alder density, (a) Hydra Creek, (b) Calvin Creek, and (c) Azalea Creek. Dates of harvest and precommercial thinning are noted to highlight stand disturbance. Sites are arranged in order of increasing alder basal area from top to bottom. Symbols are basal area increment, and whiskers are ± 1 standard error.

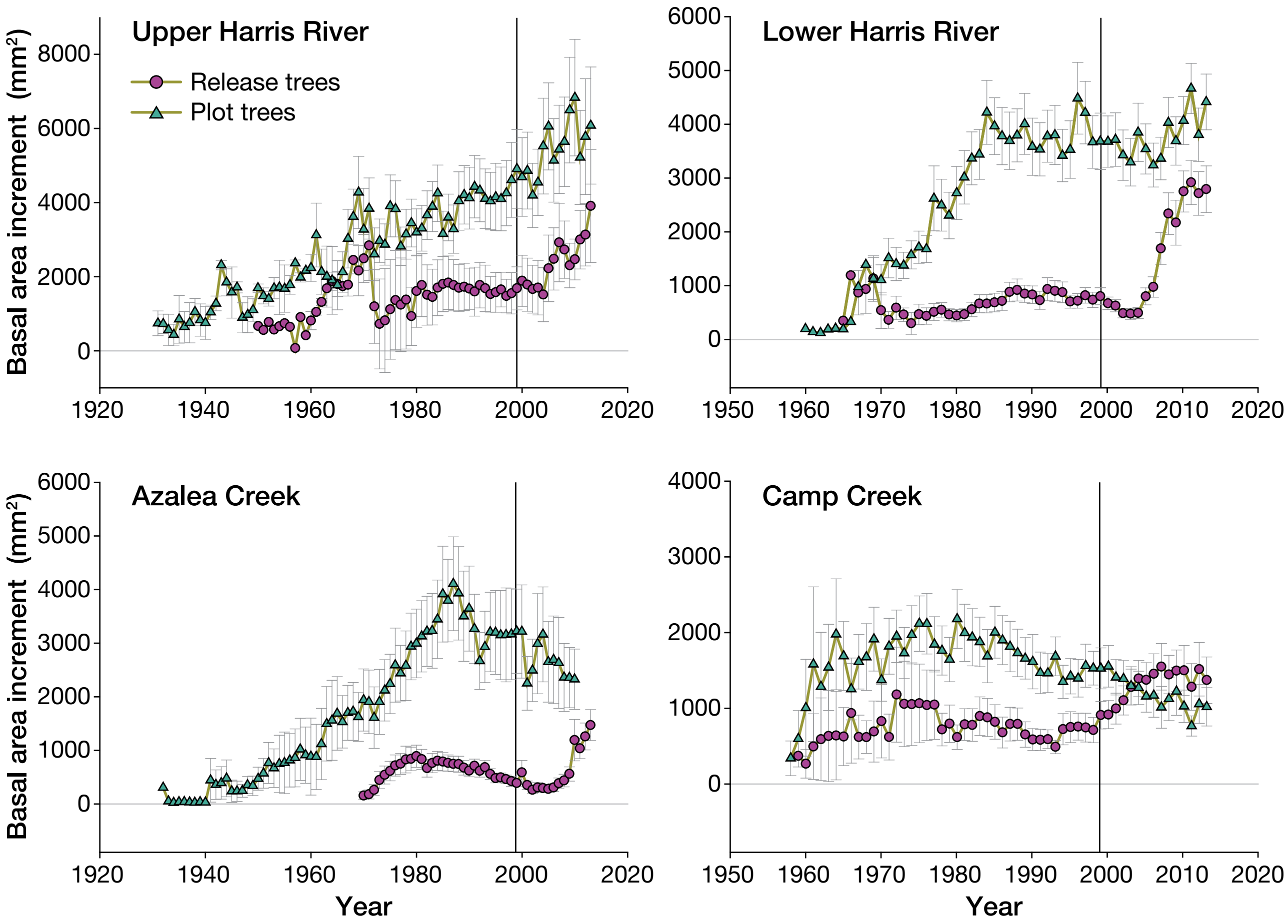


Figure 6—Comparison of conifer basal area increment between experimental (untreated) plot trees and release trees at four riparian stands treated in 1999 (as indicated by the vertical line). Data points are average annual ring-width interval converted to basal area for each year of core measurement across all experimental plot and release trees at the site. Whiskers are ± 1 standard error.

the natural distribution of alders and conifers, or through thinning treatments. Alder thinning has little effect on the growth of large conifers (Orlikowska et al. 2004), so an adequate number of dominant or codominant conifers growing with alder improves overall conifer development. Within all stands, removing competing conifers with precommercial thinning benefits conifer-dominated stands, but retaining alder in mixed species stands does not affect conifer growth.

Alder reaches its site potential tree height (about 25 m) on all landforms, whereas conifers have a greater potential to overtop alder as they grow toward their site potential tree height (about 40 m). Alluvial fans have the least optimal growth conditions for large conifers because alder suppresses conifer for an extended period. The height relationship on toeslopes is similar, but because alder density is much lower, suppression of conifers over a longer period is unlikely before the conifers achieve more height growth. Conifers on terraces are clearly in the best situation for differentiation to a future conifer-dominated stand. Alder presence decreased the conifer volume on all landforms but not the total stand volume. Notably, the conifers growing with alder had similar QMD and a more favorable size-density ratio on terraces. Therefore, favorable conifer growth across the landforms with codominant alder-conifer is consistent with previous measurements of mixed stands where the presence of alder did not influence the size of conifers (Deal et al. 2004).

The diameter and height trends indicate that the stands will achieve larger conifer growth despite a period of codominance with alders. The greater height potential and access to light for continued height growth allow conifers to ultimately dominate the alders in the riparian stands. Alders have a lifespan of about 80–120 years (Newton and Cole 1994), whereas conifers generally live much longer than 100 years, and therefore, the longer lived conifers will eventually dominate the stand.

The diameter growth of conifers will also increase when their canopies expand above the alders. The distribution of diameters and heights on floodplains, terraces, and toeslopes indicates that the riparian stands are on a favorable recovery trajectory toward large, widely-spaced conifers, which is the desired future late-seral riparian structure.

## Benefits of Mixed Species Stands

Enhancing the development of conifers through thinning has been a common silvicultural practice (Oliver and Larson 1990). However, thinning alder to enhance conifer growth does not consider the other beneficial functions of alder in riparian ecosystems. Alder presence during early stand initiation may benefit conifer growth over the long term by controlling the physical spacing of conifers and adding nutrients to the soils (Bormann and Sidle 1990, Deal et al. 2004). Across most landforms, conifer densities appear adequate to provide large-stature conifers in the future; therefore, removing alder is not necessary and may reduce several important effects of alder on riparian ecosystems aside from their benefits to conifers. Alder-conifer mixtures enhance light penetration to the forest floor and promote greater understory diversity and abundance (Hanley and Barnard 1998, Hanley and Hoel 1996). Alders also add available nitrogen to a soil system where conifers are often nitrogen limited because of nitrogen loss through leaching and denitrification and competition with microbial communities (Bisbing and D'Amore 2018, Bormann and Sidle 1990).

Alders benefit streams flowing through riparian forests by reducing canopy cover, increasing nitrogen inputs, and providing high-quality, allochthonous organic matter—material derived from outside the stream channel—from litterfall to support stream food webs. The litter decomposes and provides food for stream invertebrates (Kominoski et al. 2011, Wipfli and Musslewhite 2004). Reduced canopy cover and increased light to the stream surface is associated with increased algal primary production (Walter 1984). Therefore, alder in stands influences nutrient turnover and ecosystem productivity in both the soil and water across all landforms. The benefits of alder overall compel careful consideration before thinning of alder basal area under any condition.

## Management Options

Mixed species riparian stands may offer the greatest potential to achieve old-growth characteristics by influencing stand structure and the trajectory of stand development. Structural attributes of young-growth stands can achieve old-growth character in as little as 112 years, but most need 200–250 years (Gerzon et al. 2011). Mixed species stands vary in their response to natural conditions and thinning depending on context and location, offering opportunities to balance passive and active restoration to increase favorable outcomes and reduce costs. The lack of an observed consistent benefit through active restoration by thinning highlights a potential financial advantage of passive restoration (Jones et al. 2018). The size-density structure and volume accumulation of individual conifer trees in mixed species stands on terrace and toeslope landforms meet restoration goals to accelerate the future supply of large woody debris to streams under a passive restoration scenario. Increases in basal area increment in stands with more alder enhance conifer growth without stand thinning, supporting a passive restoration approach in these types of stands. Passive restoration on alluvial fans and floodplains may not be as effective because of poor substrate conditions impeding conifer growth and persistence, and competition by alder. Although active approaches may be more beneficial on these landforms, these stands may not respond well to thinning or tree release. It is important to consider the effects of soil conditions that may be inhibiting conifer growth on these landforms because of the mass movement of sediment during debris flows that leads to poor surface drainage and coarse, platy soils.

A size-density model within the framework of existing conditions bolsters the confidence in the trajectory of recovery and provides a monitoring tool for regional riparian restoration programs. This metric can assess current stand conditions and the progress of stand development toward the late-seral conditions that are found in natural settings. Restoration is designed to maintain or restore the desired biological and physical attributes of affected systems to enhance the integrity and function of ecosystems. Our understanding of riparian stand development after about 50 years provides valuable guidance on the variation of stand attributes, the benefits of mixed species stands, and the management options after recovery from clearcut harvest.

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## Data Availability

In late 2026, these data will be accessible through the USDA Forest Service Research Data Archive at https://doi.org/10.2737/RDS-2026-0011.

# Appendix 1: Potential Treatment Options

Potential treatment options for alluvial landforms and young-growth vegetation conditions across riparian zones in southeast Alaska.

| Geomorphic surface | Existing vegetation | Natural flooding frequency | Potential natural vegetation[a] | Desired future condition plant association and attributes | Potential prescription(s)[b] |
|---|---|---|---|---|---|
| Low floodplain | Alder | 1 to 5 years | Variable PA depending on site, PA 350, 380 or 395 likely | PA 350, 380, or 345 | Riparian 1. Select stable microsites and sites with historic conifer indicators for conifer release or establishment. Multiple brush control efforts may be necessary for conifer release. Accept alder percentages depending on PNV PA and develop a long-term plan to achieve those percentages. Consider need to import large wood to provide germination or planting sites for conifers. |
| Low floodplain | Mixed alder-conifer, assumption: conifer is on stable microsites | 1 to 5 years | Variable PA depending on site, PA 350, 380 or 395 likely | PA 380 | Riparian 2. Thin dense conifer thickets to 16 by 16 +50 percent.[c] Select the most vigorous Sitka spruce for retention or release. In alder-dominated areas, release spruce on stable microsites. Work toward alder percentages described in the PA PNV. |
| Low floodplain | Conifer-dominated | 1 to 5 years | May not exist in young-growth stands but was common in old-growth stands | Rare | Similar to Riparian 2, but instream large wood placement may return the site to high flood frequency or make some sites more stable for conifer establishment. |
| High floodplain | Conifer- dominated | 5 to 100 years | PA 310 but possibly others | PA 310 within the RMA. WL and TM outside the RMA. Consider need for RAW buffer beyond the RMA. | Riparian 3. Thin to a 16 by 16 + 50 percent, selecting a mix of the most vigorous spruce and hemlock trees. Work toward the stand structure and species composition described for PA 310. Do not place canopy gaps on relic channels. For inactive alluvial soil areas beyond 130 feet plus RAW (beyond RMA), canopy gaps and limited alder composition may be appropriate depending on LUD and IDT input. |
| High floodplain | Alder and mixed alder-conifer | 5 to 100 years | PA 310 but likely other spruce and hemlock types | PA 310 within the RMA and TM or WL for the remainder depending on LUD. Consider need for RAW buffer beyond the RMA. | Similar to Riparian 3. For inactive alluvial soil areas beyond 130 feet plus RAW (beyond RMA), canopy gaps and limited alder composition may be appropriate depending on LUD and IDT input. |
| Alluvial fan | Alder or mixed alder-conifer | 2 to 100 or more years | PA 330 is likely on the active portion, inactive portion can be either spruce or hemlock series | PA 330 on the active portion of the fan. | Active portion of the fan: prescription similar to Riparian 1 but aim for PA 330. Inactive portion of the fan: prescription similar to Riparian 3. |

Note: Alder refers to red alder (*Alnus rubra*).

IDT = interdisciplinary team, LUD = land use designation, PA = plant association, PNV = potential natural vegetation, RAW = reasonable assurance of windfirmness, RMA = riparian management area, TM = timber management, WL = wilderness LUD.

[a] Interpretation can be inferred from historical air photos and relic indicators, such as stumps. Plant associations are from DeMeo et al. (1992) and Martin et al. (1995).

[b] Potential prescriptions should be considered a starting point. Adjustment/changes to prescriptions should always be made dependent upon actual site conditions. Always manage conifers in riparian areas for a height to diameter ratio of 80 or less to withstand snow loads and competition (Emmingham et al. 2000). Potential prescriptions listed are for the first treatment post natural regeneration following clearcut harvest. Subsequent treatment(s) need to be tailored to move the stands toward desired future conditions identified in table 2.

[c] This means thin trees to a spacing of about 16 feet apart and remove an additional 50 percent of remaining trees after initial thinning.

Source: Adapted from U.S. Department of Agriculture, Forest Service. 2014. Tongass Young growth management strategy. On file with: USDA Forest Service, Pacific Northwest Research Station, 11175 Auke Lake Way, Juneau, AK 99801.

# Appendix 2: Riparian Restoration Stand Exam Field Protocol and Field Data Sheet

## Riparian Restoration Stand Exam Field Protocol

### Purpose

The riparian restoration stand exam is designed to quickly categorize riparian stands according to their current and potential effects on stream ecosystems. In particular, the survey is intended to complement ongoing riparian restoration potential surveys in southeast Alaska. The survey relies on visual estimation to assign overstory and understory communities to predefined classes and make a preliminary decision regarding the need for treatment.

### Site Selection

This survey is meant as an addition to ongoing restoration assessments conducted by Tongass National Forest personnel. As such, the site selection will be determined by their metrics. In general, targets are 20- to 40-year-old, harvested stands in riparian management areas. Currently, restoration projects are focused on floodplain, moderate gradient mixed control, and alluvial fan channel types (Johnson et al. 2006,[1] Kelliher 2010).

### Required Equipment

This survey is designed to serve as an alternative to large investments of time and expense that are required to implement stand measurements for accurate quantitative evaluation of riparian stands. No vegetation sampling gear is required, although a field tape may be useful for measuring stand density and landform dimensions. Some data from geographic information system layers are required to complete the form but are not necessary for the decision support. Key information needs are **stand age** and the **Tongass National Forest soils layer** and **stream channel type**.

## Field Data Collection

### General

**Reach ID:** A unique identifier for the survey reach, which should correspond with applicable geographic information system/Global Positioning System data, photos, and additional collected information.

**Date:** Date of field survey.

**Stand age:** Years since harvest.

**Crew:** Names/initials of field crew collecting data.

**SMU (soil type):** Soil mapping unit; includes the region code. In the Tongass National Forest soils layer, this is the code in the **FOR_SMU** field and is typically a number and letter code (e.g., 510D, 531CDX).

**Channel type (mapped):** Tongass National Forest channel type (Kelliher 2010). This is the channel type as mapped.

**Channel type (field):** Tongass National Forest channel type (Kelliher 2010). This is the channel type determined by the observations of the field crew.

**Landform:** As determined by the observations of the field crew: alluvial fan (AF), floodplain (FP), or other.

### Zone 1/Zone 2

Zones are intended to allow for clear differences in vegetation communities within a reach, either along or perpendicular to the stream. Typically, underlying soil and geomorphic and hydrologic differences define zones. Examples include: a small but well-developed floodplain immediately adjacent to the stream with a hillslope beyond, or a Tonowek/Tuxekan soil geomorphic assemblage. To capture these differences, if present, use additional zones and include a sketch of the reach in the notes, including approximate dimensions. If additional zones are needed, or if the channel type itself changes significantly, additional data sheets may be used. In this case, be sure to clearly label the sheets as "Page__ of __" by the reach ID.

### Overstory/Understory Trees

Separate classifications are made for overstory and understory trees. The overstory is defined here as the uppermost layer of branches and foliage formed by most trees in the dominant size class. Understory trees are those that do not reach into the canopy (suppressed and intermediate canopy classes).

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[1] Johnson, J.; Krosse, P.; Paustian, S.; Parks, R.D.; Paul, T.; Turner, R. 2006. Riparian young growth emphasis. On file with: USDA Forest Service, Pacific Northwest Research Station, 11175 Auke Lake Way, Juneau, AK 99801.

**Composition**: This refers to area of foliage cover. Cover can be visualized as the area of ground covered by the foliage of the species in question. Percent cover is the percentage of total cover contributed by a species or species group (alder/conifer).

- **Conifer—**Canopy is >90 percent conifer.
- **Conifer/alder—**Canopy is 50–90 percent conifer.
- **Alder/conifer—**Canopy is 50–90 percent alder.
- **Alder—**Canopy is >90 percent alder.

**Density:** The average distance between stems of at least 2.5-cm diameter at breast height. This can be quickly estimated by arm spans (about 2 m).

- **Low—**Average spacing between stems is >8 m.
- **Medium—**Average spacing between stems is 3–8 m.
- **High—**Average spacing between stems is 2–3 m.

## Understory Vegetation

Understory, nontree vegetation is broken into three classes based loosely on growth form: **ground cover** (e.g., bunchberry dogwood [*Cornus canadensis*], false lily of the valley [*Maianthemum dilatatum* (Alph. Wood) A. Nelson & J.F. Macbr.], deer fern [*Blechnum spicant* (L.) Sm.]); **large herbs** (e.g., American skunk cabbage [*Lysichiton americanus* Hultén & H. St. John], green false hellebore [*Veratrum viride* Aiton], twistedstalk [*Streptopus* Michx. spp.], large ferns); and **woody shrubs** (e.g., oval-leaf blueberry [*Vaccinium ovalifolium* Sm.], salmonberry [*Rubus parviflorus* Nutt.], red elderberry [*Sambucus racemosa* L.], devilsclub [*Oplopanax horridus* (Sm.) Miq.]). Each of these three classes is assigned an abundance category based on ground cover (see "Overstory/Understory Trees").

- **Low—**<20 percent cover. Ground is primarily bare. Large herbs and woody shrubs appear as isolated individuals or patches if present. Understory vegetation is significantly less developed than would be expected in late-seral/climax communities.
- **Medium—**20–80 percent cover. Ground cover is abundant and well distributed, but patches of bare ground are also present. Large herbs and woody shrubs are also abundant and well distributed. Understory vegetation may impede movement locally. Dense patches may alternate with more open areas. Wildlife browse is abundant. This class encompasses many conditions found in late-seral/climax upland communities.
- **High—**>80 percent cover. Ground cover is ubiquitous; bare patches are rare. Large herbs and woody shrubs are very dense. Understory vegetation will significantly impede movement and obstruct line of sight if head-height shrubs are present. These are the densest stands generally encountered in field work, such as *Sambucus/Rubus* "jungles" and extremely thick *Vaccinium* patches.

## Treatment

A composition of overstory "conifer" designation combined with either "medium" or "high" density will be classified as a "GO" for treatment. Any other combination will be a "NO GO." Note that this is a preliminary screening decision and may need further assessment.

## Notes and Sketch

Please take the time to write some notes for each reach. Consider adding the following information to this section:

- A description of the **form, shape,** and **configuration** of the stand (e.g., "alder-dominated canopy but very dense spruce understory, vegetation is mostly small ground cover," "doghair conifer, moonscape understory")
- A **sketch** of the reach if necessary to capture heterogeneity
- Notes on the presence of **cedar**, type of **substrate** (cobble? wetlands?), or significant **deviations** from the semiquantitative classes described above
- A **photo reference** if applicable
- **Anything interesting** not captured by the data sheet fields

### Photos

Digital photos of the surveyed reaches may prove helpful but are not yet a part of this protocol. On initial surveys, crews could take several photos of each stand to later assess the usefulness of the technique. It is crucial to be able to reference the photos to the proper reach; one technique that has been used successfully is to preface each set of photos with a picture of a field book with the date and reach ID written in large, easily read letters. This portion of the protocol may be revisited at a later date.

### Quality Assurance/Quality Control and Data Storage

Because this protocol depends largely on visual estimation and semiquantitative assessment, it is important for field crews to be calibrated and consistent in their estimations. Communication among crews and crew members is crucial to develop consistency between operators and to check assumptions. Likewise, crews should use field tapes initially for density estimations, and then periodically to confirm their estimates.

## Riparian Restoration Stand Exam Field Data Sheet

**Reach ID** ____________________ **Date** ____________________

**Stand age** ____________________ **Crew** ____________________

**SMU** (soil type) ____________________ **Channel type** (mapped) ____________________

**Landform:** AF / FP / other ____________________ **Channel type** (field) ____________________

### Zone 1

| | | | | |
|---|---|---|---|---|
| **Overstory trees** | | | | |
| **Composition** (circle one) | Conifer | Conifer/alder | Alder/conifer | Alder |
| **Density** (circle one) | Low | Medium | High | |
| **Understory trees** | | | | |
| **Composition** (circle one) | Conifer | Conifer/alder | Alder/conifer | Alder |
| **Density** (circle one) | Low | Medium | High | |
| **Understory vegetation** | | | | |
| **Ground cover** (circle one) | Low | Medium | High | |
| **Large herbs** (circle one) | Low | Medium | High | |
| **Woody shrubs** (circle one) | Low | Medium | High | |
| **Treatment** (circle one) | GO | NO GO | | |

### Zone 2 (if applicable)

| | | | | |
|---|---|---|---|---|
| **Overstory trees** | | | | |
| **Composition** (circle one) | Conifer | Conifer/alder | Alder/conifer | Alder |
| **Density** (circle one) | Low | Medium | High | |
| **Understory trees** | | | | |
| **Composition** (circle one) | Conifer | Conifer/alder | Alder/conifer | Alder |
| **Density** (circle one) | Low | Medium | High | |
| **Understory vegetation** | | | | |
| **Ground cover** (circle one) | Low | Medium | High | |
| **Large herbs** (circle one) | Low | Medium | High | |
| **Woody shrubs** (circle one) | Low | Medium | High | |
| **Treatment** (circle one) | GO | NO GO | | |

**Notes and sketch**
General impression; Cedar? Wetlands? Deviations from classes? Sketch of reach if significantly heterogeneous

# Cheat Sheet

## General

**Age: Stand age—**from existing silviculture data

**SMU: Soil management unit—**FOR_SMU in Tongass National Forest soils layer, usually a number and letter code e.g., 510D

**Landform: Based on field assessment—**alluvial fan (AF), floodplain (FP), or other

**Channel type (mapped)—**Tongass National Forest stream channel type, new style, as mapped

**Channel type (field)—**Tongass National Forest stream channel type, new style, as determined by the observations of the field crew

## Overstory/Understory Trees

**Composition:**

- Conifer—Canopy is >90 percent conifer. Alders may be present in small numbers throughout the stand, but the overall structure is predominately conifer.
- Conifer/alder—Canopy is 50–90 percent conifer. Alders are present, evenly mixed throughout the canopy or concentrated in microsites.
- Alder/conifer—Canopy is 50–90 percent alder. Conifers are well established in the canopy and may be starting to break through.
- Alder—Canopy is >90 percent alder (percent cover). Conifer may exist in the understory, but few, if any, have reached the canopy. Note if conifers are abundant in the understory.

**Density**: Average spacing between stems of at least breast height (1.3 m) and at least 2.5 cm diameter. If there are clear differences between size classes, record that in the notes (e.g., "overstory is low density, but there is a high-density population of regenerating spruce").

- Low—Average spacing between stems is >8 m.
- Medium—Average spacing between stems is 3–8 m.
- High—Average spacing between stems is 2–3m.

## Understory Vegetation

**Classes:**

- Ground cover—Bunchberry dogwood (*Cornus canadensis L.)*, false lily of the valley (*Maianthemum dilatatum* (Alph. Wood) A. Nelson & J.F. Macbr.), deer fern (*Blechnum spicant* (L.) Sm.), etc.
- Large herbs—American skunkcabbage (*Lysichiton americanus* Hultén & H. St. John), green false hellebore (*Veratrum viride* Aiton), twistedstalk (*Streptopus* Michx. spp.), large ferns, etc.
- Woody shrubs—Oval-leaf blueberry (*Vaccinium ovalifolium* Sm.), salmonberry (*Rubus parviflorus* Nutt.), red elderberry (*Sambucus racemosa* L.), devilsclub (*Oplopanax horridus* (Sm.) Miq.), etc.

**Abundance:**

- Low—<20 percent cover. Ground is primarily bare. Large herbs and woody shrubs appear as isolated individuals or patches if present. Understory vegetation is significantly less developed than would be expected in late-seral/climax communities.
- Medium—20–80 percent cover. Ground cover is abundant and well distributed, but patches of bare ground are also present. Large herbs and woody shrubs are also abundant and well distributed. Understory vegetation may impede movement locally. Dense patches may alternate with more open areas. Wildlife browse is abundant. This class encompasses many conditions found in late-seral/climax upland communities.
- High—>80 percent cover. Ground cover is ubiquitous; bare patches are rare. Large herbs and woody shrubs are very dense. Understory vegetation will significantly impede movement and obstruct line of sight if head-height shrubs are present. These are the densest stands generally encountered in field work, such as Sambucus/Rubus "jungles" and extremely thick Vaccinium patches.

### Treatment

A composition of overstory "conifer" designation combined with either "medium" or "high" density will be classified as a "GO" for treatment. Any other combination will be a "NO GO." Note that this is a preliminary screening decision and may need further assessment.

### Notes and Sketch

Consider adding the following information to this section:

- A description of the form, shape, and configuration of the stand (e.g., "alder-dominated canopy but very dense spruce understory, vegetation is mostly small ground cover," "doghair conifer, moonscape understory")
- A sketch of the reach if necessary to capture heterogeneity
- Notes on the presence of cedar, type of substrate (cobble? wetlands?), or significant deviations from the semiquantitative classes described above
- A photo reference if applicable
- Anything interesting not captured by the data sheet fields

## Appendix 3: Species List

| Common name | Scientific name and authority |
|---|---|
| Alaska cedar | *Callitropsis nootkatensis* (D. Don) Oerst. ex D.P. Little |
| American skunk cabbage | *Lysichiton americanus* Hultén & H. St. John |
| Bunchberry dogwood | *Cornus canadensis* L. |
| Deer fern | *Blechnum spicant* (L.) Sm. |
| Devilsclub | *Oplopanax horridus* (Sm.) Miq. |
| False lily of the valley | *Maianthemum dilatatum* (Alph. Wood) A. Nelson & J.F. Macbr. |
| Green false hellebore | *Veratrum viride* Aiton |
| Oval-leaf blueberry | *Vaccinium ovalifolium* Sm. |
| Red alder | *Alnus rubra* Bong. |
| Red elderberry | *Sambucus racemosa* L. |
| Red huckleberry | *Vaccinium parvifolium* Sm. |
| Rusty menziesia | *Menziesia ferruginea* Sm. |
| Salmonberry | *Rubus spectabilis* Pursh |
| Sitka spruce | *Picea sitchensis* (Bong.) Carrière |
| Stink currant | *Ribes bracteosum* Douglas ex Hook. |
| Twistedstalk spp. | *Streptopus* Michx. |
| Western hemlock | *Tsuga heterophylla* (Raf.) Sarg. |
| Western redcedar | *Thuja plicata* Donn ex D. Don |

## U.S. Standard Equivalents

| When you know: | Multiply by: | To find: |
|---|---|---|
| Millimeters (mm) | 0.0394 | Inches |
| Centimeters (cm) | 0.394 | Inches |
| Meters (m) | 3.28 | Feet |
| Hectares (ha) | 2.47 | Acres |
| Square millimeters ($mm^2$) | 0.00155 | Square inches |
| Square meters ($m^2$) | 10.76 | Square feet |
| Square meters per hectare ($m^2$/ha) | 4.37 | Square feet per acre |
| Trees per hectare | 0.405 | Trees per acre |
| Degrees Celsius (°C) | 1.8 °C + 32 | Degrees Fahrenheit |

**Pacific Northwest Research Station**

| | |
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| **Website** | https://research.fs.usda.gov/pnw |
| **Telephone** | (503) 808-2100 |
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USDA Forest Service
1220 SW 3rd Ave., Suite 1400
Portland, OR 97204