Site Index of Balsam Poplar/Western Black Cottonwood in Interior and Southcentral Alaska

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ABSTRACT: *Stem analysis data were obtained from 268 balsam poplar (*Populus balsamifera *L.) and black cottonwood (*P. trichocarpa *Torr. & Gray) trees on 67 sites in interior and southcentral Alaska during 1988–1990 for the purpose of height and volume growth analysis. A modified form of the Chapman-Richards growth model was used to produce polymorphic site index curves. Wide variations in curve shape, which were evident in region-to-region comparisons, required stratification of the data. Site index curves for balsam poplar north of the Alaska Range were produced using one equation and data from 35 sites. The remaining 32 sites, located south of the Range, were divided by landform (fluvial vs. upland). Sites on the middle and upper Susitna and Chulitna Rivers were placed in a separate fluvial class, giving three equations for sites south of the Range. The four equations produce the first polymorphic site index curves for poplars in Alaska. North. J. Appl. For. 15(4):174–181.*

Reduced access to forest fiber in the 48 contiguous United States and western Canada has prompted the forest products industry to look to the North for new sources of wood fiber. Interior and southcentral Alaska contain a vast forest fiber resource. Growing stock volume of trees 5.0 inches and greater is estimated to be 14.25 billion ft^3; nine percent or approximately 1.3 billion ft^3 of the growing stock is balsam poplar (*Populus balsamifera* L.) and black cottonwood (*P. trichocarpa* Torr. & Gray) (Hutchinson 1967).

Hultén (1968) describes balsam poplar as an interior species and black cottonwood as primarily coastal. The two are recognized as subspecies by some (Brayshaw 1965, Viereck and Foote 1970). However, hybrid trees can be found in either environment. The two hybridize extensively in Alaska where their ranges overlap (Brayshaw 1965, Viereck and Foote 1970). Poplars are primarily early successional species. In Alaska they most commonly are found colonizing recently deposited river alluvium. Floodplain balsam poplar forests are the most productive forests in interior Alaska (Zasada et al. 1983).

The information base for balsam poplar and black cottonwood is limited when compared to the other commercial species [white spruce (*Picea glauca* [Moench] Voss), quaking aspen (*Populus tremuloides* Michx.), and paper birch (*Betula papyrifera* Marsh.)] found in the interior and southcentral regions of Alaska. Taiga forest (Hoffmann 1958) ecosystems in Alaska have been studied in detail over the past 40 yr, especially in and surrounding the Tanana River floodplain (e.g., Lutz 1956, Wilde and Krause 1959, Viereck 1970, 1975, Van Cleve et al. 1980, 1983, 1991, Viereck et al. 1983, Chapin et al. 1986). Although this research has provided great insight into successional processes and nutrient cycling, basic forest management tools for the species are lacking. No published site index curves exist for balsam poplar or black cottonwood in Alaska. Yarie and Herman (1982) used stem analysis data and an anamorphic approach to test for differences in site index curve parameters for poplar sites north and south of the Alaska Range. They concluded that a single equation could not adequately estimate site index for both sides of the Alaska Range.

This study is part of a program designed to describe the growth and yield patterns of tree species found in interior Alaska. Objectives include development of site index curves and equations, improvement of individual tree volume tables, development of taper equations, and examination of soil-site

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relationships. This paper presents site index methodology and equations for balsam poplar and western black cottonwood for both sides of the Alaska Range.

Areas from which balsam poplar and black cottonwood data were obtained include the Northern Forest Formation (excluding the Western Interior Zone) and the Kenai Peninsula and Prince William Sound Zones of the Coastal Forest Formation (Zasada and Packee 1995) (see Figure 1).

Methods

Tree data were collected to permit complete stem analysis. Methods were based on those of Johnson and Worthington (1963) and Herman et al. (1975). Well-stocked, single cohort stands were subjectively selected for sampling. Stands had to be minimally 50 yr old (the base age) at breast height; to be considered a single cohort, the range of tree ages could not exceed 10 yr. Stands with many gaps or large quantities of deadfall were avoided. A single representative "plot" was established in each stand.

Four sample trees were selected from each acceptable stand. Trees with forks, crooks, flattened or broken tops, beaver scars, heart rot, or excessive epicormic branching were avoided. Sample trees had to be dominants or codominants showing no external evidence of suppression. Individual trees were selected sufficiently far apart so as not to have directly competed with one another. Sample trees were from locations typical of the site. At most sites, sample trees were selected from an area of approximately 0.25 ac; no fixed plot shape or dimensions were used in order to minimize topographic and soil variability.

Sample trees were felled for stem analysis. Total tree height was measured to the nearest 0.1 ft. At 4 ft intervals from a 0.5 ft stump to the tip, a cross-section disk 1 to 2 in. thick was removed. Sample disks were numbered by site and tree. Disks were allowed to air-dry outside; particularly wet or frozen disks were placed in a grain dryer to speed thawing and drying.

Dried disks were sanded with a belt sander using 80 or 100 grit sandpaper to enhance visibility of decay pockets, knots,

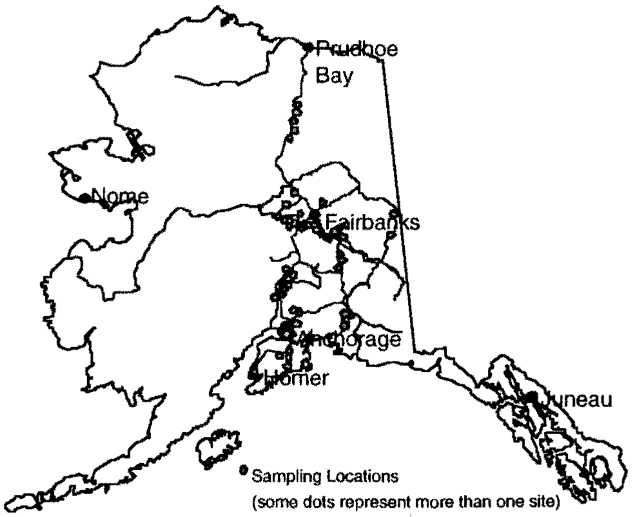

Figure 1. Locations of sample sites.

and unusual ring patterns (false, missing, suppressed, or wavy rings). An average radius, free of defects, along which rings were to be measured was selected and prepared with a surgical scalpel. A few disks (usually from the 0.5 ft section) were unreadable due to butt decay.

Ring increments were counted and measured using a Bannister Increment Measuring Machine (Fred C. Henson Company 1991) attached to an Apple II computer running CompuTA (Evans 1981) ring measurement software. Some trees were found to be less than 50 yr breast height age. Only the ring counts were used for site index analysis; ring width data were retained for future volume and increment analyses.

Carmean's (1972) method was used to adjust the height represented by the innermost ring on each disk. Carmean's correction requires two assumptions: (1) height growth for a given year has an average rate between the disk of that year and the next higher disk and (2) the disk was cut at the middle of that year's growth. Adjusted height gives a better estimate of total tree height at a given age; this is the height (H) used in Equations (1) and (2) below. Height at age 50 was estimated for trees less than 50 yr old by extrapolating the height growth curve manually with a flexible spline curve. Adjusted height-age data were plotted by site on transparencies and compared visually. Curve polymorphism between sites was clearly evident. In many instances, curves for sites or site groups were nondisjoint (they crossed) with other site groups. Sites were alternatively grouped by land resource area (Rieger et al. 1979), physiographic division (Wahrhaftig 1965), and landform in an effort to find disjoint (noncrossing) curve families. Soil type was considered as a stratification level; however, many sites were located outside the limits of existing soil surveys. This led to the addition of a soil characterization phase which will be presented in a future paper.

The Alaska Range was used to segregate the data into "north" and "south" units based on curve comparisons and the findings of Yarie and Herman (1982). Data from the north unit (all site types) showed a visually acceptable degree of variability and were retained as one subsample. Data from the south unit could not be reasonably grouped as a single subsample, due to the markedly nondisjoint height growth patterns observed. The best stratification that could be made was separation of fluvial sites (including alluvial fans) and upland sites. Sites on the middle and upper Susitna and Chulitna Rivers were considered to be a separate site group and were separated from the other southern fluvial sites, giving four separate subsamples for analysis. The site groups are described as follows:

Group 1—North of the Alaska Range: all sites.

Group 2—South of the Alaska Range: typical fluvial sites.

Group 3—South of the Alaska Range: upland sites.

Group 4—South of the Alaska Range: Susitna–Chulitna fluvial sites.

Summary tree data, listed by group, are shown in Table 1. Tree data were divided into 5 ft site index classes based on

Table 1. Summary data for sample trees.

	Data analysis groups			
	Group 1	Group 2	Group 3	Group 4
No. trees used in analysis	140	43	53	24
Height—mean (ft)	65.3	52.1	73.4	100.5
Height—range (ft)	39.1–90.5	27.3–98.5	32.9–97.6	55.4–124.5
Dbh—mean (in.)	10.9	10.3	13.7	16.2
Dbh—range (in.)	5.9–18.5	5.5–18.3	7.2–19.8	11.8–24.9
Breast height age—mean	80.2	73.9	69.2	95.7
Breast height age—range	45–160	43–135	30–118	65–147

adjusted height at 50 yr breast height age. All data from a given tree were placed in the same site index class. Using nonlinear ordinary least squares regression (Norušis and SPSS 1993), we fitted the Chapman-Richards growth function, in the form,

$$H = a(1 - e^{-b(age)})^c \qquad (1)$$

where

H = adjusted disk height,

age = breast height age at adjusted disk height, and

a, b, c = parameters to be estimated,

to the data in each site class. From this we obtained sets of parameter estimates for each class and determined "average" site index for the class by setting breast height age equal to 50 yr and solving for site index (height). Parameter estimates were plotted, by site group, against site index values of the respective 5 ft classes. Figure 2 shows the relationship between the estimates of the "c" parameter and the "average" site index of each of the thirteen 5 ft site index classes in Group 1. For each parameter, there appeared to be a linear relationship between parameter estimate and site index. Based on these findings, the a, b, and c parameters were replaced with linear functions of site index to give a polymorphic version of the Chapman-Richards equation. Since breast height age was used instead of total age, a constant 4.5 ft was added to the equation to constrain the y-intercept. The modified Chapman-Richards equation is

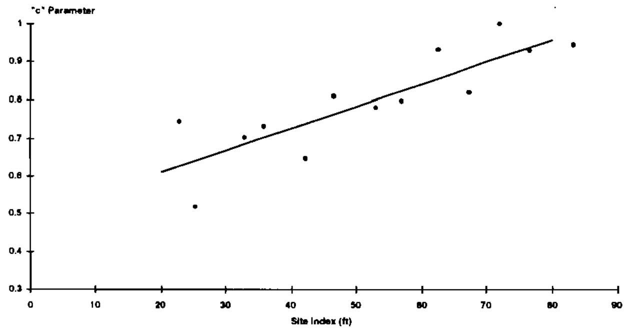

Figure 2. Results of regression of height group parameter estimates on site index (group 1—*c* parameter).

$$H = 4.5 + (b_1 + b_2SI)\cdot(1 - e^{(age)(b_3+b_4SI)})^{b_5+b_6SI} \qquad (2)$$

where

H = adjusted disk height,

age = breast height age at adjusted disk height, and

SI = site index is height of the tree at 50 yr breast height age, and

$b_1, b_2, b_3, b_4, b_5, b_6$ = parameters to be estimated.

The modified equation was fitted to data of each of the groups using nonlinear ordinary least squares regression (Norušis and SPSS 1993). Starting values for the parameters were obtained from linear regressions of parameter estimates on site index values. Different starting values were tried to ensure that "short" solutions were not being obtained and that the models were stable. Regression results were accepted after several successive runs yielded the same parameter estimates.

Results

Parameter estimates and R^2 values for the four groups are given in Table 2. R^2 values (0.96–0.98) indicated that the fits were acceptable. Some parameter estimates were not significant ($\alpha = 0.05$). Nonsignificance of a parameter occurred in two forms in this model with different implications for each form. If parameter b_1, b_3, or b_5 is not significantly different from zero, it merely suggests that the relationship of the parameter (a, b, or c in the original form) to site index passes through the origin. This probably does not have an important interpretation. On the other hand, if parameter b_2, b_4, or b_6 is not significantly different from zero, it implies that curve characteristics—asymptote, slope, or shape, respectively—have no relationship to site index. While this is contrary to the results obtained in the model building process, it is possible that this case could be valid. Improvement of data sets will eventually help to correctly establish these relationships.

Statistical prudence ordinarily suggests dropping nonsignificant parameters and refitting the model. However, since no parameter was nonsignificant in more than one group, all parameters were retained in order to keep the

Table 2. Site index equation parameter estimates and 95% asymptotic confidence intervals.

	b_1	b_2	b_3	b_4	b_5	b_6	R^2
Group 1	38.74	0.6782	0.001145	−0.0004211	0.9569	0.0004131	0.968
	(35.37,	(0.6228,	(−0.0001046,	(−0.0004578,	(0.8938,	(−0.0005239,	
	42.11)	0.7337)	0.002395)[a]	−0.0003843)	1.020)	0.001350)[a]	
Group 2	59.58	0.7149	−0.006641	−0.0001655	1.423	−0.005944	0.956
	(44.00,	(0.5078,	(−0.01042,	(−0.0002264,	(1.282,	(−0.007264,	
	75.16)	0.9220)	−0.002859)	−0.0001046)	1.564)	−0.004624)	
Group 3	32.39	0.8132	0.006049	−0.0005010	0.5236	0.009177	0.972
	(25.50,	(0.6900,	(0.001963,	(−0.0006091,	(0.3997,	(0.006607,	
	39.28)	0.9364)	0.01013)	−0.0003928)	0.6475)	0.01175)	
Group 4	134.2	0.006973	−0.005674	−0.0001858	2.635	−0.01657	0.979
	(117.0,	(−0.1767,	(−0.007064,	(−0.0002164,	(2.338,	(−0.01956,	
	151.5)	0.1907)[a]	−0.004284)	−0.0001553)	2.932)	−0.01359)	

[a] Confidence interval indicates parameter estimate is not significant ($\alpha = 0.05$).

models directly comparable. We felt that retaining one form of the model for all sites would be better than several "regional" forms, at least until the causes for differences in curve families from different regions and landforms can be determined to greater satisfaction.

Polymorphic curves were plotted using the new parameter estimates. The form of Equation (2) required that site index estimates be obtained using an iterative method (Biging and Wensel 1985). A BASIC (Microsoft Corp. 1987) computer program was used to calculate site index in this study. The program code can be obtained from the senior author. Spreadsheet programs with iterative capability can also solve for site index using our equations.

Data from individual trees were compared to formulated curves and residuals were plotted in order to judge goodness of fit. Plots for Group 1 (North of the Alaska Range: all sites) are provided as examples. Figure 3 shows partial tree data and formulated site index curves, and Figure 4 shows residuals of all observations in the group. The "barbell-shaped" residual plot was expected due to the use of a base-age dependent model. Height at age 50 yr was calculated to check deviation of predicted height at base age from site index (Table 3). Differences between predicted and "actual" height (as determined by ring count and height adjustment) at all ages were averaged by 10 yr age class to check bias in the curves with respect to age (Table 4).

The lack of guarantee that height will be equal to site index when age is equal to base age is a shortcoming of parameter prediction site index models. Difference equations (Clutter et al. 1983, Goelz and Burk 1992) have been shown to relieve this problem; but, in our study, an exploratory application of a polymorphic difference form of the Chapman-Richards model yielded unsatisfactory results. The nonlinear regression procedure appeared to "converge" appropriately and give acceptable parameter estimates. However, site index curves produced by the difference equation were extremely poor representations of the height growth patterns shown by our data. Until we find a method that can satisfactorily model the curve polymorphism and, at the same time, force height equal to site index at base age, the curves must be adjusted slightly.

We suggest using the following procedure to adjust the site index values obtained using our equations: (1) solve for site index using an iterative method; (2) insert the site index result into the equation, set age to 50 yr, and solve for $height_{50}$—height at age 50 should equal the site index found in the first step; however, in reality it is likely to differ slightly; (3) divide expected site index by $height_{50}$ to get a

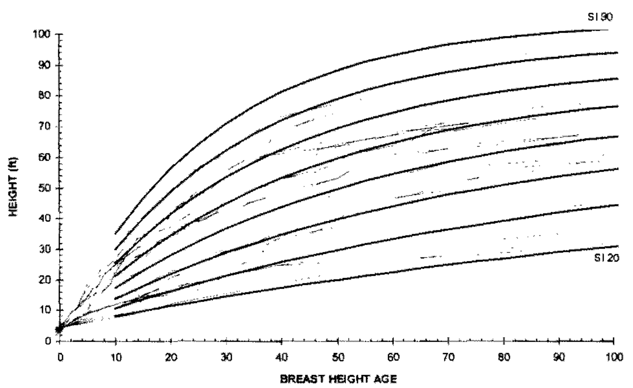

Figure 3. Comparison of tentative site index curves for poplar north of the Alaska range with height-age data from group 1.

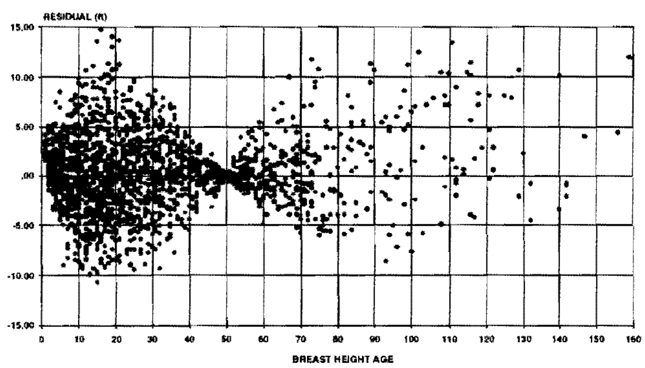

Figure 4. Residuals plot (actual SI–predicted SI) for group 1 data.

Table 3. Error predicting height equal to site index at age 50 yr.

		Site index								
		20	30	40	50	60	70	80	90	100
Group 1	Height @ 50 yr	20.0	29.7	39.7	49.7	59.6	69.4	78.9	88.2	97.3
	Error (actual SI–predicted SI)	0.0	0.3	0.3	0.3	0.4	0.6	1.1	1.8	2.7
	Error (%)	0.0	1.0	0.8	0.6	0.7	0.9	1.4	2.0	2.8
Group 2	Height @ 50 yr	26.3	33.7	41.9	50.7	60.1	69.8	79.9	90.1	100.5
	Error (actual SI–predicted SI)	–6.3	–3.7	–1.9	–0.7	–0.1	0.2	0.1	–0.1	–0.5
	Error (%)	–24.0	–11.0	–4.5	–1.4	–0.2	0.3	0.1	–0.1	–0.5
Group 3	Height @ 50 yr	19.0	29.7	39.7	49.7	59.8	69.9	80.1	90.4	100.5
	Error (actual SI–predicted SI)	1.0	0.3	0.3	0.3	0.2	0.1	–0.1	–0.4	–0.5
	Error (%)	5.3	1.0	0.8	0.6	0.3	0.1	–0.1	–0.4	–0.5
Group 4	Height @ 50 yr	18.5	26.7	36.2	46.8	57.9	69.0	79.9	90.4	100.1
	Error (actual SI–predicted SI)	1.5	3.3	3.8	3.2	2.1	1.0	0.1	–0.4	–0.1
	Error (%)	8.1	12.4	10.5	6.8	3.6	1.4	0.1	–0.4	–0.1

correction factor; (4) multiply the original site index estimate by this correction factor to adjust the site index estimate and curve to pass through the index age of 50.

This solution is strictly aesthetic and introduces some bias into the curves. Overall bias after curve adjustment is less than 0.5 ft within each group, but is higher in some age and site index classes. Adjusted curves are shown as light lines superimposed on the formulated curves in Figures 5–8.

Validation

The stem analysis data used by Yarie and Herman (1982) to produce anamorphic curves were used in this study as a verification data set. A total of 364 height-age observations from 26 trees on 12 sites was available for verification. Nineteen trees came from sites along the Tanana River, and one tree came from a site on the Porcupine River; site index was estimated for these sites using the equation for Group 1. The remaining six trees came from sites along the Susitna River, so site index was estimated using the equation from Group 4 (South of the Alaska Range: Susitna—Chulitna fluvial sites). No verification data were available for site Group 2 (South of the Alaska Range: typical fluvial sites) and Group 3 (South of the Alaska Range: upland sites). The results obtained using the verification are given in Table 5. In Group 1, our equation tended to underpredict site index in the lower age classes and overpredict site index in the higher age classes. In Group 4, opposite tendencies appeared. These differences could be due to specificity of the smaller sample of Yarie and Herman or differences in technique. However, in spite of apparent zones of upward or downward bias in the equations, the overall standard deviations obtained with the polymorphic equations derived in this study were slightly lower (Group 1: 6.8 vs. 7.1 ft) or equal (Group 4: 6.2 ft) when compared to the standard deviations obtained with the anamorphic equations derived by Yarie and Herman. This suggests that the curves developed from our effort are valid.

Table 4. Site index prediction bias by age class.

		Age class										
		10–19	20–29	30–39	40–49	50–59	60–69	70–79	80–89	90–99	100–109	110+	All
Group 1	*n*	448	344	268	181	144	106	74	34	24	16	41	
	Bias (ft)	–0.52	0.20	0.39	–0.09	–0.18	–0.35	–1.04	0.30	–0.05	1.37	2.55	–0.05
	SD	9.04	5.92	4.31	3.17	1.45	3.49	3.77	3.94	5.24	5.21	6.50	6.06
Group 2	*n*	185	158	122	93	68	42	33	16	8	8	2	
	Bias (ft)	0.11	0.45	0.13	–0.43	–0.40	–1.58	–3.59	–1.03	3.74	10.23	10.88	–0.04
	SD	10.95	6.96	4.53	1.96	1.44	3.10	4.60	5.36	6.28	8.55	1.41	7.08
Group 3	*n*	106	76	66	48	31	22	11	12	4	1	5	
	Bias (ft)	–0.30	–0.04	–0.61	0.39	0.15	–0.27	–0.41	–0.82	1.83	–2.41	2.41	–0.14
	SD	11.50	7.21	3.38	1.66	0.75	1.36	2.62	3.29	2.86	—	2.95	7.07
Group 4	*n*	72	75	63	54	47	39	23	16	9	9	3	
	Bias (ft)	0.92	–0.60	0.82	0.44	1.06	0.39	–0.54	0.19	0.18	–3.13	3.70	–0.33
	SD	11.26	6.39	4.79	2.32	2.08	4.30	4.76	5.59	2.86	6.40	5.40	6.32

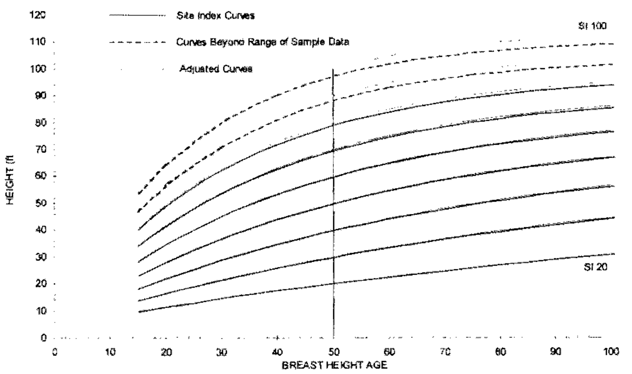

Figure 5. Site index curves for group 1: north of the Alaska range, all sites.

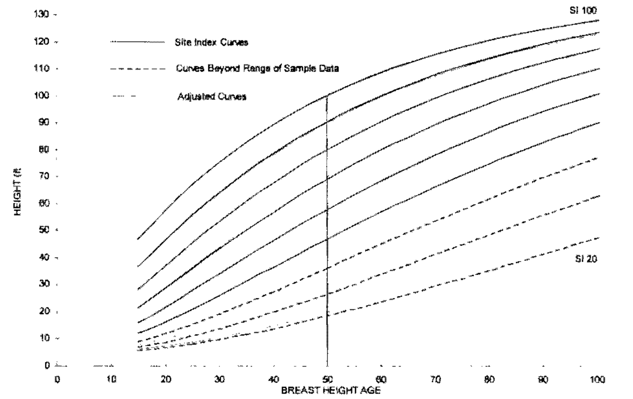

Figure 6. Site index curves for group 2: south of the Alaska range, typical fluvial sites.

Application of Site Index Curves

Site index curves presented here are the results of the first attempt to construct polymorphic site index curves for poplars in Alaska. Due to the large area covered in the study and the wide variety of sites encountered, the data were necessarily divided into subsamples that were smaller than desired. Guidance is provided here so that the equations derived in this study can be applied appropriately.

We suggest the following operational sampling guidelines:

1. A 0.25 ac plot should be located on a single terrain feature (terrace, island, slope position) in order to minimize variability in soil and moisture conditions. For example, in a floodplain stand, avoid sampling trees in abandoned channels that may intersect the stand or on a toe slope position adjacent to the stand.
2. Obtain total height and breast height age for the two tallest dominant and two tallest codominant trees on the plot. Determine site index for each tree individually and average site index for the plot.

Group 1 (North of the Alaska Range: All Sites)

These curves can be used for all sites north of the Alaska Range. None of the data used in curve construction were obtained from west of 151°W longitude, so verification should be made prior to wide use in that area. Most of the data used to construct these curves came from floodplain stands; data from upland sites were limited to lower site classes. Applicability of these curves to high-quality upland sites (if they exist) is unknown. These curves should perform best on the floodplains of the Tanana River and its tributaries. Predictive ability is lower at ages below 20 and above 100 yr due to bias in the model and high variability of growth patterns in those age ranges. Site curves higher than site index 85 ft are extrapolations; any observations of site index greater than 85 ft in the Interior should be treated with caution.

Group 2 (South of the Alaska Range: Typical Fluvial Sites)

These curves should be used for all fluvial sites south of the Alaska Range except those along the middle and upper Susitna and Chulitna Rivers. Data used for curve construction were obtained from sites with a wide variety of fluvial conditions ranging from the Copper River Basin to the coastal areas of the Kenai Peninsula. There is relatively wide variation in height growth below 30 and above 90 yr of age. Site index values lower that 40 ft were poorly represented in the data, so estimates in this range should be used with caution. It is likely that some site conditions that are markedly different from those sampled exist in the area; some attempt at local verification should be used prior to wide application of these curves. It is also probable that sites in this group will eventually be placed into more "localized" groups (e.g., Group 4) as additional data are obtained.

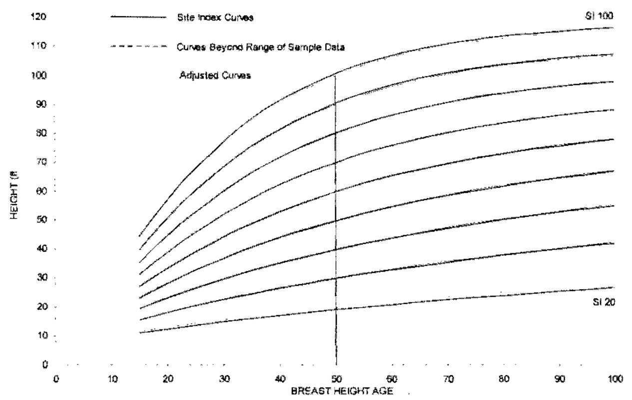

Figure 7. Site index curves for group 3: south of the Alaska range, upland sites.

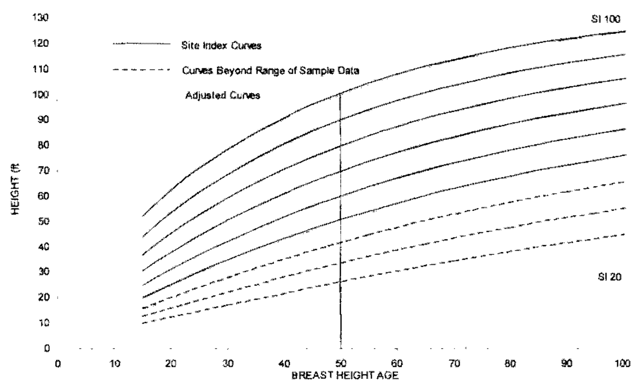

Figure 8. Site index curves for group 4: Susitna-Chulitna fluvial sites.

Table 5. Site Index prediction bias by age class for data used by Yarie and Herman (1982).

		Age class											
		10–19	20–29	30–39	40–49	50–59	60–69	70–79	80–89	90–99	100–109	110+	All
Tanana / Porcupine	*n*	59	53	49	30	18	14	13	8	11	6	11	
Group 1 equation	Bias (ft)	–4.96	–1.24	–0.82	–0.17	–0.04	0.55	1.99	5.76	1.28	6.18	4.70	–0.82
	SD	8.57	6.97	4.87	2.16	1.35	2.79	5.54	5.73	7.30	8.06	8.40	6.80
Yarie and Herman	Bias (ft)	–3.26	–0.59	–0.60	0.08	0.29	0.90	1.90	5.25	0.73	5.27	4.36	–0.29
Balsam poplar	SD	9.72	8.00	5.41	2.12	1.55	3.09	6.28	5.89	7.13	6.40	6.48	7.10
Susitna River	*n*	13	12	11	11	9	7	8	4	5	4	8	
Group 4 equation	Bias (ft)	4.55	0.90	1.68	1.18	0.79	–0.12	–0.82	–1.13	–3.89	–8.74	–7.33	–0.18
	SD	8.70	6.74	4.97	2.35	0.91	2.47	4.88	4.39	3.65	6.24	4.62	6.17
Yarie and Herman	Bias (ft)	–0.86	–3.82	–1.59	–0.43	1.05	1.32	1.33	4.18	1.66	–0.86	7.36	0.33
Black cottonwood	SD	7.69	7.63	4.89	1.85	1.17	3.63	5.58	7.36	8.18	10.74	2.96	6.23

Group 3 (South of the Alaska Range: Upland Sites)

These curves should be used for all well-drained upland sites south of the Alaska Range. As in Group 2, the data used to construct these curves came from a wide variety of sites. Markedly different soil conditions are often represented by data from only one or two sites. Again, local verification is recommended. There is relatively wide variation in height growth below 30 yr of age. There was some evidence that a few of the stands included in the sample were the result of some past human disturbance. This suggests that site index of old field stands, for example, can be estimated with these curves. It is probable that sites in this group will also be placed into more "localized" groups as additional data are obtained.

Group 4 (South of the Alaska Range: Susitna—Chulitna Fluvial Sites)

These curves should be used for fluvial sites along the middle and upper Susitna and Chulitna Rivers. The data used to construct the curves for this group comprised the smallest subsample used in the study. These curves performed well using the independent data which contained ages between 10 and 149 yr breast height age and site index values between 57.5 and 96.9 ft. There is a slight tendency to underpredict site index at ages less than 20 yr and overpredict site index at ages greater than 90 yr (see Table 3).

Poplars in Alaska occur under a wide variety of physical conditions. Sensitive measures of site, such as site index, are difficult to apply when little is known about the factors that affect it. This study has begun to quantify the expression of site factors by modeling height growth patterns. Now that polymorphic site index curves are available, poplar site quality can be estimated more objectively and accurately. This information will facilitate location of additional sampling sites so the site index database for poplar can be improved.

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