721
RS-6-12-8
0-1

Unpublished

REVIEW DRAFT
February 1, 1994

Size and Age Structure of Trees in the Old-growth Forests of Southeast Alaska

Wilbur A. Farr
Mike McClellan

USDA Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory,

2770 Sherwood Ln., Suite2A, Juneau, AK 99801, U.S.A.

JLM512 0292

other resources such as fish, wildlife, recreation, aesthetics (Schoen et al 1981, Schoen and Kirchoff 1988), and biodiversity (Samson et al. 1989), however, has refocused attention on the old-growth and for the need to find new ways to protect these resources (U.S. Forest Service 1991).

Forest inventories, conducted in coastal Alaska since the 1950's, have grouped all older productive stands into the single classification "old-growth". There are no classifications based on stand structure, age, or origin. Only volume classes and forest types have been classified (Van Hees and Labau, 1983 1984; Hutchison and LaBau 1975). In the study reported on here, sample plots in productive stands of old-growth were analyzed to determine species composition, tree size, and tree age to gain a better understanding of stand structure.

Methods

Study area

The principal forest type of southeast Alaska is collectively called western hemlock (Tsuga heterophylla (Raf.) Sarg)-Sitka spruce (Picea sitchensis (Bong.) Carr.) (Ruth and Harris 1979, Harris and Farr 1974), a type found along the north Pacific coast from southern Oregon north and westward to southcentral Alaska. In recent years ten old-growth forest types comprised of groupings of particular plant associations have been defined in southeast Alaska (DeMeo 1989; Martin 1989; Pawuk and Kissinger 1989). An old-growth definition task group has also developed, from data analysis and professional judgement, minimun stand level attributes for old-growth that include estimates of

numbers of large and decadent trees, canopy layers, standing snags, down material, and canopy cover (U.S. Forest Service 1992a and 1992b). These new definitions will be used in future resource inventories to characterize the old-growth.

The geography, geology, vegetation, and management of the forests of southeast Alaska are described in Harris et. al. (1974) , Harris and Farr (1974), and U.S. Forest Service (1991). There is a rugged mainland coastal strip with deep fiords bordering British Columbia to the east, and hundreds of small to large offshore islands totaling 9.5 million hectares of land. The area has a relatively mild and wet maritime climate with abundant moisture throughout the year and frequent periods with strong winds (Searby 1969). Summer droughts are rare (Farr and Harris 1979). There are relatively few weather stations in southeast Alaska and all are located near sealevel. They average 1400 to 2700 degree days per year above 5°C. (Farr and Hard 1987).

Federal lands account for 95% of the land area, 80% of which is in the Tongass National Forest. The remainder is State, Native, and private ownerships (U.S. Forest Service 1991). Fifty-nine percent of the land area in the Tongass National Forest is forested, and about 58% of the forested area (2.35 million ha) is classified as productive forest land; i.e. it has the biological capacity and ability to produce usable industrial wood products.

Field Methods

Data on stand structure were available from 67 locations in productive forests–17 on the Yakutat forelands and 50 on islands and mainland south of 59° North Latitude (Fig 1). All sites were chosen at random from 680 forest inventory locations established in the mid- to late-1950's. At each location there were three 0.08 ha rectangular plots. One of the three plots at each location was chosen at random for destructive sampling. Except for a few dangerous culls, all trees >12.7 cm (5 in.; 1 in. = 2.54 cm) in diameter at breast height were felled and sectioned. A total of 1660 trees were ~~cut~~ sampled ?

Species, diameter and age at breast height, and total height were recorded for all felled trees. Detailed information was also collected on type and quantity of internal decay for an old-growth decay study (Farr and others 1976).

Statistical Analysis

Tables, histograms, and analysis of variance were used to characterize species composition, diameter, height and age by species and crown position for all trees and for plots. Regression analysis and analysis of covariance were used to develop the relationship between total height and diameter and between tree age and diameter at breast height for the major tree species and test the hypothesis that common regression models could be used to predict total height and tree age for all species.

Results

General

Sample plots on the Yakutat forelands (Fig. 1) were all located at elevations within 60 m of sealevel (mean = 28.3 m; n = 17; SE = 5.1 m). Plots elsewhere in southeast Alaska (south of Yakutat) ranged in elevation from just above sea level to 518 m (mean = 80.7 m; n = 50; SE = 2.4 m).

Stand characteristics were different at Yakutat then elsewhere in southeast Alaska (Table 1). The Yakutat plots had a much higher average percentage of spruce (72 vs 10), fewer trees per ha (237 and 330), and a younger mean tree age (171 vs 216). The Yakutat forelands were covered by a glacier 600-700 years ago (Billings 1970, Yehle 1975). Following glacier retreat the exposed forelands became forested with Sitka spruce and black cottonwood (Populus trichocarpa Torr. & Gray) that, over time, gave way to mixed stands of spruce and hemlock. Glaciers retreated from most other areas of southeast Alaska much earlier--6,000 to 7,000 years ago when the mean annual temperature was warmer than today and precipitation considerably less (Goldthwait 1966). Because stands at Yakutat are of more recent origin and their structure generally different, they were excluded from much of the analysis. Numbers, sizes, and ages of trees at Yakutat and the rest of southeast Alaska are summarized in Tables 1 and 2.

Species Composition and Tree Size

Eighty-three percent of trees sampled in southeast Alaska were western hemlock (Table 1). There were relatively few Sitka spruce (10%), western redcedar (Thuja plicata Donn, 4%), or Alaska cedar (Chamaecyparis nootkatensis (D. Don) Spach, 3%). Spruce were better represented in the overstories of stands (15%) than in understories (8%). Dominant and codominant trees (including Yakutat) were 68% hemlock, 27% spruce, 3% redcedar, and 2% Alaska cedar. These percentages agree closely with the growing stock values reported by Hutchison and LaBau (1974).

Hemlock were generally smaller in diameter than spruce or cedar (Table 1). This was true for both overstory and understory trees. Mean diameter of overstory hemlock, spruce, redcedar, and Alaska cedar were 53.2 cm, 74.4 cm, 77.1 cm, and 60.4 cm, respectively. Ninety percent of overstory hemlock, spruce, redcedar, and Alaska cedar measured on the plots were less than 73 cm, 111 cm, 124 cm, and 95 cm in diameter, respectively. ?

The largest diameter trees of each species sampled were hemlock--115 cm, spruce--154 cm, redcedar--147 cm, and Alaska cedar--119 cm. Larger trees of each species do occur in southeast Alaska, but they are not common. Record trees for the region are: hemlock--188 cm; spruce--290 cm; redcedar--290 cm; and Alaska cedar--105 cm[1]. Ninety percent

No

[1]Information on file at the Forestry Sciences Laboratory, 2770 Sherwood Lane., Suite 2A, Juneau, AK 99801.

of all hemlock, spruce, redcedar, and Alaska cedar trees were less than 64 cm, 104 cm, 94 cm, and 69 cm in diameter, respectively.

The tallest trees were also spruce. Spruce up to 60 m tall and hemlock up to 52 m tall were measured. The tallest western redcedar were 40 m tall, and Alaska cedar, 30 m. Mean heights for each species were about half the maximum heights.

Overstory characteristics of old-growth stands

Mean diameter, total height, and age for the 100 largest diameter trees per ha were summarized (Table 1). Mean diameter of the largest trees was 64.0 cm (SE = 1.06 cm), mean height 34.7 m (SE = 1.20 m), and mean age at breast height 308 years (SE = 5.8). Plot mean diameters ranged from 36 to 69 cm, mean heights from 19 to 39 m, and mean ages from 88 to 359 years).

Height-Diameter Relations

Western redcedar and Alaska cedar were significantly ($p<0.0001$) shorter in total height than western hemlock or Sitka spruce for trees of the same diameter (Fig. 2). There were no significant differences in relationships between the cedars nor between hemlock and spruce.

Tree ages

How old are the old-growth trees in southeast Alaska? The oldest trees sampled by species were: Sitka spruce--785 years; Alaska cedar--715 years; western hemlock--659 years; and western redcedar--650 years. Older cull trees that could not be aged because of advanced internal decay may have been present on the plots. Ninety percent of all overstory trees were >180 years old; 84% were >200 years; 47% were >300 years old; 15% were > 400 years; and 5% were > 500 years old at breast height.

Distribution of trees by 50-year age class differed by species (Fig. 3). The least tolerant and fastest growing species (spruce) had an inverse J-shaped histogram of ages common to all-age stands (Leak 1975). Slower growing, more tolerant, hemlock and cedar did not exhibit an inverse J-shaped histogram of ages as there were relatively few trees of those species in the youngest age classes. Lack of individuals, especially in the first age class (26-75 years), was probably due to sampling as small diameter trees (<12.7 cm) were not included in the study. Most 12.7 cm hemlock and cedar were more than 75 years old.

On average, Alaska cedar and western redcedar were about 30-40 years older than western hemlock or Sitka spruce (Table 1). Overstory spruce and hemlock averaged about 300 years old; redcedar 337. For overstory trees, 96% of hemlock, 85% of spruce, 100% of Alaska cedar, and 96% of redcedar were > 150 years old.

Age-diameter relations

The relation between tree age and diameter at breast height was linear for all species (Fig. 4). Sitka spruce and western redcedar are largest in diameter for their age (no significant difference in slope or intercept, $p < 0.001$), followed by western hemlock, and Alaska cedar. Regression slopes for Alaska cedar and western hemlock were significantly different ($p < 0.001$). Western hemlock and western redcedar also differed significantly in slope ($p < 0.001$).

Most Alaska cedar and western hemlock were relatively old, even for small diameter trees. The 13 cm Alaska cedar and western hemlock, for example, averaged about 130 years old. Redcedar and Sitka spruce of the same diameter were much younger, about 60 years old.

Structure of individual plots

Tree ages within and between plots were highly variable. One sample plot was even-aged young-growth (<150 years old), with a mean age of 104.6 years ($n = 7$, SE=20.72). This was possible because the minimum inventory classification area was 4.05 ha (10 acres). With 0.08 ha sample plots it was possible to have small areas of young-growth mixed in with the old-growth. Other sample plots ranged from being multi-aged old-growth to all-aged old-growth (Table 2). There were also plots that had an even-aged or all-aged residual overstory from a former stand with a much younger all-aged understory. A surprising 36% of plots had 2 or 3 distinct age classes of trees

>12.7 cm in diameter at breast height. Thirty-five percent of plots at Yakutat had 2 or 3 distinct age classes (Table 2). Examples of different age structures are shown in Fig 5.

Discussion

The productive hemlock-spruce forests of southeast Alaska are mostly (89%) old-growth and there is a wide range of stand conditions. Thirty-six percent of plots in this study contained one to three distinct age classes (at breast height) in trees 12.7 cm and larger with a 100 to 350 year age difference between classes. Growing conditions within the old-growth stands in southeast Alaska apparently change gradually and understory conifers germinate and develop over long periods of time. Rates of growth of understory trees tend to be highly variable.

The most common old-growth tree is shade tolerant western hemlock. Spruce, and cedar within its range, regenerate in the understory, but in far fewer numbers than hemlock. Spruce requires a more open setting and a mixed soil or mineral soil seed bed for germination and establishment (Harris and Farr 1974, Deal et al. 1991). Little is known about the regeneration requirements of Alaska cedar and western redcedar in Alaska.

The old-growth productive forests of southeast Alaska have developed over hundreds or, perhaps thousands of years. It takes hundred of years for a stand to develop

naturally from bare ground into old-growth. Regeneration of conifers is rarely a problem following the removal or destruction of a former stand and, on most productive forest sites, crown closure takes place within the first 30 years (Harris and Farr 1974). The stem exclusion phase that follows crown closure (Oliver and Larson 1990) may last one hundred or more years in these forest type and last until overstory stocking is sufficiently reduced from successional changes that adequate light reaches the forest floor to allow for the establishment of new regeneration. Although the new regeneration will develop very slowly in the shade of the overstory, it will over time develop into a second distinct canopy. Several decades later additional regeneration will become established beneath the two-storied stand, and the process continues. Eventually, the canopy layers meld into an all-age stand. The death of individual trees and periodic windthrow of individual or small groups of trees also provides suitable environments for new regeneration, thus contributing to an even wider range of growing conditions. Some examples of different age structures found on plots in this study are shown in Figure 5.

Forests of southeast Alaska have been little impacted by fire or widespread insect attacks common to other forested regions of the United States so there are far fewer examples of even-aged stands, except for areas previously logged or windthrown. Yearly gales cause uprooting and breaking of individuals and groups of trees (Harris 1989). Even-aged stands of wind origin dot the landscape though most are but a few hectares in size. In a study of the Thanksgiving Day storm in 1968 on Prince of Wales

and adjacent Islands, Harris (1989) found windthrow patches up to 71 ha in size. Average patch size of complete blowdown was only eight ha. Disturbances to individual stands range from minor to major depending on amount and frequency of wind damage and makeup of the overstory and understory. Much of the damage from wind storms occurs to individual trees or small groups of trees. Within a few years of a windthrow event a new age class may appear in the understory or the growing space created by windthrow will be filled by the growing crowns of surrounding trees (Oliver and Stephens 1977). If a large patch of trees is destroyed, a new stand will quickly take its place. Composition of the new stand will depend upon amount and vigor of regeneration already present in the understory, availability of seed from surrounding stands, amount of disturbance to the canopy and forest floor, and other yet poorly understood factors.

Most trees in the old-growth forests of southeast Alaska, especially the hemlock and Alaska cedar, are relatively old. Minimum diameter (12.7 cm) hemlock and Alaska cedar average about 130 years old at breast height and small overstory hemlock average about 170 years old. Spruce are much younger--74 and 110 years, respectively at breast height. Eighty-six percent of overstory trees in this study were >150 years old and five percent were >500 years old. Trees in these stands are much older than trees will be under most forms of even-aged management. Rotation lengths for even-aged stands in southeast Alaska are projected to be 100 to 150 years (U.S. Forest Service 1991). The natural mean turnover rate of mature trees in the old-growth is probably in excess of 500 years.

Literature Cited

Alaback, P. B. 1990. Dynamics of old-growth temperate rainforests in southeast Alaska. In "Proceedings of the 2nd Glacier Bay Science Symposium, September 19-22, 1988, Gustavus, Alaska" (A. M. Milner and J. D. Wood, eds.), pp. 150-153. National Park Service, Alaska Region, Anchorage, AK.

Alaback, P. B. 1984. A comparison of old-growth and second-growth western hemlock-Sitka spruce forests in southeast Alaska. In Meehan, W. R.; Merrill, T. R. Jr.; and Hanley, T. A., eds. Fish and wildlife relationships in old-growth forests: proceedings of a symposium held in Juneau, AK, April 1982. American Institute of Fishery Research Biologists, Morehead City, NC.

Alaback, P. B., and Juday, G. P. 1989. Structure and composition of low elevation old-growth forests in research natural areas of southeast Alaska. Natural Areas Journal (9):27-39.

Alaback, P. B., and Sidle, R. C. 1986. Biomass, structure, and nutrients of riparian vegetation on a small watershed on Chichagof Island, southeast Alaska. In Correll, D. L, eds, Watershed research perspectives. Smithsonian Environmental Research Center, Edgewater, MD., p. 135-165.

Billings, R. F. 1970. Soil management report for the Yakutat forelands based on reconnaissance soil survey. Juneau, AK: U.S. Department of Agriculture, Forest Service, Alaska Region. 51p.

Bowers, F. 1987. Effects of windthrow on soil properties and spatial variability in southeast Alaska. Ph.D. Thesis, Univeristy of Washington. 200 p.

DeMeo, T. 1989. Preliminary forest plant association management guide, Ketchikan Area, Tongass National Forest. USDAFor. Serv., Alaska Region, Field Guide.

Farr, W. A., LaBau, V. J., and Laurent, T. H. 1976. Estimation of decay in old-growth western hemlock and Sitka spruce in southeast Alaska. Res. Rep. PNW-204. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 24 p.

Farr, W. A., and Hard, J. S. 1987. Multivariate analysis of climate along the southern coast of Alaska-some forestry implications. Res. Rep. PNW-RP-372. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 38 p.

Goldthwait, R. P. 1966. Glacial history. In Soil development and ecological succession in a deglaciated area of Muir Inlet, southeast Alaska. Inst. Polar Stud. Rep. 20, Ohio State Univ., Columbus. p 1-14.

Harris, A. S. 1989. Wind in the forests of southeast Alaska and guides for reducing damage. Gen. Tech. Rep. PNW-GTR-244. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 63 p.

Harris, A. S., and Farr, W. A. 1974. The forest ecosystem of southeast Alaska. 7. Forest ecology and timber management. Gen. Tech. Rep. PNW-25. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 109 p.

Harris, A. S., Hutchison, O. K., Meehan, W. R., and others. 1974. The forest ecosystem of southeast Alaska. 1. The setting. Gen. Tech. Rep. PNW-12. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 40 p.

Harris, A. S., and Farr, W. A. 1979. Timber management and deer forage in southeast Alaska--forest ecology and timber management. In Wallmo, O. C., and Schoen, J. W., eds., Sitka black-tailed deer. USDA Forest Service and Alaska Department of Fish and Game, Juneau, AK; p. 15-24.

Hutchison, O. K., and LaBau, V. J. 1975. The forest ecosystem of southeast Alaska. 9. TImber inventory, harvesting, marketing, and trends. USDA For. Serv. Tech. Rep. PNW-34.

Martin, J. R. 1989. Preliminary forest plant associations of southeast Alaska: Chatham Area, Tongass National Forest. USDA For. Serv., Alaska Region, Field Guide.

McClellan, M. H. 1991. Soil carbon and nutrient dynamics of windthrow chronosequences in spruce-hemlock forests of southeast Alaska. Ph.D. Thesis, Oregon State University. 130 p.

Oliver, C. D., and Larson, B. C. 1990 Forest stand dynamics. McGraw-Hill, New York, 467 p.

Oliver, C. D., and Stephens, E. P. 1977. Reconstruction of a mixed species forest in central New England. Ecology 58: 562-572.

Pawuk, W. H., and Kissinger, E. J. 1989. Preliminary forest plant associatios of the Stikine Area, Tongass National Forest. USDA For. Serv., Alaska Region, Field Guide.

Ruth, R. H., and Harris, A. S. 1979. management of the western hemlock-Sitka spruce forests for timber production. Gen. Tech. Rep. PNW-88. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 197 p.

Samson, F. B., Alaback, P., Christner, Jere, and others. 1989. Conservation of rain forests in southeast Alaska: Report of a working group. Trans. 54th N. A. Wildl. & Nat. Res. Conf. 54: 121-132.

U.S. Forest Service. 1991. Tongass land management plan revision. Publication R10-MB-146. Juneau, AK: U.S. Department of Agriculture, Forest Service, Region 10.

U.S. Forest Service. 1992. Ecological definitions for old-growth forest types in southeast Alaska. Publication R10-TP-28. Juneau, AK: U.S. Department of Agriculture, Forest Service, Region 10.

Van Hees, W. W. S., and LaBau, V. J. 1983. Timber resource statistics for the Prince of Wales Unit, Alaska, 1973. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 30 p.

Van Hees, W. W. S., and LaBau, V. J. 1984. Timber resource statistics for the Yakutat inventory unit, Alaska, 1975. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 31 p.

Yehle, L. A. 1975. Preliminary report on the reconnaissance engineering geology of the Yakutat area, Alaska, with emphasis on evaluation of earthquake and other geologic hazards. Denver, CO: U.S. Department of Interior, Geological Survey. 136 p.

Table 1. Statistics for trees in old-growth stands in southeast Alaska and Yakutat

(A) Individual sample trees

Species	Southeast						Yakutat					
	All trees		Overstory		Understory		All trees		Overstory		Understory	
	(Number)	(%)	(Number)	(%)	(Number)	(%)	(Number)	(%)	(Number)	(%)	(Number)	(%)
Western hemlock	1107	83	416	78	691	86	92	28	27	18	65	37
Sitka spruce	138	10	78	15	60	8	234	72	122	82	112	63
Western redcedar	53	4	28	5	25	3	0	0	0	0	0	0
Alaska cedar	36	3	11	2	25	3	0	0	36	0	0	0
Totals	1334	100	533	100	801	100	254	100	149	100	177	100

(B) Means

Variable	Southeast					Yakutat		
	Western hemlock	Sitka spruce	Western redcedar	Alaska cedar	All trees*	Western hemlock	Sitka spruce	All trees*
DBH(cm)--all trees	34.2	52.6	52.9	35.1	36.9a	37.7	48.9	45.7b
Understory	22.8	24.1	25.8	24.0	23.0a	29.1	30.4	29.9b
Overstory	53.2	74.4	77.1	60.4	57.7a	58.4	65.8	64.5b
Top 100/ha	59.2	75.7	81.1	74.0	64.0a	60.2	74.7	71.8
Height(m)--all trees	21.5	28.6	21.2	17.1	22.1a	20.6	26.5	24.8b
Understory	15.8	17.3	13.3	13.5	15.8a	16.4	19.8	18.6b
Overstory	31.1	37.3	28.3	25.1	31.7a	30.6	32.6	32.2a
Top 100/ha	34.8	37.4	28.5	26.4	34.7a	30.6	34.3	33.6a
BH age--all trees	214	215	242	253	216a	170	171	171b
Understory	165	99	135	187	160a	139	117	125b
Overstory	295	303	337	**	300a	246	221	225b
Top 100/ha	302	298	353	**	308a	252	240	243b
Trees/ha--all trees	273.5	34.1	13.1	8.9	329.6a	66.9	170.0	236.9b
Understory	170.7	14.8	6.2	6.2	197.9a	47.2	81.4	128.6b
Overstory	102.8	19.3	6.9	2.7	131.7a	19.6	88.7	108.3b
Top 100/ha	72.8	19.0	6.5	1.7	100	20.2	79.8	100

* Variable means for all trees in southeast and at Yakutat that are followed by a different letter are significantly different; $P < 0.01$.

** Too few trees for a mean.

JLM512 0309

Table 2. Number of sample plots by location and structure, southeast Alaska and Yakutat.

Location	Structure					
	Even-aged[1]		Overstory			residuals and all-aged understory
	Young	Old	Two-aged	Three-aged	All-aged	
Southeast Alaska						
Ketchikan	0	0	2	3	5	2
Petersburg	0	0	2	4	7	1
Sitka	1	0	0	1	8	1
Juneau	0	0	4	2	7	0
Yakutat	1	1	5	1	6	3
Southeast						
Total plots	1	0	8	10	27	4
Percent of plots	2.0	0	16.0	20.0	54.0	8.0
Yakutat						
Percent of plots	5.9	5.9	29.4	5.9	35.3	17.6

1 Stands where the understory and overstory trees are the same age. Young stands are < 150 years old. Older stands are >= 150 years old.

JLM512 0310

Figure Captions

Fig. 1. Location of 67 old-growth study plots in southeast Alaska.

Fig. 2. Relation between tree height and diameter at breast height by species for old-growth in southeast Alaska.

Spruce $Ht = 1.3 + 51.71(1-\exp(-0.011454*D^{1.0380}))$;
$n = 138$; $R^2 = 0.882$; $SE = 4.16$

Hemlock $Ht = 1.3 + 51.41(1-\exp((-0.012375*D^{1.0703}))$;
$n = 1107$; $R^2 = 0.843$; $SE = 3.76$

Redcedar $Ht = 1.3 + 32.11(1-\exp(-0.011326*D^{1.1907}))$; and
$n = 53$; $R^2 = 0.897$; $SE = 2.78$

Alaska cedar $Ht = 1.3 + 29.79(1-\exp(-0.014931*D^{1.1587}))$.
$n = 35$; $R^2 = 0.802$; $SE = 3.04$

Fig. 3. Percent of trees by species and 50-year age class in southeast Alaska.

Fig. 4. Relation between age and diameter at breast height by species for old-growth in southeast Alaska.

Alaska cedar $age = 74.1 + 5.0774*D$;
$n = 35$; $R^2 = 0.639$; $SE = 97.38$

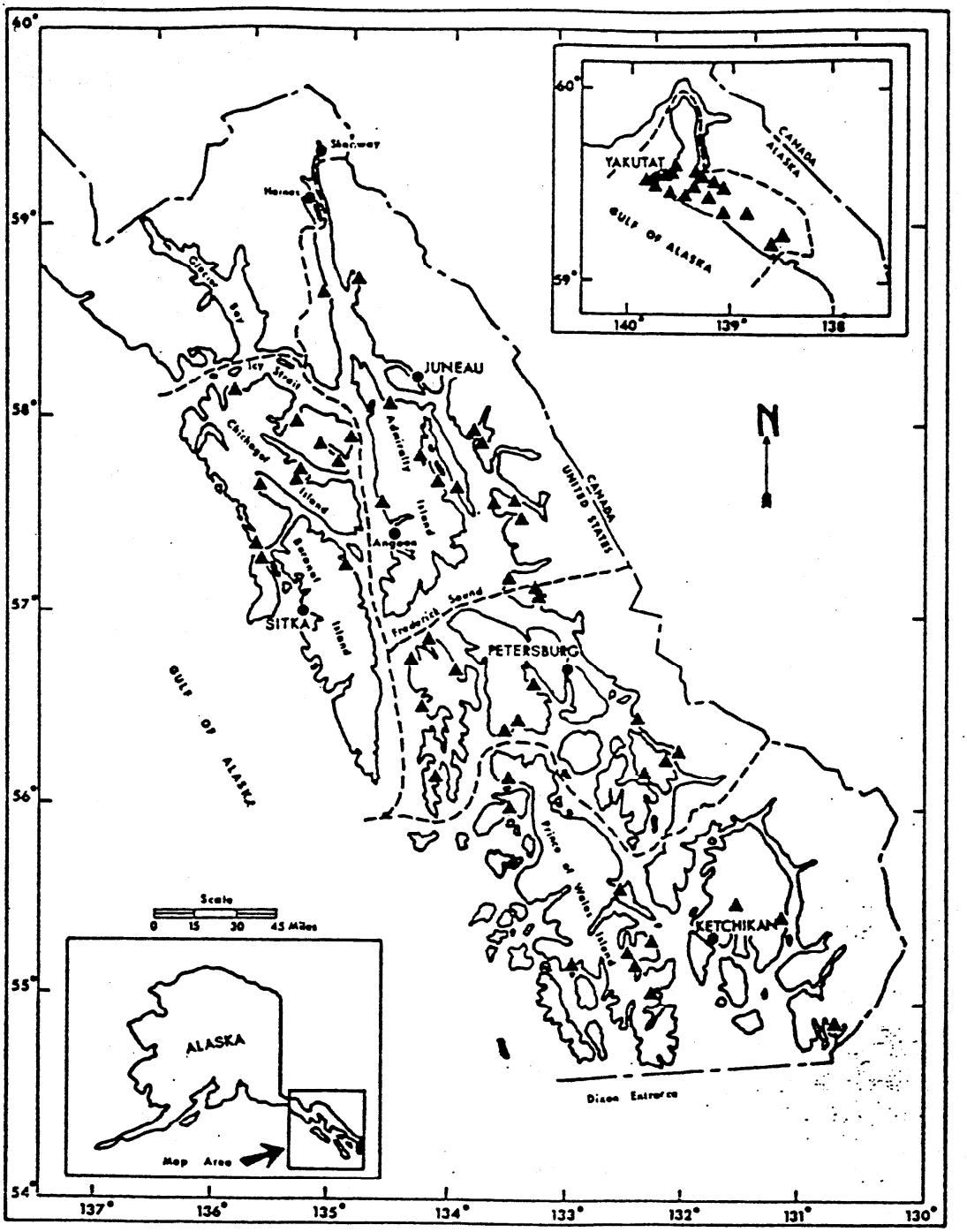
Hemlock $age = 85.1 + 3.7590*D$;
$n = 1107$; $R^2 = 0.495$; $SE = 73.02$

Redcedar $age = 35.8 + 3.8911*D$; and
$n = 53$; $R^2 = 0.786$; $SE = 70.48$

Spruce $age = 28.7 + 3.5376*D$.
$n = 138$; $R^2 = 0.555$; $SE = 105.72$

Fig. 5. Relations between age and diameter at breast height for trees on even-aged, multi-aged, and all-aged sample plots in southeast Alaska. (A) An even-aged stand. (B) A two-aged stand. (C) A three-aged stand. (D) An all-aged stand. (E) A stand with an even-aged residual overstory and an all-aged understory. Open circle, western hemlock; filled circle, Sitka spruce; Open triangle, western redcedar.

JLM512 0311


YAKUTAT
CANADA
ALASKA
GULF OF ALASKA
JUNEAU
SITKA
PETERSBURG
KETCHIKAN
Chichagof Island
Baranof Island
Admiralty Island
Frederick Sound
Prince of Wales Island
Dixon Entrance
UNITED STATES
N
Scale
0 15 30 45 Miles
ALASKA
Map Area
137°
136°
135°
134°
133°
132°
131°
130°
60°
59°
58°
57°
56°
55°
54°

JLM512 0312

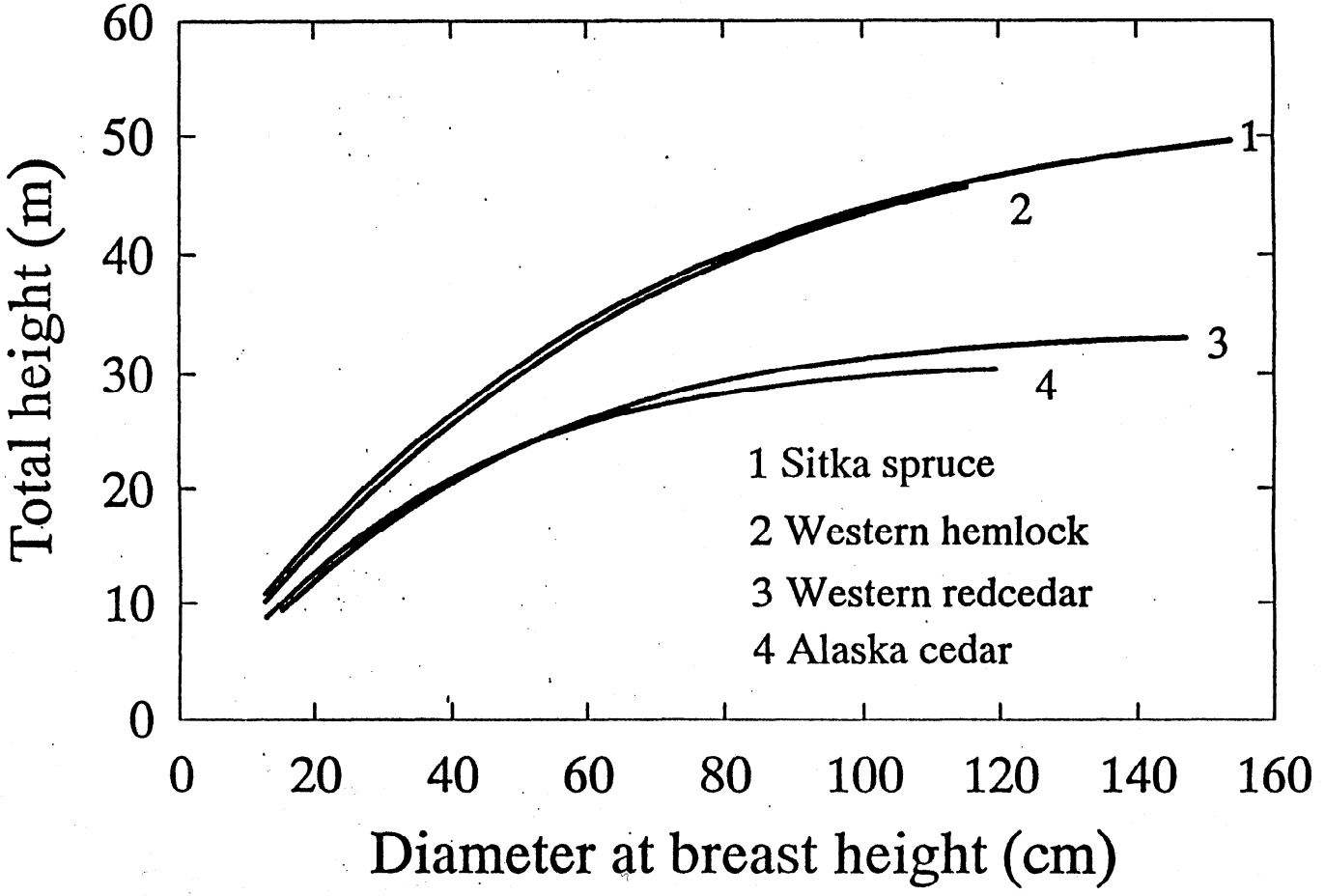


Fig. 2

JLM512 0313

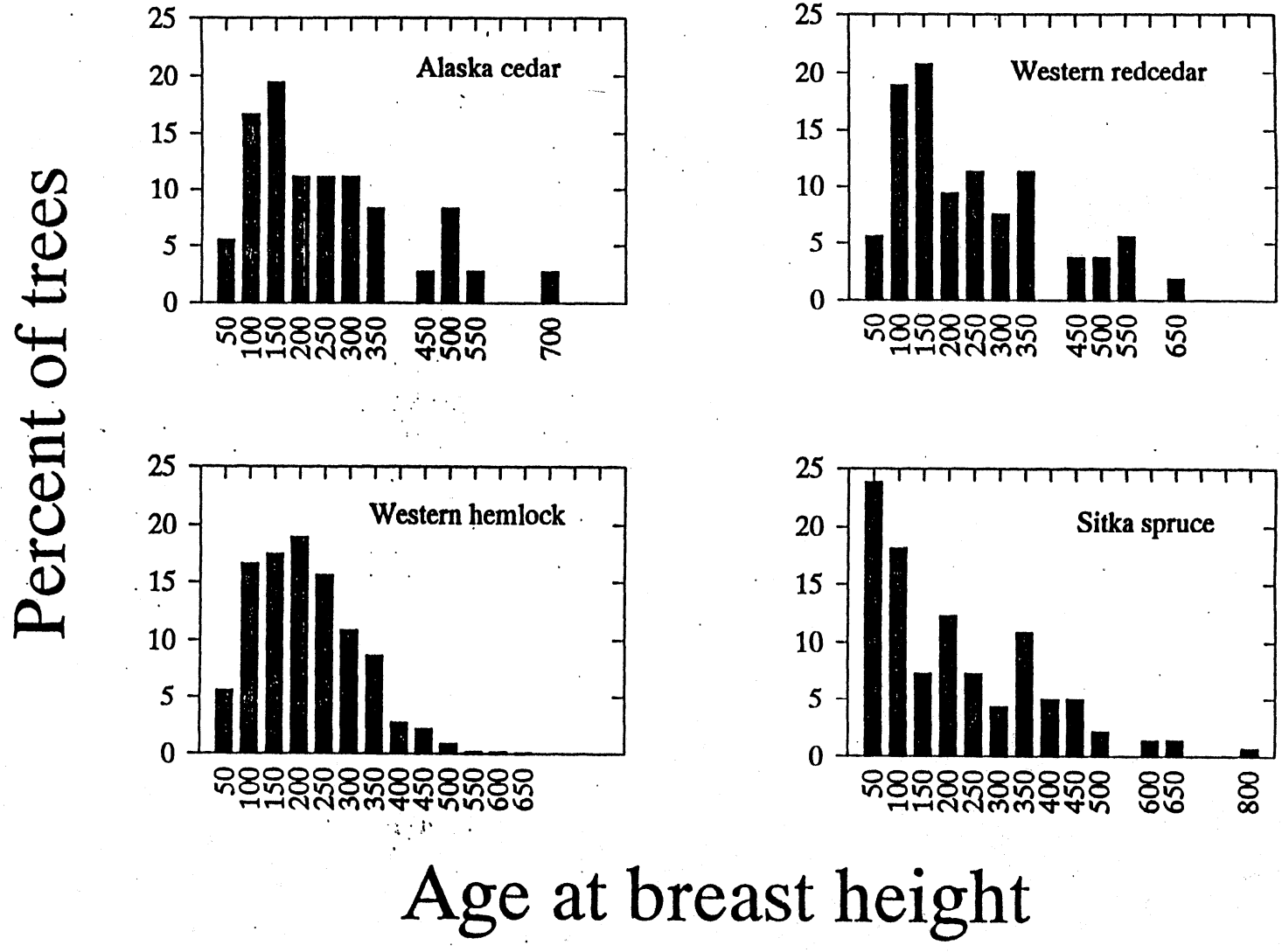
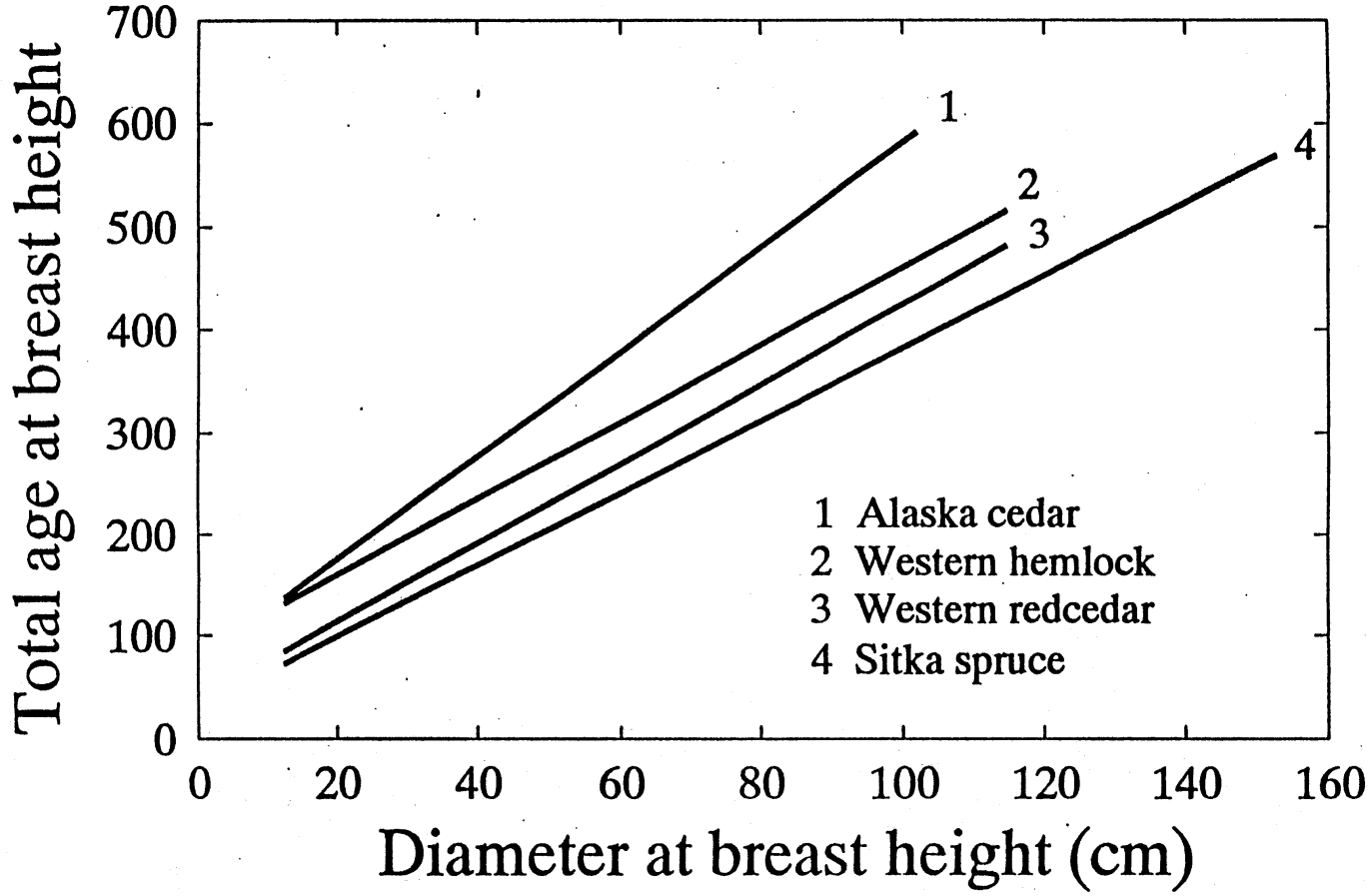


Fig. 3

JLM512 0314



JLM 512 0315

Fig. 4

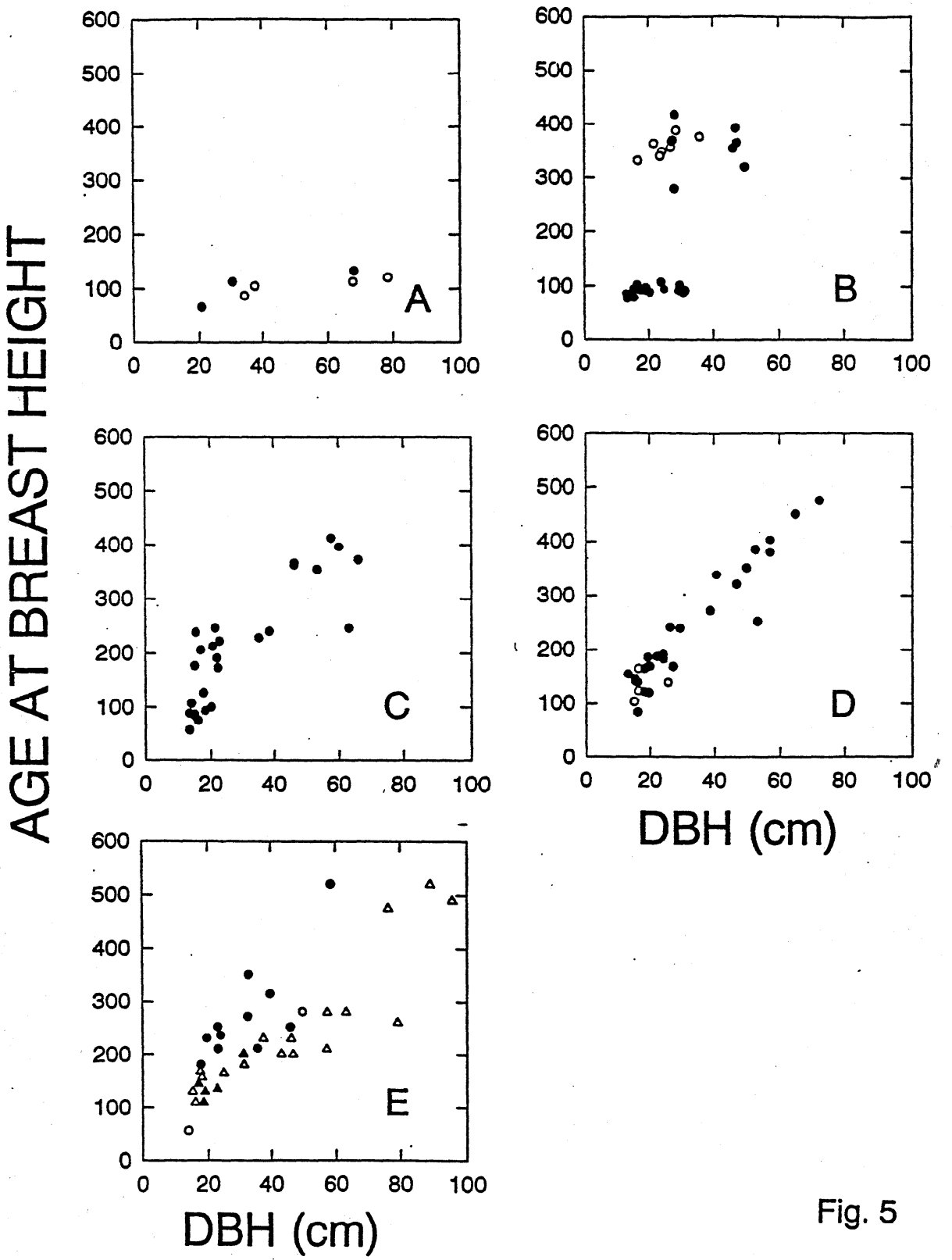


Fig. 5

JLM512 0316