Fire History Disturbance Study of the Kenai Peninsula Mountainous Portion of the Chugach National Forest

Written by

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Abstract

Forests in the vicinity of the Kenai Peninsula portion of the Chugach National Forest are of special ecological interest because of their transitional nature between coastal and interior forest types. The Continental Interior boreal forest and Maritime Pacific coast ecological regions merge on the Forest. Fire has historically been present in this century in the Kenai Mountains but whether fire is the important disturbance process creating structural and landscape diversity within this ecosystem is unknown. This report describes three distinct periods of fire frequency - prehistoric (pre 1740), settlement (1741-1913), and post-settlement (1914-1997). Fire reports on the Forest from 1914-1997 were summarized and attributed into a GIS data base documenting fire occurrences for the post-settlement period. A historic fire map was generated for known disturbance burn polygons. A historic land classification document containing maps and photographs, reveals widespread fire disturbances at the turn of the century, settlement period. The present study examined the fire history disturbances of three isolated mature forest areas to reconstruct the age distributions of living trees. Twenty-four historic burns were also examined, future work will reconstruct the age distributions of living trees sampled. Radiocarbon dates of soil charcoal were collected under mature forest stands to document pre-historic fire occurrences. Within the historic burns, remnants of older stumps and isolated residual trees reveal mature forests existed prior to disturbance. Needleleaf forests adjacent to these historic burns have ages greater then 200 ybp. The ages of living Lutz spruce and mountain hemlock within the mature forests sampled are greater then 200 ybp, subsurface soil charcoal is greater then 500 ybp. Although abiotic disturbances such as wind, snow avalanche, landslides, glacial recession, and flooding have been recognized for the important ways in which they influence the pattern of vegetation and tree recruitment on the Forest, the role of fire is now recognized as an important disturbance process over many millennia in this transitional climate. The historical records of fires and tree ages, together with the present mature forests and beetle kill fuel loads, suggest that the next interval of stand-regenerating fires is near.

Introduction

Abiotic disturbances such as wind, snow avalanches, landslide, glacial recession and flooding have, for some time, been recognized for the important way in which they influence the pattern of vegetation that develops on the Kenai Peninsula portion of the Chugach National Forest. Fire has historically been present in this century in the Kenai Mountains but whether fire is the important disturbance process creating structural and landscape diversity within this ecosystem is unknown. Forests on the Peninsula had not received logging activity prior to 1740. Uncut forests provide a rare opportunity to discern the natural dynamics of vegetation in a expanding landscape becoming dominated by both human and insect disturbances. The Forest contains a diverse mosaic of primarily hemlock-dominated stands. Among the hemlocks grow numerous white spruce and Sitka spruce. White spruce is largely dependent on fire to provide the open mineral seedbed necessary for its regeneration. Its presence implies disturbance by fire. Observations of potential fire regimes are illustrated by the small islands of fire-prone and fire-dependent white spruce vegetation that exists within the sea of mountain hemlock and Sitka spruce forest, occupying habitat conditions that are unfavorable for fire on cool and wet topographic positions of the Forest.

There are limitations with the accuracy of forest history reconstructions due to lack of living trees having survived recent spruce bark beetle infestations. Isolated areas still remain throughout the forest where the stand ages still span the time of fire history. This report describes three distinct periods of fire frequency on the Forest: pre-historic, settlement, and post-settlement. In addition, a study examined the fire history disturbances throughout the Forest in three isolated mature forest areas and twenty-four old historic fire burns reconstructing the age distributions of living trees. Evidence of fire was recorded by radiocarbon dating soil charcoal and documenting burn polygons with residual trees and charred stumps. The results illustrate a long interval fire cycle that could have controlled the recruitment and mortality of most spruce and probably most hemlock trees in this forest over the past 500-3,000 yrs. In addition to the fire history information provided in the text, information on prescribed fire management is included in Appendix A.

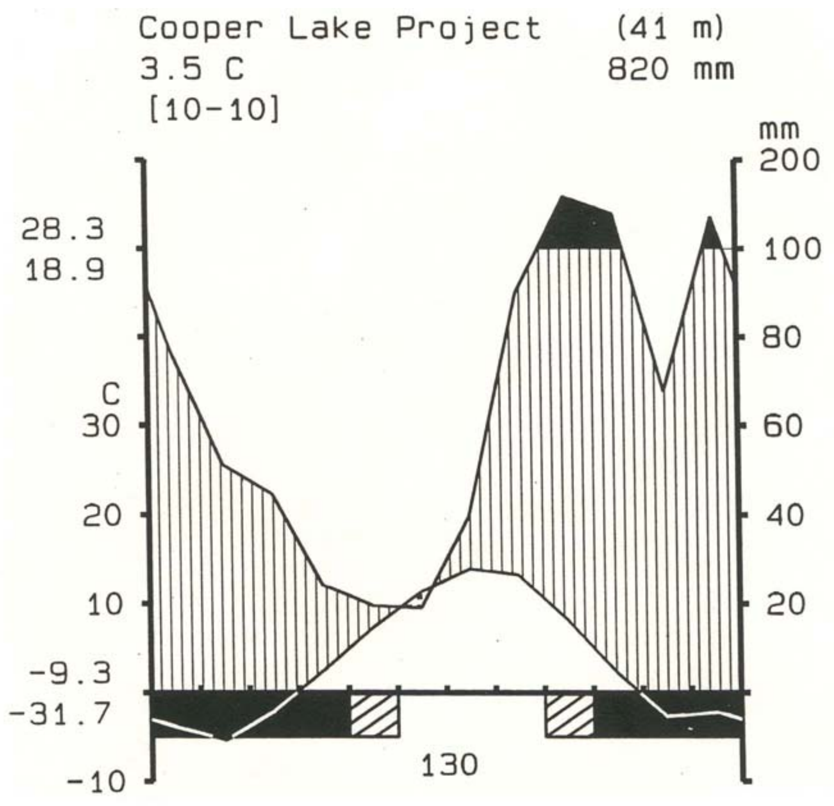
Study area

Environment

Located in south-central Alaska, the 8,268 square miles Kenai Peninsula lies between Cook Inlet to the north and west and Prince William Sound to the south and east. Geographically, the Peninsula is commonly divided into two major subsections. To the west are the Western Kenai lowlands. The characteristic rolling topography of the lowlands is created by Pleistocene glacial deposits left by advances of the Harding Ice Field. Forest succession on the lowlands often leads to bogs and open stands of black spruce characteristic of the boreal forest. On dryer sites, succession results in stands of white spruce and paper birch. The Kenai Mountains, rising to an elevation of over 6,560 feet, form a second geographic unit over the eastern half of the peninsula. The Forest is divided by the boundary of the Eastern Kenai Mountains subsection and the Western Kenai Mountains subsection (Davidson, 1996). Steep sided U-shaped valleys, deep outwash deposits and hummocky high and low valley bottoms left by receding valley glaciers are remnant landforms characterizing the Forest. The rugged terrain (wide variety of slope, aspect, and elevation), becoming drier towards the interior rainshadow portions of the mountains (20-80" of precipitation, see Cooper Landing climate diagram Fig. 1), and proximity to wet coastal weather (200 to 400 inches of total precipitation per year, of which 59 to 157 inches is snowfall) result in a variety of unique vegetation patterns. Three-fourths of the land area is nonforested and is characteristic of the Alpine Tundra Biome (Rowe, 1972; Brock and Nowacki, 1993). Upland tundra, subalpine and coastal forest types prevail (Viereck et al. 1992).

Figure 1. Climatic diagram following Walter (1985). Key: Upper curve is mean monthly temperature, lower curve is mean monthly precipitation where 20mm precip. = 10 deg. C. Lower horizontal bars represent frost periods: hatched bar is mean latest/earliest frost date, clear bars indicate absolute latest/earliest dates. A=Station name, b=elevation,

c=mean annual temperature, d=mean annual preciplk,mm,=years of data, f=highest temperature recorded, g=lowest temperature recorded



Vegetation
Wildfire is an important environmental factor in the Alaska taiga, and present-day vegetation mosaics reflect past fire history (Viereck, 1973). The northern boreal forest is primarily open, slow-growing spruce interspersed with occasional dense well-developed forest stands and treeless bogs. This type of regional vegetation or "taiga" is differentiated from the closed, fast-growing forests of the more southerly region of the boreal forest zone. Contrary to the taiga, the Kenai Peninsula is a transitional zone between boreal forest merging with the coastal rainforest. Sitka spruce thrives in the near coastal zone where climatic conditions limit the frequency and intensity of naturally occurring fires (Agee, 1994). Mountain hemlock is considered to occur as a subalpine forest which usually burns infrequently, however fire is the primary large-scale disturbance agent in these forests (Agee, 1989). White spruce is adapted to a wide range of edaphic and climatic conditions of the Northern Coniferous Forest and has a transcontinental range across Alaska where it overlaps with Sitka spruce near sea level (Burns and Honkala, 1990). Fire has played an integral role in the evolution and maintenance of the flora and fauna of northern circumpolar forest habitats. Throughout the range of white spruce, fire has been an important, sometimes dominant factor in forest dynamics. White spruce is probably more susceptible to destruction by fire than any other tree in Alaska (Lutz, 1953).

V*egetation history*

The early Holocene was characterized by warm temperatures and low precipitation. The earliest pollen assemblages on the Kenai Peninsula - Hidden Lake indicate a mesic herb-willow tundra was replaced by birch shrub tundra around 13,400 ybp (Ager, 1983; Appendix B). Between 11,000 and 8000 ybp poplar-willow scrub vegetation occupied areas of central Kenai Peninsula, the northern Chugach Mountains, and northern Cook Inlet (Appendix C). Alder appearance in this region between 9000 and 8000 ybp, apparently arriving first on the coast and spreading rapidly to the north and west might reflect the higher precipitation of the region (Appendix D & E). White spruce appeared at about 8000 ybp on the Kenai Peninsula and the Anchorage area. The spruce migration began southward from interior Alaska into the Copper River Valley and Cook Inlet area. Sitka spruce, mountain hemlock and western hemlock did not appear in south-central Alaska until about 3000-4000 ybp (Peteet, 1991; Appendix F). The establishment of stands of coastal conifers was the result of a migration northwestward along the coast of the Gulf of Alaska that took place as storm tracts strengthened during the late Holocene (Huesser, 1983).

Soils

Soil development in the subarctic is a function of climate and topography, whereas parent material, time and organisms are of lesser importance. Short time span since glaciation combined with cold temperatures restricts chemical weathering. The present soil developed within the last 5000-10,000 ybp on steep slopes, U-shaped valleys, and glacial outwash deposits. Throughout the forest and meadow soils a 1/2 to 6 inch layer of very fine volcanic ash material occurred on top of glacial till (Fig. 2, Fig 3). These tephra deposits (3,500 to 3,700 ybp) are an upper Holocene marker in horizons of southcentral Alaska (Riehle, 1990). Charcoal evidence in all soil profiles examined in this study occurred above this tephra deposit. Leaching of weathered bases from glacial tills favours trees like Spruce. Soil acidification processes reflect leached podzol's which characterize the soil development of the area.

Very little research has been carried out on the effects of fire on soils and watersheds in Alaska (Dryness, 1978; Van Cleve & Viereck, 1983; Dryness et al. 1989), limited results make it difficult to describe soil effects. It is recognized that conditions after burning represent a mosaic and observations and sampling are stratified by classes. Forest floor conditions after fire in black spruce are classified into five-class system: 1) unburned, 2) scorched, 3) lightly burned, 4) moderately burned, and 5) heavily burned. Fire is a rapid decomposer.

In many areas of the world, including the subarctic, organic materials accumulate more rapidly than they are broken down by decomposition. Rates of microbial decomposition are ordinarily speeded up after a fire, largely because of increased temperatures. In these areas fire often plays the role of a rapid decomposer by releasing large quantities of readily available plant nutrients such as nitrogen, phosphorus, potassium, calcium, and magnesium. Fire affected forest floor chemistry in different ways in four forest types studied (Dryness et al., 1989). Despite the almost uniform increases in forest floor ph,

Fig. 2 Meadow soil

Fig. 3 Forest soil

amounts of exchangeable K, Ca, and Mg did not markedly increase in the forest floor with burning, except for heavily burned areas in white spruce and black spruce plots. There was an overall decline in C and N content of the forest floor with increasing burn severity.

Probably the most far-reaching effects of fire on soil in subarctic forests are caused, in the final analysis, by changes in soil temperature. Burning causes higher soil temperatures by consuming a portion of the insulating surface organic layer and blackening the surface. Most studies indicate surface soils, which have been recently burned, warm up more quickly at the beginning of the growing season and are substantially warmer than unburned soils. Although all the consequences of this temperature differential still are not known, we do know it stimulates germination and growth of some plants, accelerates rates of decomposition and mineralization, and results in a retreat of the surface of the permafrost table.

Methods

Site selection

With the aid of Forest Service personnel, disturbance event polygons that appeared to contain Lutz spruce (Picea x lutzii) dominated forest affected by the same disturbance event were located on 1:15,840 aerial photographs. Foot travel to and within these polygons for field observations and reconnaissance on the forest composition were made prior to sampling transect points. There were limitations with the accuracy of forest history reconstructions on these sites due to lack of living trees having survived recent spruce bark beetle infestations. Isolated areas still remain throughout the forest where the living trees stand ages could still span the time of disturbance history.

After further evaluation using timber cover type maps and discussions with foresters assessing timber salvage units, three (3) primary areas were chosen the first field season for sampling in forest stands with tree ages exceeding 200 years. The forest types are a mixture of hybrid Lutz spruce and mountain hemlock (Tsuga mertensiana). Random locations were subjectively chosen within each polygon after assessing the homogeneity of the site and forest type. A one hundred and fifty (150) meter transect point was located, transect width was variable (between 3 and 6 m wide) in order to sample approximately 100 trees independent of stand density. At each point, a random transect direction was chosen.

During the second field season an old forest land classification revealed large burns pre-1924 throughout the Forest. After digitizing these polygons, and locating them on aerial photographs, these old historic fire burns sites were visited in the field. Transects were positioned on the edge of twenty four (24) burns. A fifty (50) meter transect point was located, transect width was variable (between 3 to 5 m wide) in order to sample approximately 30 trees independent of stand density. Historic photograph points were relocated in two localities to document changes over time.

Aspect, slope and elevation were measured by compass, clinometer, and altimeter, respectively. Diameter at breast height, core height, diameter at core height, total tree height, and basal area by species were recorded for each tree in the plot. Fuel's data was sampled along the first 20 meters. A soil pit was dug in the periphery to characterize the site and look for evidence of soil charcoal. Soil charcoal was collected during the first field season. Samples were sieved and processed at Beta Analytic for radiocarbon determinations using AMS techniques.

Ages of Living Trees

All living trees were cored as close to the root crown as practical in all plots. In most instances core height averaged one foot above the soil surface. Increment cores were mounted on boards, sanded and counted under a binocular microscope. Total tree age on a sample was determined by adding to the age estimates of core height above germination level taken from saplings on the site. Further correction factors need to be determined for the region. For missed piths, I estimated each cores continuous rings using circle templates of different radii. I counted the number of rings across this same distance in the innermost intact wood. This number of rings then was added to the count of actual rings. By experimenting with cores that actually contained piths, I found that this method consistently underestimated the number of rings. Calculated errors in age estimates still need to be determined. Future work needs to cite Bevington (1969), who calculated the combined covariances in growth-rate estimates, ages of missed piths, and covariance between growth rates and tree ages at various heights.

Historic Fire Disturbance Map

The forest fire records from 1914-1997 were attributed into a GIS data base. Fire polygons were mapped from individual fire reports onto 1:63,000 USGS topo quads. Fire locations within polygons were also mapped as point occurrences. The old historic land classification atlas including fire burn polygons were additionally digitized. Moose burn polygons were mapped onto to 1:15,840 aerial photographs and digitized into GIS data layer. All layers were combined into a historic fire disturbance map. The timber cover types were compared to assess relationships between historic burns and mixed broadleaf forest types.

Results

Three isolated mature forest areas and 24 old historic fire burns were sampled during two field seasons 1995-1996 (Table 1, Appendix G). Tree stand age structures were reconstructed by their age distributions of living trees for the three mature forests (Fig. 4). The Hunter site is a productive forest with devil's club and wood fern understory (Fig. 5, Fig 6). There are clumps of sapling regeneration, tree recruitment of both spruce and hemlock seedlings were common on nurse logs that have fallen and rotted and

Table 1

Study Sites	Vegetation type	Elev.	Slope	Aspect	Charcoal evid.		Age	Recruitment
1995								
Palmer Creek	Tsumer-Picsit/Menfer-Moss	1300	20	270	no charcoal		uneven	mostly hemlock
North Kenai Lake	Piclut/Menfer-Moss	750	10	160	1540 +/- 40 BP	stand replacing	even	spruce & hemlock
Hunter	Tsumer-Piclut/Echhor-Drydil	1100	30	150	1290 +/- 40 BP		uneven	spruce & hemlock
1996								
Bear Creek site 1	Betken-Picsit/Echhor-Calcan	800	25	234	charred stumps	stand replacing	even	spruce & hemlock
Bear Creek site 2	Betken-Picsit/Echhor-Drydil	1000	20	180	charred stumps	stand replacing	even	spruce & hemlock
Lower Palmer Creek	Betken-Picsit-Tsumer/Moss	700	10	290	charred stumps	stand replacing	uneven	sparse spruce
East Moose Creek	Picgla/Betnan-Empnig	1900	5	312	charred stumps	stand replacing	uneven	sparse spruce
Hungry Creek	Picgla/Betnan-Empnig	1950	15	130	charred stumps	stand replacing	uneven	spruce & hemlock
Russian River Ferry	Picgla-Poptre/Empnig-Vacvit	700	0	180	charred stumps	stand replacing	even	spruce
West Slaughter Creek	Picmar-Picgla/Betnan-Empnig	1250	2	290	charred stumps	stand replacing	uneven	spruce
West Juneau Lake	Picgla/Linbor	1600	9	300	charred stumps	mixed severity	even	spruce & hemlock
East Juneau Lake	Picgla/Betnan-Empnig	1400	3	100	charred stumps	stand replacing	even	spruce & hemlock
West Swan Lake	Tsumer-Picgla/Betnan-Empni	1700	10	280	charred stumps	stand replacing	uneven	spruce & hemlock
Aspen Flat site 1	Picgla-Poptre/Betnan	700	24	250	charred stumps	stand replacing	even	spruce
Aspen Flat site 2	Picgla/Betnan-Arcuvi	600	1	280	charred stumps	stand replacing	even	spruce
Tenderfoot Hillslope	Tsumer/Menfer	1500	40	290	no charcoal	no fire evidence	uneven	hemlock
Crescent Lake Trail	Tsumer/Menfer	1100	5	160	charred stumps	mixed severity	uneven	hemlock
Manitoba East	Tsumer/Moss	1800	15	280	charred stumps	stand replacing	uneven	none
Manitoba West	Tsumer/Moss	1400	20	80	no charcoal	no fire evidence	uneven	hemlock
East White Creek	Betken-Picgla/Menfer-Empnig	1280	25	280	charred stumps	stand replacing	even	birch, spruce, hemlock
Pass Creek	Tsumer/Menfer	1250	9	310	charred stumps	stand replacing	uneven	hemlock
Rimrock Creek	Tsumer-Piclut-Betken/Empnig	650	25	160	charred stumps	mixed severity	uneven	hemlock
Upper Palmer Creek	Tsumer-Piclut-Betken/Menfer	1200	18	270	charred stumps	mixed severity	uneven	hemlock
Upper Trail Lake	Betken-Piclut	550	57	130	charred stumps	stand replacing	even	birch & hemlock
West Shore Kenai Lk	Betken-Piclut	1280	27	176	charred stumps	stand replacing	even	birch, spruce, hemlock
Henry Creek	Betken-Piclut	850	10	100	charred stumps	mixed severity	even	birch, spruce, hemlock
Falls Creek	Betken-Piclut	600	37	76	charred stumps	mixed severity	even	birch, spruce, hemlock

Fig. 4

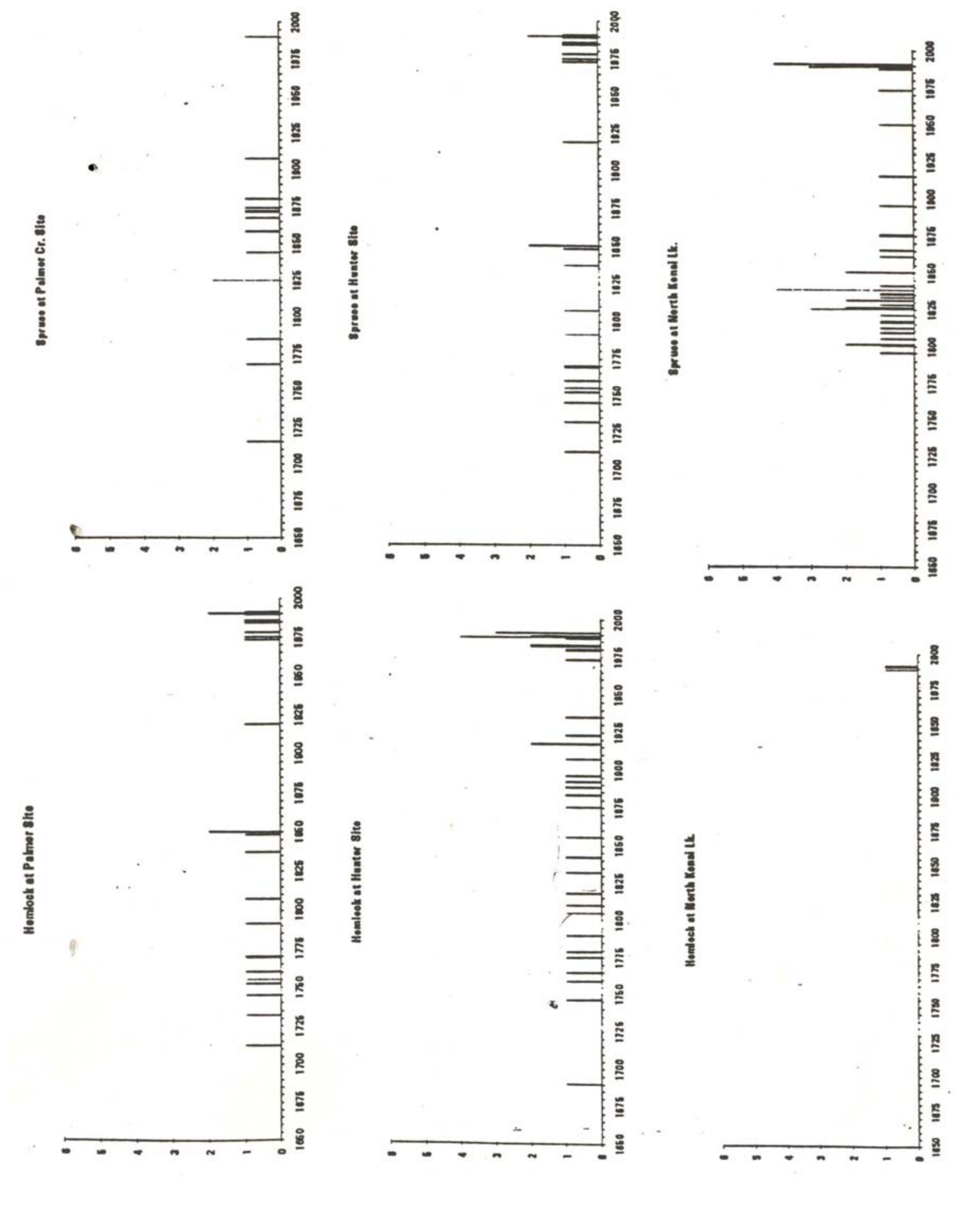
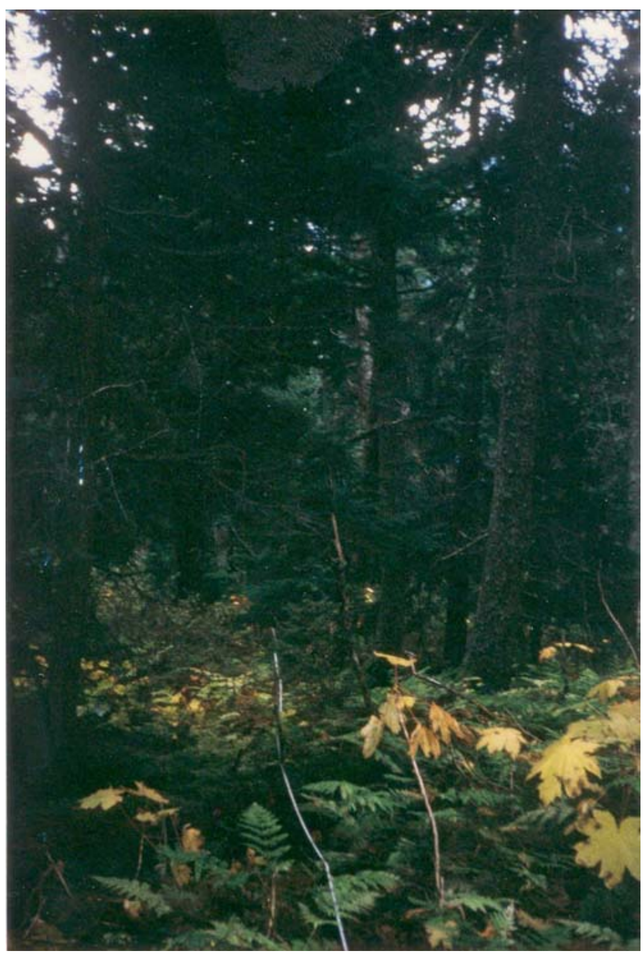

Spruce at Palmer Cr. Site
Spruce at Hunter Site
Spruce at North Kenai Lk.
Hemlock at Palmer Site
Hemlock at Hunter Site
Hemlock at North Kenai Lk.

Fig. 5

Fig. 6



provide an excellent micro site for new regeneration. Windthrow is somewhat scattered, these gap disturbances influence tree recruitment. Soil subsurface charcoal was found under the Hunter site dating 1270 +/- 40 BP (Appendix H). The disturbance polygon is included in a larger silviculture treatment, the stand polygon size is 200 acres (Unit 63, L. Ang, 1995). The basal area for spruce is 160-240, avg. 180. The basal area for mountain hemlock is 240-360, avg. 280. The size of the spruce is 20" dbh live, range 14-40. The size of the mountain hemlock is 16" dbh live, range 6-24. The age/vigor of both spruce is about 240 yrs., mountain hemlock is greater then 200 years. Growth of spruce is .8 to .20 inch per decade, avg. 15. Growth of mountain hemlock is .6 inch per decade, with greater then 50% heart rot.

The Palmer Creek site is an older growth mountain hemlock and Sitka spruce forest with an uneven age structure (Fig. 7, Fig 8). Tree recruitment was primarily hemlock seedlings. Very little gap disturbances were noted on the site. No soil charcoal was found within the soil profile. The disturbance polygon is included in a silviculture treatment, the stand polygon size is 145 acres (Unit 1, Neff-Shea and Simonson, 1995). The basal area for spruce is 120 live avg., range 0 to 240, 70 dead avg. The basal area for hemlock is 150 avg., range 10-26. The size of spruce is 20" dbh live and dead, range 10-26. The size for hemlock is 20" avg, range 10-24. The age/vigor of both species is greater then 200 years. Growth of both species is greater than .3 inch per decade. The site index is 70.

The North Shore Kenai Lake site is the third mature forests sampled (Fig. 9, Fig. 10). An even-aged stand, dominated by Lutz spruce contains both surface and subsurface soil charcoal. The subsurface soil charcoal date is 1530 +/- 40 BP (Appendix I), the surface charcoal was not dated due to misunderstanding of contamination from fungus and bacteria. Tree recruitment is primarily saplings of Lutz spruce with patches of mountain hemlock. The wind throw and blowdown is building creating widespread gap disturbances (Fig. 11). The soil profiles sampled throughout these slopes have a strong signature of charcoal (Fig. 12). The disturbance polygon is included in a larger silvicultural prescription treatment, the stand polygon is 500 acres (Unit 19, L. Ang, 1995). Most of the stand is spruce with very little hemlock along the top edge. The basal area for spruce is 300 avg., range 200-380. The basal area for mountain hemlock is 260 avg., range 200-380. The size of spruce is 16" dbh avg., range 10-20. The size for hemlock is avg. 8, range 5-12. The age/vigor of spruce and hemlock is 200+ yrs. Growth for spruce is .4 to .16 inch per decade. Growth for mountain hemlock is .4 inches per decade.

Further reconnaissance of fire disturbances throughout the forest during the 1995 first field season revealed three additional prehistoric fire events. The Black Mountain site (proposed RNA) contains a mature mountain hemlock forest with rusty menziesia understory (Fig. 13, Fig. 14). The subsurface soil charcoal date is 3010 +/- 40 BP (Appendix J). The Unit 5C - Schillter Creek site, North Shore Kenai Lake, contains

Fig. 7

Fig. 8

Fig. 9

Fig. 10

Fig. 11

Fig. 12

Fig. 13

Fig. 14

another older growth mountain hemlock forest with rusty menziesia understory (Fig. 15, Fig. 16). The subsurface soil charcoal date is 2470 +/- 50 BP (Appendix K). The Unit 13D - North Shore Kenai Lake contains another older growth mountain hemlock forest with rusty menziesia understory (Fig. 17, Fig. 18). The subsurface soil charcoal date is 570 +/- 60 BP (Appendix L).

Within the historic burns remnants of older stumps (Fig. 19, Fig. 20) and isolated residual trees reveal mature forests existed prior to settlement disturbance (Fig. 21, Fig 22). Limited dead wood exists to extend the time span of the fire history that we can reconstruct from earlier successional stages of tree recruitment on a site. Historical written accounts and photographs of fire occurrences were collected. Two locations were visited with historical photographs in Aspen Flats and Juneau Lake vicinities. Photographs were retaken to document changes over time (Fig. 23, Fig. 24, Fig. 25, Fig. 26). Fire reports were attributed from 1914-1997 and a GIS historic map was generated documenting known polygon and point references of fire in this century.

Discussion

Stand age structure, radiocarbon soil charcoal dates and evidence of fire charred stumps were used to construct a fire history for the mountain hemlock/Lutz spruce vegetation type of the Kenai Peninsula's mountainous portion of the Chugach National Forest. Records to construct a much more detailed picture of the fire history on living trees is limited to the past 300 years because older mountain hemlock and Lutz spruce trees are rare on the Forest. Age-class analysis of three mature habitat types on the forest reveal uneven and even age structures, extended and suppressed recruitment and gap-phase regeneration. Charcoal was found subsurface in the soil profile below the present litter and duff on two of the three sites. Radiocarbon dates were 1540 +/- 40 ybp and 1270 +/- 40 ybp. Two sites are located in the interior portions of the forest, whereas the third site occurs closer to the coastal climate. Three distinct periods of fire frequency were established; prehistoric (pre 1740), settlement (1741-1913), and post-settlement (1914-1997). The influx of ignition sources increased during the settlement period and greatly decreased during post-settlement. The difference was attributed to the influx of mining and railroad activity during settlement era which created the vegetative mosaic now observed throughout the Forest.

Prehistoric period

The fires over the last 150 years of settlement contributed to the present forest mosaic. These fire disturbances have boosted the wide range of diversity in composition of forest types on the Chugach portion of the Kenai Peninsula. Prior to the settlement period of the late 1800's, the majority of the coniferous forests were recorded (Langille, 1904; Holbrook, 1924) to be in late successional stages. The size of the old, charred stumps

Fig. 15

Fig. 16

Fig. 17

Fig. 18

Fig. 19

Fig. 20

Fig. 21

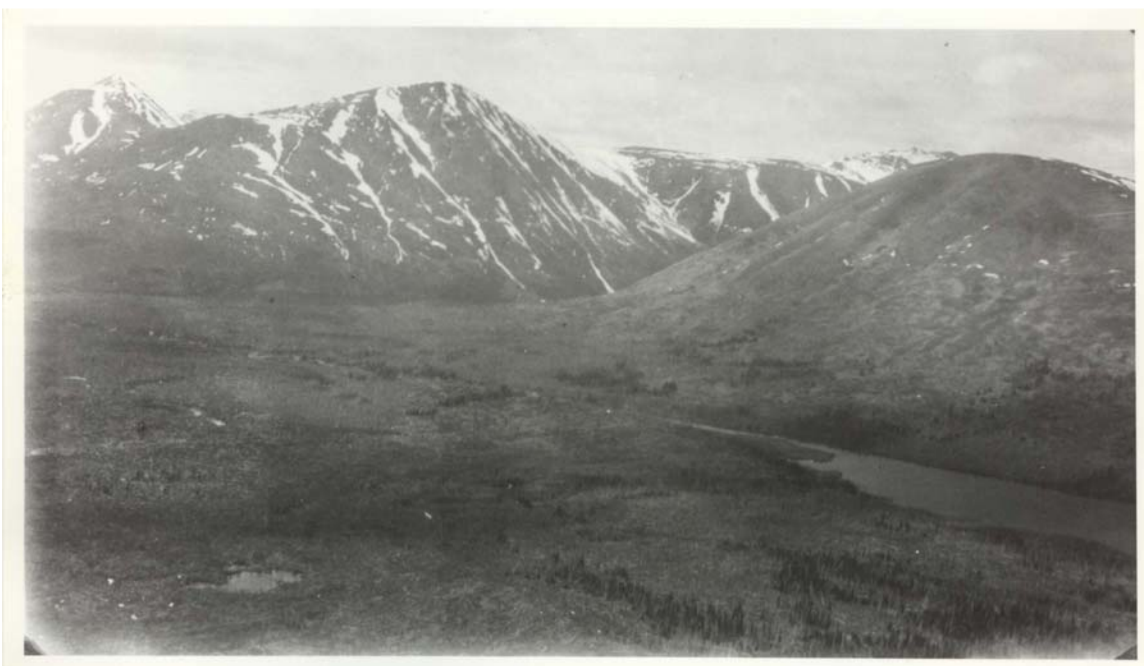
Fig. 22

Fig. 23

Fig. 24

Fig. 25

Fig. 26



found within the fire disturbance areas are approximately the same size as today's (Fig. 27). Forest and nonforest acreages on the Forest reflect the compositional changes of needleleaf forests bordering the burned areas, which are more than 200 years old (Fig. 28, fire disturbances (Table 2).

Of the 270,000 thousand acres of forest lands on the Chugach portion of the Kenai Peninsula, 215,000 thousand acres are needleleaf forest and 55,000 thousand acres are mixed or broadleaf forest types. The vast majority of trees are dominated by mountain hemlock, secondarily by white and Sitka spruce needleleaf forests, and thirdly by birch and cottonwood deciduous forests. The large number of acres burned on the Forest during settlement (30,000 acres, Holbrook, 1924) included conversion of some mature spruce stands to grass, brush, and broadleaf tree vegetation types. Numerous burned areas were likely reburned. The evidence of these fires can be seen in the present birch and aspen forest mosaics comprising 35,000 acres of mixed or broadleaf forest types. The abundance of grassland, alder and brush non-forest types also reflect fire disturbances. However, the actual burned acres are difficult to determine because avalanche and landslide also contribute to widescale disturbances of these non-forest community types.

The evidence for pre-historic fire events on the forest from radiocarbon dates on soil charcoal range from 4500 ybp (Reiger, 1995) to 570 ybp. Historical evidence supporting a climax forest is cited by the following authors Langille (1904) and Holbrook (1924) concluded from evidence indicated by old logs and decayed stumps of large size, that a prehistoric forest of greater proportions once existed, probably destroyed by fire before the Russian occupancy of the region, each succeeding generation diminishing in size and quantity until they are reduced to their present impoverished state. Although large historic fires were recorded on the Forest during the settlement period, we do not now how this compares with the number and size of fires during prehistoric fire history.

This present study confirms with Tande's (Rothe, et al. 1983) data suggesting that the Anchorage area and the Kenai Mountains have low incidences of natural fire and long periods of time between fires. Young stands of trees in the forests of the Kenai Mountains are rare as in Anchorage vicinity. The age of forest stands are between 190-350 and 45- 100 years old on the Kenai and between for 195-230 and 45-80 in Anchorage. Due to the lack of fire scar evidence, natural fires on the Forest were rarely detected in the age structure of the Forests. Charred charcoal was commonly found in soil profiles below the organic mat (Fig. 29, Fig. 30). The study site on the north shore of Kenai Lake had an even age-class spruce forest with prolific charcoal on the soil surface and beneath fallen root mats (Fig. 31, Fig. 32).

<u>Settlement history</u>

Beginning in the late 19th century and continuing through the early 20th century, this period shows high fire frequencies on the Kenai Peninsula. The forests of the Kenai Peninsula represent a nearly natural situation. Before settlement there was virtually no

Fig. 27

Fig. 28

Table 2

Forest/Nonforest Acreages for the Chugach portion of the Kenai Peninsula:

Nonforest type	Acres
Alpine	277,133
Rock	201,305
Ice/Snowfields	157,906
Alder	141,053
Brush	67,751
Grassland	54,879
Water	36,154
Willow	9,681
Riverfill	4,036
Snowslide	3,793
Muskeg	2,406
Urban	1,718
Borrow pit	156
Total Nonforest type	958,000

Forest type	Acres
Hemlock	81,801
Hemlock/White spruce	49,893
Hemlock/Sitka spruce	28,295
White spruce	42,255
Sitka spruce	12,185
Birch	18,186
Birch/Hemlock	99
Birch/White spruce	7,552
Birch/Sitka spruce	2,973
Cottonwood/White spruce	3,606
Cottonwood/Sitka spruce	954
Cottonwood/Balsam poplar	15,477
Cottonwood/Birch	531
Cottonwood/Birch/White spruce	50
Aspen	3,010
Aspen/Hemlock	111
Aspen/Sitka spruce	1,557
Aspen/Birch	378
Black spruce	737
No data	213
Total Forest Types	269,479

Fig. 29

Fig. 30

Fig. 31

Fig. 32

utilization or disturbance of the resource except by the aboriginal people. In an interview with the Kenaitze tribe, the use of fire was discussed to reduce travel barriers between the Kenai area to the Russian River (Shuster, 1997). Microblade projectiles recorded along the Russian River and artifacts from a Kenai River area conclude that inhabitants of Kachemak tradition emphasized year round use of harvesting salmon and hunting land mammal at certain seasons possibly as early as 10,000 ybp on the Forest. Perhaps the earliest written occurrence of Russian occupancy on the Forest was in the late 1793 (Pierce, 1980). Russian shipbuilders prospected in the Kenai Peninsula mountains for iron ore. It is said that burned rocks along Russian river are remainders from Russian iron smelting attempts. The iron ore was transported down along Resurrection River to the bay. The Russian mining engineer, Doroschin ascended the Kenai River in 1841 in search of gold prospects. He reported a major forest fire on the Kenai Peninsula in the Skilak River valley (Lutz, 1956). Geologic expeditions documented the general features of the land including fire occurrences in 1900 (Mendenhall, 1900). Mineral prospects at the time the Forest was created 1909-1915, indicated that a rapid settlement and development of this country took place in the late 1890's.

The coming of the American gold seekers saw the first use of the forests, exploiting the forests to obtain lumber for sluice boxes (Langille, 1904). Many of the gold seekers were careless with fire, with the result that they burned not only a large part of the timber but their cabins and outfits as well (Fig. 33, Holbrook, 1924). The forest utilization experienced a few local sawmills limited to a small percentage of timber needs of the inhabitants. The railroad contractors exploited the entire Kenai Lake region to obtain mountain hemlock ties for the line from the lake to the Arm (Fig. 34, Langille, 1904).

Commentaries from the Foresters' diaries early in this century, describe extensive fires on the Forest between 1913-1915 (Fed. Archives, Anchorage, AK). The basic causes for fires are attributed to railroad activity igniting the vegetation. The drought conditions following the 1912 Katmai Volcano eruption also contributed to the fire behavior creating favorable weather for burning. Holbrook (1924) also reports, 'the region has been visited by numerous fires and most of the better grade of timber has been burned'. He mapped approximately 30,000 acres of burned area on the forest. The large disastrous fires include the 1896 fire in the Canyon Creek watershed covering 4,000 ac (Fig. 35, Fig 36), Juneau Creek, Kenai River, and Quartz Creek watersheds covering 10,000 ac (Fig. 37, Fig. 38), and the Resurrection Creek watershed covering 10,000 ac (Fig. 39, Fig. 40) including the Hope fires (Fig. 41) namely Cripple Creek, Bear Creek and Sunrise (Fig. 42) fires (1904-1930) burning at least 6,000 ac cumulative.

Little was known of the Kenai Peninsula's biological characteristics before 1875. Until the nineties, it was evidently Stone barren-ground caribou, and moose were scarcely known to old residents. Between 1871 and 1910 widespread fires created habitat favorable to moose, and in the present century the Kenai has become famous for its great moose herds. Davis & Franzmann (1979) and Lutz (1956, 1960) describe fire-moose-caribou interrelationships. Unlike the moose, which prefers pioneer plant communities or at least

Fig. 33

Fig. 34

Fig. 35

Fig. 36

Fig. 37

Fig. 38

Fig. 39

Fig. 40

Fig. 41

Fig. 42

vegetation representing early stages of successional development, the barren-ground caribou normally lives in environments characterized by climax plant communities, tundra and forest tundra transition. Buckley (1958) states that for those species, such as caribou, that require climax conditions, fire has undoubtedly reduced the quality of the range, and has contributed to the decline of caribou in Alaska noted during the first half of the century. With other species, such as moose, the result has been quite the opposite. A rapidly growing moose herd became evident about 1910, coincidental with the disappearance of caribou.

Post-settlement history

Human impact on the forests has varied and early impacts have been masked by those which came later. From 1914 to 1997 a total of 1364 fires are reported burning 65,000 acres. Moose burns and hazardous reduction fires add an additional 10,000 acres. The presence of numerous hardwood forests, aging from 45-100 year old forest stands, reflects increases in human activities during the late 1800's and into the mid-1950's. Trees are harvested mostly for local timber and fuel needs as the land is cleared for settlements, railroads, roads, and power transmission lines. Fires are associated with all these human activities. During the period from 1914 to 1953 there was an average of 22.5 fires per year on the Kenai Peninsula portion of the Forest, of which (at least) 73 percent were related to railroad (Blanchet, 1987; Fig.43, Fig. 44). Fires averaged 62.7 acres in size yielding an average 1409 acres burned per year. Following the end of the steam engine era around 1954, fires decreased sharply in both size and number on the Kenai.

The tremendous amount of recreational use of the area results in a high incidence of human-caused fires (Vanderlinden, 1991). The most significant fires are the Kenai Lake fire in 1959 burned 3,278 acres, the Russian River fire in 1969 burned 2,730 acres/270 acres on Forest land (Fig. 45), the Caribou Creek fire in 1985 burned 3,000 acres (Fig. 46), and the Pothole Lakes fire burned 7,371 acres/544 on Forest land (Fig. 47). The Gull Rock area has had multiple fire occurrences through history, the most recent fire in 1993, smoldered for 2 months in the fall (Fig. 48). These human-caused fires often are started in or near developed areas and can occur in a much greater range of conditions than lightning storms could occur. Past fire management direction has been to suppress all detected wildfires, primarily to protect urban areas; primarily timber harvesting to reduce fire hazards in Cooper Landing area (Fig 49, Fig. 51).. Although the actual acres of fires have decreased in the last century, the number of ignitions is still significant, increasing in the last decade (Fig. 50, Fig. 51). From 1914 to 1953 the main cause of ignition was related to railroad (Fig 50). Following the end of the steam engine era around 1954, the greatest cause of fires on the Kenai has been campfire starts by careless recreationalists (Fig 50). Perhaps -the feasibility of a very aggressive fire prevention program aimed at recreational users of the area needs to be investigated.

Evidence of fire succession in the mountain hemlock/Lutz spruce forest type

The effects on vegetation succession after settlement fires in the latter century reflect a tree re-establishment of mixed deciduous forests within 100 years after disturbance, pre-

Fig. 43

Fig. 44

Fig. 45

Fig. 46

Fig. 47

Fig. 48

Fig. 49

Fig. 50

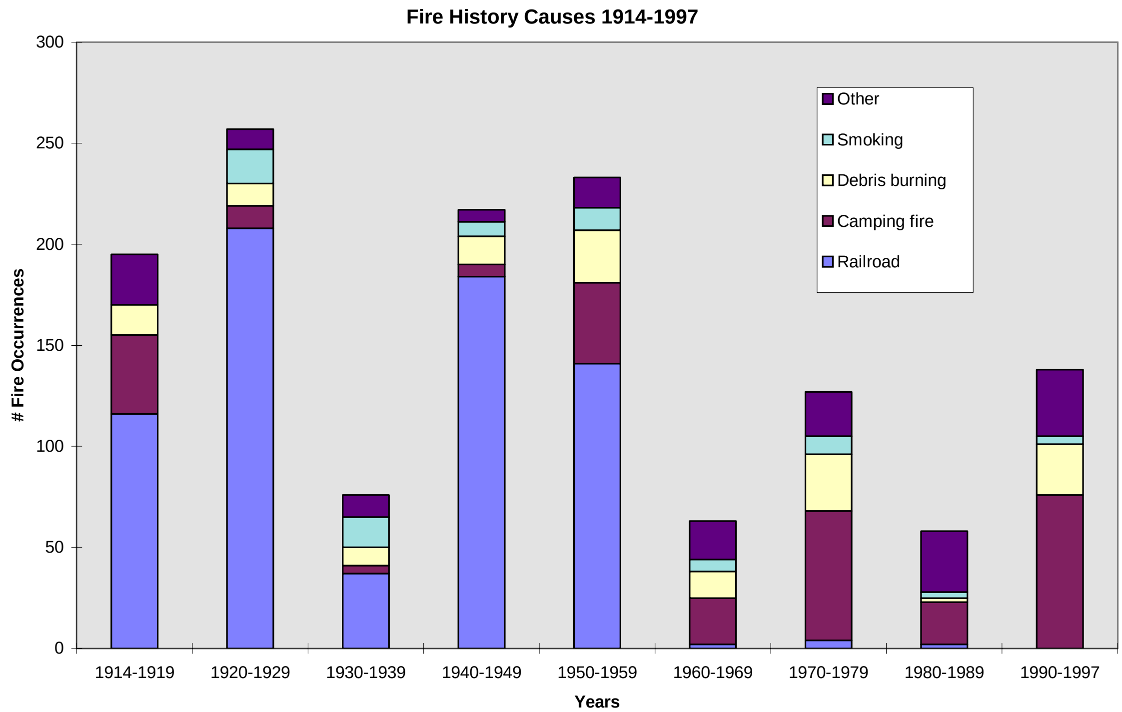
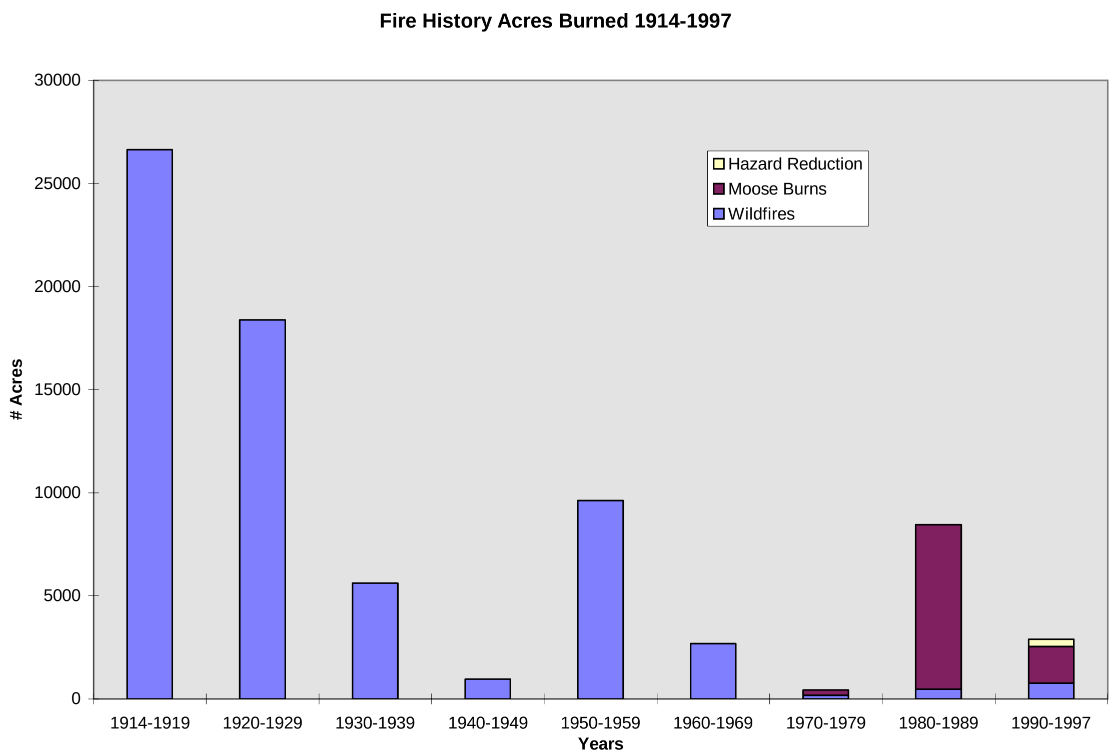

Fire History Causes 1914-1997
Fire Occurrences
300
250
200
150
100
50
0
Other
Smoking
Debris burning
Camping fire
Railroad
1914-1919
1920-1929
1930-1939
1940-1949
1950-1959
1960-1969
1970-1979
1980-1989
1990-1997
Years

Fig. 51


Fire History Acres Burned 1914-1997
Acres
30000
25000
20000
15000
10000
5000
0
Hazard Reduction
Moose Burns
Wildfires
1914-1919
1920-1929
1930-1939
1940-1949
1950-1959
1960-1969
1970-1979
1980-1989
1990-1997
Years

1890. Birch is the most abundant tree in the larger acres burned, and on recently disturbed sites. The various birch forests sampled span a wide range of age structures which are similar to the hardwood stage of succession occurring 46-150 years after fire in the boreal forest ecosystem (Foote, 1983). In the subalpine environment of the Forest, the tree re-establishment process may Kenai lake has an even-aged stand of Lutz spruce dominated needleleaf forest. Scattered dead birch trees were found throughout the stand sampled. The stand age of the Lutz spruce examined in the Kenai Mountains is also similar to the white spruce stage of succession occurring 150-300 years after fire in the boreal forest ecosystem (Foote, 1983). Regeneration of mountain hemlock is occurring in the understory. The time it would take to reach a late successional forest dominated by mountain hemlock would take minimally another 100 years. Older Lutz spruce and mountain hemlock trees cored in the vicinity average between 300-350 years old.

This disturbance polygon reflects the time for mountain hemlock to reinvade a site. It predominates in stands older than 200 years (Dickman and Cook, 1988). Radiocarbon date in the subsurface soil is 1540 +/- 40 ybp. Surface charcoal was not dated, yet is older then the present forest and younger then the previous fire event. Two other radiocarbon dates in the vicinity of this site on the North Shore of Kenai Lake have ages ranging from 2430 +/- 50 ybp and 570 +/- 60 ybp representing two additional fire events. This disturbance polygon indicates that a fire event occurred in the past greater then 200 to 300 years before present. At least 300-400 years is predicted for a mature hemlock forest to dominate on this site after a stand replacing fire disturbance.

Fire Management

Fire Regime:

The behavior of these nineteenth and twentieth century fires suggests that five distinct fire regimes exist side-by-side throughout the forest. The frequency of these fire regimes is variable throughout the Forest watersheds. The eastern portion of the Kenai Mountains have a coastal influence, limited fire occurrences are reported. The western portion of the Kenai Mountains sits in a rainshadow, with an interior drier climate, the fire regime is predicted to have more frequent fires. The settlement period reflects large acreages burned more extensively in this area. Although lightning is rare on the Peninsula, the limited documented occurrences have been reported in this portion of the Forest.

The spatial arrangements of the communities on the Forest are influenced by temperature and moisture gradients. The communities in drier, warmer environments have the shortest fire intervals, whereas the communities in cooler, wetter environments have the longest fire intervals. These fire frequencies also reflect the landscape heterogeneity within which they occur. Needleleaf forests within this landscape are dominated by the following vegetation types.

1) No fire occurrence - Sitka spruce forest along the coastal zone from sea level to timberline. No obvious fire disturbances were noted in the soil or age structure,

2) North facing upland cool, moist slopes have rare fire occurrence at edge of stands - Mountain hemlock on mountain sideslopes and ridges to timberline from the coastal zone to the interior of the forest. Charred bowls resembling shallow fire scars were found in small remnant gaps and at the edge of burns at the lower boundary of mountain hemlock forests.

3) Infrequent natural lightening fire occurrence - Black spruce and bog habitats are relatively sparse and occur along toeslopes and valley bottoms. Fire evidence was noted on the edges of these habitats.

4) Frequent human-fire occurrence - Lutz spruce (hybrid between white spruce and Sitka spruce) occurs in mixed stands with paper birch in the valley bottoms and mixes with mountain hemlock on the mid and lower portions of mountain sideslopes. The distribution of Lutz spruce is correlated with the historic burns which occurred predominately in valley bottoms and lower sideslopes. Fire travels from the valley bottom Lutz spruce stands, but often stops at the lower boundary of mountain hemlock dominated forests. Broadleaf forest within this landscape are dominated by paper birch which is plentiful, occupying many valley bottoms and upland sideslopes mixing with Lutz spruce and to a lesser degree with mountain hemlock. The wide distribution, age structure and abundance of birch reflects the past fire history of this century. Balsam poplar grows predominately on flood plains adjacent to rivers. Quaking aspen occurs sporadically on the very dry warm and well-drained sites in the rain shadow of the forest interior. Both hardwoods can be found on upland sites with a recent fire history.

5) Frequent human-fire occurrence - Nonforest vegetation types, predominately brush and grassland with evidence of fire disturbance occur adjacent to the lutz spruce needleleaf forest types from sea level to timberline on a variety of slope positions. Alpine tundra consisting of mesic meadow, dwarf willow, heather and lichen communities did not appear to have experienced recent fire disturbances except at the edge of timberline.

A fire-return interval of 1,146 years was estimated for the “Sitka spruce” type in western Washington and disturbance cycles of 400 years and 200 years from the northern and southern Oregon coasts (Agee et al. 1989, Agee, 1994). This is not meant to imply a precise return interval but does indicate that Sitka spruce forests burn rarely. Disturbances in “mountain hemlock forests” other than fire may be important in forest stand dynamics such as laminated root rot or mortality of individual standing trees (Dickman and Cook, 1989). It appears that multiple interactions between fire and fungus influence the fire-return interval of mountain hemlock and lodgepole pine in Oregon forests. Fire return intervals have been calculated between 200 years or less and 600 years depending on the infestation of the fungus. Alaskan and Canadian interior white spruce forests burn about once every 113 years, fire cycles average 105-300 years along the Mackenzie & Porcupine Rivers of Alaska (Rowe et al., 1974; Yarie, 1981). On the Kenai Peninsula the climate is wetter then the interior boreal forest, yet drier then the coastal rainforest. The hybrid Lutz spruce forests would have fire frequencies that are longer then the interior, but shorter then the coastal rainforests. These four dominant coniferous forest species in southcentral Alaska reflect varying fire cycles, however cumulatively this southern region of the boreal forest zone reflects a long-interval stand replacement fire regime.

Fire Risk:

Risk of natural fires has been described as being low in these spruce-hemlock plant associations of the Chugach National Forest portion of the Kenai Peninsula because of unfavorable cool and wet fire weather, rapid natural decay, and a low occurrence of natural lightening ignitions. The majority of fires on the Forest are human caused as lightening occurs very infrequently, less than 3 occurrences were reported in the last century. Beginning in the early 20th century until the 1950's there was a period of high fire frequency from railroad activity on the Kenai Peninsula portion of the Chugach National Forest. These fires have decreased in acreages burned as fire prevention techniques improved following the end of the steam engine era around 1953.

The number of occurrences is still significant on the forest, since 1960's the greatest cause of fires on the Kenai Peninsula portion of the Chugach National Forest has been campfire starts by careless recreationists. Due to the increase in population and better detection on the Forest, the number of occurrences appears to be increasing in this recent decade. Location of fire starts on the Kenai Peninsula portion of the Chugach National Forest between 1960 and 1997 concentrate almost exclusively along the road corridor (Blanchet, 1987; GIS point occurrences data layer, 1997). Since the 1960's, Cooper Landing, Crown Point and Moose Pass areas show particularly high concentrations of fire starts (Appendix M). Fire suppression activities in the future are likely to continue to concentrate in these areas. The highway corridor from the Forest Boundary on the Sterling Highway (at Russian River) over to Crown Point on the Seward Highway is particularly susceptible. With the exception of the Russian Lakes Trail, fire starts along Forest trail systems are generally quite low. Unfortunately these fire starts along trails sometimes burn much greater acreages since they are farther removed from access by fire suppression crews. The Russian Lakes Trail shows a considerable fire start history, particularly in the vicinity of Lower Russian Lake. This high concentration of fire starts is likely due to both the high use of this trail (especially up to Lower Russian Lake) and the relatively low precipitation received by this area.

The majority of fire starts and large fires have occurred primarily in these grassland vegetation types in early fire season, from mid April, May and June, with some activity in August and September (J. See, 1997 pers. comm.). Ignitions in the spring spread rapidly in grassland and either stop due to higher moist surfaces or slow down to creeping upon reaching the brush and forest or crown fires develop where slope angles increase. Locations that have burned and return initially in grass are very susceptible to reburning when the previous year's dead grasses are exposed and dried. The window for burning increases during late spring from 10-14 hours and gets narrower in late September reduced to 3 hours long in these fine flashy 1 hour fuels. In the fall, after the season's frost again kills the grass vegetation, it is susceptible to burning if weather conditions permit and snow pack hasn't compacted the grass into a mat (J. See, 1997 pers. comm.).

Fire Hazard:

Fuels analysis is limiting but cannot be divorced from fire occurrence. The time required for fuel accumulation modulates the control of climate and weather over fire occurrence and may be a critical factor in the Forest fire cycle. Although ignitions and small, low-intensity fires may occur at any time on the Forest given suitable weather, fuel accumulation may require 150-200 years to reach a point where it can support intense fires capable of damaging and killing canopy trees. The most flammable fuels pose no threat if there are no ignitions. The large fire occurrences on the Forest, with only limited lightening suggest human cause disturbances. Human-caused fires account for over 99% of all fires on the Forest indicating that a prevention program could be successful. The large number of acres burned on the Forest during settlement indicates that human-cause ignitions, fuel loads, and weather conditions were optimal for burning. These mature forest stands that burned must have had sufficient fuels to result in stand replacement fires, being at or near the upper end of historical fire intervals. Suspect drought conditions probably contributed to the higher acreages burned. Although the written fire history prior to 1950 is sketchy, drought weather conditions resulting from the 1912 Katmai eruption have been suggested to contribute to large scale fires from 1913-1915 burning approximately 20,000 acres on the Forest, 1915 was recorded as the worst fire year on record.

The present forest conditions resulting in increased fuel loads from beetle kill, careless human-caused ignitions and drought weather conditions are important mechanisms for fire managers to evaluate for predicting risks and hazardous large scale fire occurrences on the Forest. Long-term drying (drought) conditions occur on the average once every five years on the Kenai Peninsula. "Red flag" weather conditions (high wind speed and low humidities <30%) occur on the average once every five years. The odds of both events occurring simultaneously are between 1 in 10 and 1 in 20 years (estimated) because they are not totally independent events (Sees, 1997). History supports this assertion considering the frequency of large wildland fires on the Kenai Peninsula. Large fires (> 600 acres, pers. comm. J. See, 1997) have not been very common on the Forest in the last 25 years, with only 2 fires recorded greater than 100 acres. However, there has been a large fire on the Peninsula every 10 to 20 years. Fire data summarized on the Forest from 1971-1992 reported "high fire years" in pairs in 1973 and 1974 with 23 and 26 fire occurrences, and again in 1983 and 1984 with 10 and 13 fire occurrences (Rounsaville, 1992). Recent fire data summarized for the 1990 decade has 1993 with 35 and 24 fire occurrences in 1994, both seasons were longer and drier than usual (M. Black, 1995). Presently 1997 had 28 fires and 1998 is predicted to be another high fire season.

"El Nino" climatic events occurred in 1972-1973, 1982-1983, 1991-1992 and 1997-1998, the later being the strongest in this century (Appendix M). High fire seasons throughout Alaska have followed El Nino (pers. comm. NOAA weather forecasters, 1997). El Nino activity is difficult to correlate with patterns of precipitation due to the fluctuations in the split jetstreams (pers. comm. Sue Ferguson, 1997). El Nino events are correlated with less snow cover at lower elevations due to warmer temperatures then normal in winter and spring, snow melts earlier resulting in longer fire season's. Insect populations could be greater than normal. Cold damage to plants may be greater than normal as seasonal frosts occur after abnormal warm periods predisposing plants to invasion by insect infestations at these wound sites.

Conclusions

Fire, as a natural occurrence, has contributed to the landscape diversity most recently in the settlement period on the Kenai Peninsula portion of the Chugach National Forest and periodically for the last several thousand years. Prior to the settlement period of the late 1800's, the majority of the age structures of coniferous forests surveyed were recorded to be in late successional stages. The results of this study reflect the vegetation community component of landscape diversity was lower prior to the settlement period (i.e., prior to 1740) and increased in the late 1800's and early 1900's during a period of major fire occurrences. The largest fires on the Forest occurred during the settlement period with mining and mineral exploration from 1849-1902, followed by railroad development between 1903-1953.

The present landscape mosaic reflects past human-caused wildfires over the last 150 years, creating vast areas of successional ecosystems. These wildfires and prescribed fire in the last few decades, (primarily small moose burn fires) has generally increased the richness and patchiness of the vegetation types, the natural fire regime generally decreases vegetation diversity. The richness of the vegetation mosaic resulting from fire disturbances in this century have significantly influenced wildlife habitat from a caribou to a moose dominated system. The richness of the vegetation community component supporting seral species appears to have decreased during the last half-century as a result of fire suppression. Present spruce bark beetle effects present a new sequence of vegetation mosaics.

Of the 270,000 thousand acres of forested lands, 35,000 acres is the mixed deciduous forests of birch, aspen and spruce reflecting fire disturbances. The Forest is dominated by mountain hemlock trees comprising 160,000 acres; 82,000 acres is pure mountain hemlock, 78,000 acres is mixed mountain hemlock/white and Sitka spruce. Charcoal fragments in the soil were found across a wide expanse of these hemlock forest types. The frequency of fire regime is variable throughout the Forest watersheds. The eastern portion of the Kenai Mountains have a coastal influence, limited fire occurrences are reported. The western portion of the Kenai Mountains sits in a rainshadow, with an interior drier climate, the fire regime is predicted to have more frequent fires. The settlement period reflects large acreages burned more extensively in this area. Although lightning is rare on the Peninsula, the limited documented occurrences have been reported in this portion of the Forest.

Although abiotic disturbances such as wind, snow avalanche, landslides, glacial recession, and flooding have been recognized for the important ways in which they influence the pattern of vegetation and tree recruitment on the Forest, the role of fire is now recognized as an important disturbance process over many millennia in this transition climate. The results illustrate a long interval fire cycle that could have controlled the recruitment and mortality of most spruce and probably most hemlock trees in this forest over the past 500-3,000 yrs. The historical records of fires and tree ages, together with the present mature forests and beetle kill fuel loads, suggest that the next interval of stand-regenerating fires is near. The present forest conditions resulting in increased fuel loads from beetle kill, careless human-caused ignitions and drought weather conditions are important mechanisms for fire managers to evaluate for predicting risks and hazardous large scale fire occurrences on the Forest.

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Appendix A

Chugach National Forest AMS

Prescribed Fire Management

written by

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November, 1997

Prescribed Fire Management

Prescribed fires and natural fires have become part of the working tools of today's fire managers, who have an ever-expanding set of land management goals, including protection of commercial timber, managing fuels around rural developments (also called the urban interface), and reintroducing or maintaining the natural role of fire in forest ecosystems (Agee, 1996). The national policy on "forest health" is to use a variety of methods to alter conditions perceived to be "unhealthy", including prescribed fire for fuel reduction and ecosystem restoration. Within the last decade, the economic feasibility of harvesting timber on the Chugach National Forest has been reevaluated. The Chugach cannot be considered a major timber producing forest at this point in time (Timber Considerations in the Chugach Forest Plan Revision, 1997). Current fire management on the Forest is assessing alternatives to include the use of prescribed fire and criteria for determining the priorities for treatment: 1) fuel reduction, 2) potential for improvement of wildlife habitat, 3) ability to protect anadromous and high value resident fish streams, and 4) opportunities for creating species and age class diversity to maintain ecosystem integrity, 5) public concerns about hazards, risks, esthetics, and recreation.

<u>*Historical use of prescribed fire*</u>

I. Hazard reduction

Fire management on the Chugach National Forest portion of the Kenai Peninsula has focused on managing increased fuels from the beetle epidemic around the "urban/wildland interface". Prescribed fires were evaluated to be used to reduce hazardous fuel loadings and maintain fuel breaks which play an important role reducing high intensity wildfires and potential losses of homes and businesses. The Chugach National Forest is concerned about providing protection of human life and property, particularly in Cooper Landing, Moose Pass, Crown Point and Hope Townsite areas on the Kenai Peninsula.

From 1990 the Forest Service focused on fuel reduction for 2,700 acres of heavily infested stands after evaluating two Cooper Landing Environment Assessments (1986 & 1990). The prescribed treatments included 350 acres of prescribed fire and 2,350 acres with timber sales and mechanical fuel reduction contracts. The completion of this work was sporadic due to timber sale defaults, no bid sales, limited access and increasing spruce mortality. Sales of standing dead trees have generally not been successful. In retrospect, fuels reduction associated with 2,350 acres of timber harvest began in 1991 and was successfully completed in 1994, reducing the high risk to Cooper Landing residents.

Only a limited number of prescribed burns were implemented by management on selected slash piles associated with timber harvesting. From 1992-1993, 145 acres of slash was piled and burned. Although the 350 acres of prescribed treatments were not completed, substantial natural fuel breaks surrounding the Cooper Landing area provide ample protection from wildland fires burning into town (pers. comm., W. Oja, 1997). The 1991 Pothole Lakes fire provided an unexpected natural fuel break in the vicinity of a proposed prescribed burn. The 1959 Kenai Lake fire and the 1969 Russian River fire also provide natural fuel breaks in the vicinity. The mixed broadleaf forest provides a natural fuel break under normal weather conditions. Under adverse weather conditions associated with the Big Lake fire 1996, the broadleaf forests ignited unexpectedly when dry.

The Moose Pass and Crown Point areas also have an increase in fuel loading and fire hazard associated with the beetle killed spruce forests. The environmental assessment (1994) addressed six critical areas surrounding Moose Pass and Crown Point for fuel reduction. Two timber harvest activities have occurred on both Forest Service and State Land initially proposed as fuel breaks (pers. comm. W. Oja, 1997). Prescribed burning was proposed as alternatives on Forest Service land to create firebreaks along the road corridors. The use of prescribed fire in the vicinity of Moose Pass and Crown Point is limited due to the proximity of burning close to these two urban interfaces. However, the proximity of lakes and the mixed deciduous forests north and south of Moose pass provide natural fire breaks. The Seward Ranger District recently developed a five year prescribed fire plan (June 1997) for 1998-2001, to treat 7,230 acres to improve both wildlife and fuels reduction encompassing Federal lands in these vicinities.

It is important to note that the Forest condition over much of the early part of this century did not involve dead spruce (Rounsaville, 1992). The sizes of fires on the Forest have decreased since the fire suppression program was initiated in the 1940’s and 1950’s. Culbertson (1977) states that effective wildfire suppression by man in the area did not occur until the 1950’s and 1960’s. There have been no increases in fire numbers or fire sizes that could be attributed to the increase in dead fuels on the Forest. The spruce bark beetle impacts did not become a part of the fire picture until the last ten (10) to fifteen (15) years. Spruce bark beetles (SBB) infestations were first noted in the 1920’s in Alaska. The 1960’s saw the first attacks on the Kenai Peninsula. On the Chugach National Forest portion of the Kenai Peninsula, over 56,000 acres were infested by 1984 and over 12,000 acres had suffered heavy mortality. The current total is over >70,000 acres infested. Reports from inland show that spruce bark beetles have spread to near Anchorage. There is nothing to suggest that the infestation is slowing or stopping.

One of the most significant effects of spruce bark beetle activity is the invasion of grass into the understory after the dying crowns allow additional sunlight for photosynthesis. The surface coverage of blue joint reed grass has been shown to increase from under 5 % to over 50 % five years after a spruce bark beetle attack. Total fuel loadings (vegetation) increased from about 10 tons per acre to over 35 to 100 tons per acre. When sustained dry conditions occur in the spring fire season, fire danger can increase very rapidly. Fuel loadings that are heavy with an abundance of flashy surface fuels can spread fire into beetle killed spruce jackstraw resulting in hot, intense fires.

This extreme fire behavior characteristic was observed during 1996, the Crooked Creek Fire made a run in excess of eight miles in one burning period, 18 hours from the start. This beetle kill grass/timber fuel type burns 20 times faster and 6 times more intensely than the fuel type associated with healthy white spruce stands, particularly in the spring and early fall when the grass is cured (J. See, 1997). These results support the concept in fuel management that fuel consumption which eliminates large logs contributes little to hazard reduction since the greatest potential for the ignition and spread of fire is among the fine fuels. Although large diameter fuels add to the total fuel load of a site, their fire-hazard potential depends greatly on the presence of fine fuels.

Historically, fire occurrence and weather patterns on the East half of the Kenai Peninsula indicate a marginal chance of extreme of fire behavior conditions occurring (M. Black, 1995). Interpretation of John See's weather and fire behavior analysis for the Cooper Landing project indicate less than a 2% chance of having a "bad" fire day each fire season, based on a 150 day fire season (M. Black, 1995). Presently, the new beetle kill grass/timber fuel type emerging can be very dangerous (J. See, 1997). Rapid rates of spread can outrun a person, especially when the fire is being pushed upslope by the wind.

The Cooper Landing area receives an average of 26 inches of precipitation annually. The Moose Pass and Crown Point areas have a moister climate, with an average annual precipitation of 40 inches below timberline, or roughly 14 inches more annual precipitation than Cooper Landing. These are two driest areas within the urban/wildland areas. Both areas are subject to periodic high winds at all times of the year.

Due to the removal of timber representing the larger 100-1,000 hour fuels, the risk of hot intense fires has been reduced in the vicinity of Cooper Landing. The fine flashy fuel build-up of understory grass and brush still remains a hazard in the area. Grass fires have a rapid rate of spread, yet can be more readily controlled compared to the grass/timber fuel type (pers. comm. W. Oja, 1997).

Fuel reduction by mechanically removing standing dead trees at the urban interface maybe necessary since the consequences of a prescribed fire getting out of control along this boundary may be significant. However, this only addresses part of the problem. The increased use of prescribed burning to treat the active fine fuels has risks and might not be applicable especially in urban interface areas.

Timber reduction by mechanically removing standing dead trees is not recommended when large fuels are needed to support a fire of adequate duration to penetrate the organic mat exposing mineral soil. Moose burn studies show that dead trees were needed on the site to generate adequate fire intensities (Weixelman, 1987). Moose burn sites needed slash burns which created very favorable hardwood seedling and sprouting conditions. Nonslash burns resulted in lower fire intensities and patchier burns with widely varying amounts of browse establishment. It is possible that fires in these spruce beetle/grass fuel forest types will be less hazardous in areas with increased rotten logs which pick up moisture faster than sound logs. In the early fire season these sites will have less hazardous fires in the spring, although fine fuels will have dried out, the larger size rotten fuels will still be slightly wet and only partially consumed by a fire.

II. Habitat Enhancement

It is well documented that fire plays an important part in the ecology of moose in southcentral Alaska (Spencer and Hakala). Since 1883, large wildfires on the peninsula have created prime moose winter range. Many known fire occurrences (1896, 1906, 1908, 1913, 1914, 1915) during the late 1800's and early 1900's burned approximately 30,000 acres on the Forest. Since this time, large fires had been rare, until the occurrences of the 1959 Kenai Lake, the 1969 Russian River Lake, the 1985 Caribou Creek, and the 1991 Pothole Lake fires burning approximately 17,000 acres.

Culbertson (1977) sites one of the earliest reports on moose range problems on the Kenai was by Edwards in the 1940's. He reported range deterioration due primarily to moose numbers exceeding the range's carrying capacity. Effective wildfire suppression by humans in the area since the 1950's and 1960's has been cited as a cause of disappearing moose range. Railroad fires in many instances favored winter browse species for moose (Blanchet, 1987). Moose winter range along the railroad has diminished since the number and size of fires on the forest prior to 1953 were primarily related to the railroad.

A prescribed fire program from 1976 to 1993 treated 9,880 acres on moose winter range on the Chugach National Forest. This was part of an ongoing project to increase the quantity and quality of hardwood browse available to moose on winter range where current browse productivity was low. In addition, with the encroachment of the urban interface on traditional moose wintering areas, it became necessary to rejuvenate old ranges or create new ranges to reduce the pressures on existing moose winter ranges. The District's landmass can support 500 to 1,000 acres/year in prescribed burning for wildlife enhancement (pers. comm. Susan Howell, 1997). These acres were determined in 1977, when 139 areas including 22,000 acres were identified to be treated with prescribed fire (L. Culbertson, 1977). Since 1977, approximately 10,000 acres were burned, which averaged 625 acres per year. In reality, burn unit size ranged from 30-2,500 acres (Prescribed Burning R-10, Regional Office).

The two vegetation types treated for prescribed burning for moose habitat improvement on the Forest were spruce-hardwood and shrubby willow occurring entirely in the valleys and valley floors of watersheds. These areas correspond to the early settlement burned areas which created the majority of moose habitat in the early part of this century. Adequate fire intensities were generated by slash burns which created very favorable hardwood seedling and sprouting conditions. Nonslash burns resulted in lower fire intensities and patchier burns with widely varying amounts of browse establishment. All burns from 1976 to 1986 were spring burns conducted in May and June. Burning in the fall from September to November is recommended after the first killing frost or natural curing of grasses. The advantage to burning during the fall is that the drier litter and duff layers will create hotter fires at ground level. This will result in greater consumption of the moss and duff layers allowing for improved hardwood seedling growing conditions (Weixelman, 1987).

In a recent study of boreal forest stands in southcentral Alaska, a combination of overstory reduction and timely exposure of mineral soil was essential for promoting early successional hardwood growth and associated habitat enhancement (Collins, 1996). Prescribed fire in southcentral Alaska has been shown to be the most economical and natural means to accomplish habitat enhancement (Collins, 1996). However, habitats created by burning favor some animals and discriminate against others. In planning for the management of the wide variety of forest animals, options must be considered. For areas managed primarily for caribou winter range, complete fire suppression may be the best policy; whereas within areas established primarily for moose management, it may be possible to allow all wildfires to burn unless they endanger life or property or threaten to expand into areas with higher priority for fire suppression (Davis & Franzmann, 1979; Klein, 1982). Although burning may improve access to seeds and other foods, fire is probably more neutral than beneficial to most birds and small mammals (Quilan, 1978).

Preparation of prescribed burning to insure the desired fire intensity will also affect bird and small mammal community succession. Early successional stages support fewer species, lower densities, and lower diversities of breeding birds and small mammal populations than mature forest on the Kenai Peninsula. The breeding birds associated with white spruce on the forest may not return to mature forest levels for 20-40 years following wildfire (Quilan, 1978). The highest trapping success of 8 small mammal species; northern red-backed vole, masked shrew, wandering shrew, tundra vole, red squirrel, least shrew and snowshoe hare occurred in forests older then 120 and 200 years. Based on densities of each species in the various aged stands, Black-capped Chickadees, Boreal Chickadees, Brown Creepers, Swainson’s Thrushes, Golden-crowned Kinglets, and White-winged Crossbills appear to prefer white spruce forest 100 years or older (Quilan, 1978).

Conditions Current in the Prince William Sound and Copper River Delta ecosystems of the Chugach National Forest -

Management direction in the current Forest Plan is to use prescribed fire as appropriate, for silvicultural site preparation, wildlife habitat improvement, or slash hazard treatment. The use of prescribed fire as a tool for resource management is limited in the Pacific Coastal Mountain Forest-Meadow Provinces and the Gulf Coastal Mountain Forest-Meadow Provinces (Davidson, D.F. 1996), because of unfavorable cool and wet fire weather, rapid natural decay and a low occurrence of natural lightening ignitions. Prescribed fire is often undependable due to shortness of burning opportunities and weather limitations during the burning season.

Conditions Current on the Kenai Peninsula ecosystems of the Chugach National Forest -

Current fire management in the Alaska Mixed Forest Province is most concerned with managing increased 1) hazards from fuels from both the mature forest structure and the beetle epidemic, 2) risks from recreation use which has resulted in a high occurrence of ignitions and areas with a high fuel complex adjacent to the "urban/wildland interface". In addition, wildlife managers want to continue to introduce fire as a tool for habitat enhancement.

The present forest conditions resulting in increased fuel loads from beetle kill, careless human-caused ignitions and drought weather conditions are important mechanisms for fire managers to evaluate for predicting risks and hazardous large scale fire occurrences on the Forest. Long-term drying (drought) conditions occur on the average once every five years on the Kenai Peninsula. "Red flag" weather conditions (high wind speed and low humidities <30%) occur on the average once every five years. The odds of both events occurring simultaneously are between 1 in 10 and 1 in 20 years (estimated) because they are not totally independent events (Sees, 1997). History supports this assertion considering the frequency of large wildland fires on the Kenai Peninsula. Large fires (> 600 acres, pers. comm. J. See, 1997) have not been very common on the Forest in the last 25 years, with only 2 fires recorded greater than 100 acres. However, there has been a large fire on the Peninsula every 10 to 20 years. Fire data summarized on the Forest from 1971-1992 reported "high fire years" in pairs in 1973 and 1974 with 23 and 26 fire occurrences, and again in 1983 and 1984 with 10 and 13 fire occurrences (Rounsaville, 1992). Recent fire data summarized for the 1990 decade has 1993 with 35 and 24 fire occurrences in 1994, both seasons were longer and drier than usual (M. Black, 1995). Presently 1997 had 28 fires and 1998 is predicted to be another high fire season.

Regional climate of "El Nino" events occurred in 1972-1973, 1982-1983, 1991-1992 and 1997-1998, the later being the strongest in this century. High fire seasons throughout Alaska have followed El Nino (pers. comm. NOAA weather forecasters, 1997). El Nino activity is difficult to correlate with patterns of precipitation due to the fluctuations in the split jetstreams (pers. comm. Sue Ferguson, 1997). El Nino's events are correlated with less snow cover at lower elevations due to warmer temperatures then normal in winter and spring, snow melts earlier resulting in longer fire season's. Insect populations could be greater than normal. Cold damage to plants may be greater than normal as seasonal frosts occur after abnormal warm periods predisposing plants to invasion by insect infestations at these wound sites.

I. Hazard Reduction

The nature of the fuel complex in the mature forests is of concern. The time required for fuel accumulation modulates the control of climate and weather over fire occurrence and may be a critical factor in the forest fire cycle. The mature forests stands at the time of settlement must have had sufficient fuels to result in stand replacement fires, being at or near the upper end of historical fire intervals (pers. comm. S. Barrett, 1996). Existing fuel loadings from a 1994 study in the Resurrection Creek drainage of the Chugach National Forest averaged 35 tons per acre in dead and down spruce beetle fuels. Fuel loadings in wetter climatic areas averaging 12-14 tons per acre are considered to be at hazardous levels during fire season. Presently the status of fuel maps on both state and federal forestlands are insufficient due to the inadequacy of the fuels data (pers. comm. J. See, 1997). Most of the fuels data in both state and federal agency GIS data centers is older then 5 years and the fuel loads have changed drastically within the beetle killed spruce forest types. The dynamic ongoing insect infestation changes the fuel complex over time fairly rapidly in a somewhat unpredictable fashion. It is difficult to predict exactly what the degree/scope of infestation will be over time, whether a stand will be 100% killed, when dead standing trees will fall (M. Black, 1995).

II. Habitat enhancement

The encroachment of the urban interface on traditional moose wintering areas still remains a problem. It is still necessary to rejuvenate old ranges or create new ranges to reduce the pressures on existing moose winter ranges. The District's landmass can support 500 to 1,000 acres/year in prescribed burning for wildlife enhancement (pers. comm., S. Howell, 1997). These acres were determined in 1977, when 139 areas including 22,000 acres were identified to be treated with prescribed fire (Culbertson, 1977). Since 1977, approximately 10,000 acres were burned, which averaged 625 acres per year. In reality, burn unit size ranged from 30-2,500 acres. The program decreased over the last several years due to weather conditions unfavorable for burning, and a lack of personnel with the appropriate qualifications. The program is currently on the upswing, with a 450 acres burn in 1993 and a prescribed fire plan for 1998-2001 for the Seward Ranger District addressing habitat enhancement on moose winter range.

Need to establish or change management direction in the Prince William Sound or Copper River Delta ecosystems of the Chugach National Forest -

Criteria for use of prescribed fire to improve Forest conditions will be evaluated, however there will be limited use due to weather conditions (annual precipitation exceeds 100 inches in many areas). Management needs are limited in the Prince William Sound and Copper River areas concerning the use of prescribed fire as a tool for resource management.

Need to establish or change management direction on the Kenai Peninsula ecosystem of the Chugach National Forest -

A prescribed fire program has been in effect on the Forest since 1976 for wildlife improvement, and since 1990 for hazard reduction. Current management needs to address 1) the increased fuel loads and areas which have increased fire hazards, 2) the increased risk of fires caused from human ignitions, 3) habitat improvement to meet the recreational demands of game hunting and viewing on the Seward Ranger District, 4) the natural role of fire in sustaining ecosystem integrity, and 5) public concerns about the use of fire in national forest management.

While the use of prescribed fire can be used as a tool for management on the Forest, fire disturbance processes may take decades or a century or more for tree re-establishment in this maritime climate where infrequent fire regimes can occur over a millennia. The dominance of deciduous trees presently on the Forest resulted from historic burning. These sites supported a mature age structure of the needleleaf forest vegetation prior to disturbance over 150 years ago. The fire regime has long intervals between fire events suggesting that fire is not the primary disturbance agent necessary for all tree recruitment on the Forest.

There is concern that the logistics of site preparation involved are expensive and the prescription windows are narrow due to weather constraints. The window of opportunity to successfully conduct a prescribed fire program can be limited and unpredictable due to the short periods in the spring and fall for burning and not all springs are conducive for burning. Some burning seasons may be exceptionally wet or dry which might preclude the completion of some of the burning units. Other years may have conditions which allow for additional acres to be treated.

I. Hazard reduction

Current management direction needs to evaluate fuel loadings in critical areas on the Forest. The last fire behavior and fuel models evaluated for Cooper Landing Environmental Assessment (1990) no longer apply to the Forest since present fuel loads and conditions have changed over the last seven years. The most important need on the Forest is to have a prescribed fire program for reduction of fuels, making wildfires less damaging to the urban/wildland environment and more easily controlled. The nature of the fuel complex in the mature forests needs further study. The understory grass and brush may require mechanical treatment in urban interface areas to reduce fine flashy fuel fire hazards and to initiate recruitment of tree cover which will eventually shade and reduce understory cover. There is a need to further evaluate the best season for burning fine flashy grass fuels and associated fire behavior on the Forest. There is a need to further exam whether removal of timber is necessary in other areas of the Forest with a mixed broadleaf forest or in a cool, wet spruce-hemlock and pure hemlock forests to reduce high fire intensities. Although it is recommended to expose mineral soil for regeneration of boreal forest species, the implications that hot intense fire would increase soil erosion and alter regrowth need to be evaluated on the Forest.

II. Risk of fires caused from human ignitions

Although ignitions and small, low-intensity fires may occur at any time on the Forest given suitable weather, fuel accumulation may require 150-200 years to reach a point where it can support intense fires capable of damaging and killing canopy trees. The most flammable fuels pose no threat if there are no ignitions. The large fire occurrences on the Forest, with only limited lightening suggest human cause ignitions. Human-caused fires account for over 99% of all fires on the Forest indicating a need for a prevention program to educate the public on fire behavior, fire season, emphasizing high fire hazard and risk in high use recreational areas. The greatest threat to life and property in these urban/wildland areas is probably from an accidental human caused fire starting within or adjacent to private structures, rather than from a fire burning into structures from the outside (M. Black, 1997).

III. Habitat enhancement

Wildlife populations, and moose in particular have or are reaching their maximum ability to provide for peoples needs in Alaska (Culbertson, 1977). Moose range has been deteriorating on the Forest since 1950's, the old burned areas of the early settlement fires creating winter range moose habitat have reached later successional stages. Wildlife biologist, Susan Howell on the Seward Ranger District, recommends an increase in use of prescribed fire treatments as a means to achieve desirable habitat conditions for moose and other species requiring early seral stages of vegetation types providing more diversity of habitats.

Current use of prescribed fire for moose habitat improvement might well be warranted, however these management practices might not be emulating past ecosystem functioning. There is a need to clarify the management of reestablishing moose habitat through use of prescribed fire because it might be viewed as "artificial ecology", the population densities of moose are being maintained at higher numbers compared to presettlement occurrences. There is a need to clarify the role of fire as a factor in the evolution of the forest and animal species on the Kenai Peninsula. Fire has created habitat for moose, snowshoe hares, and other wildlife dependent on early seral vegetation, public demands to maintain high moose populations needs to be considered in future management objectives. There is a need for management to determine population densities for forest bird and small mammal species requiring mature forest habitats.

IV. Other potential uses of prescribed burning for ecosystem management

Other natural disturbances such as insect infestations, windthrow, avalanche, and flooding create gaps for tree recruitment. These forest ecosystem processes need to be evaluated concerning the natural role of fire in sustaining ecosystem integrity. The role of fire is presently being questioned in forest pathology research, in conjunction with the fungal pathogens role in forest structure. Recent studies have shown that fire can reduce fungal pathogen in the soil in mature forests, provided the fires are hot enough to burn the root systems and through the duff layer to mineral soil, thus providing another natural role of fire in forest ecosystems (Dickman & Cook, 1988; Filip & Yang-Erve, 1997).

V. Public concerns about the use of fire in national forest management

There is a need to educate the public about the role of fire and associated risks and hazards of prescribed burning. Prescribed fire is an appropriate management tool on the Kenai Peninsula considering the current ecological conditions. A prescribed fire plan addressing guidelines for the Chugach National Forest has been approved (USDA, Forest Service, 1997). The mature forest fuel complex combined with the grass/spruce beetle fuel type presents optimal fire opportunities on the Forest. The large number of acres burned on the Forest during settlement indicates that human-cause ignitions, fuel loads, and weather conditions were optimal for burning. Presently, the forest conditions resulting in increased fuel loads from beetle kill, careless human-caused ignitions and drought weather conditions are important mechanisms for fire managers to evaluate for predicting risks and hazardous large scale fire occurrences on the Forest.

Prescribed fire may be the most difficult vegetation management activity to implement due to air quality issues and regulations. Smoke management must be a strong consideration in deciding on the extent and location of some burn activities, wind direction being critical to carry smoke away from populated areas. Special areas such as Wilderness Study Areas, and potential Wild and Scenic Rivers, may require special consideration for air quality because of the high recreation use in these areas. Increased urban-interface situations need to receive special consideration when developing tactics and strategies for fire management operations.

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Appendix B

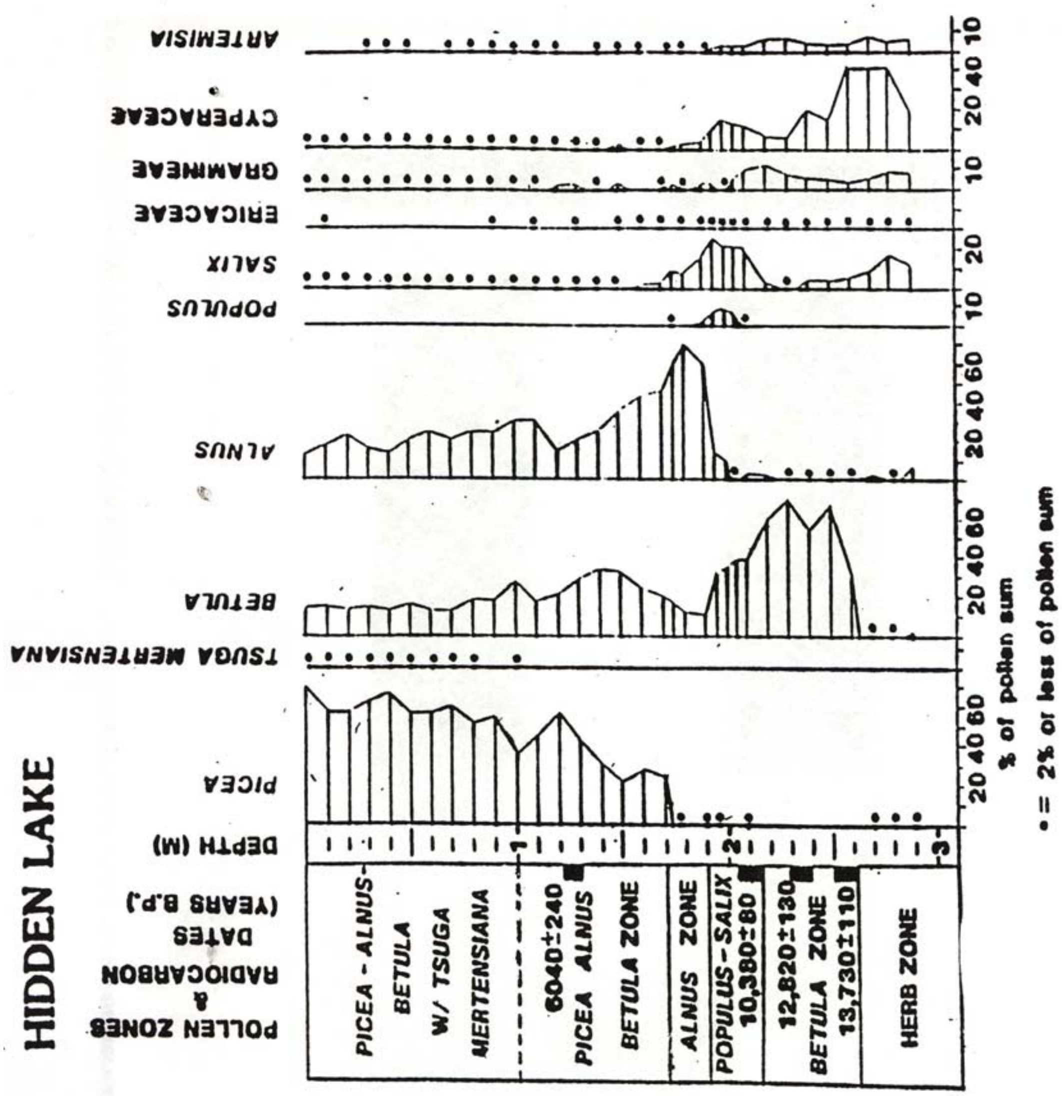


Figure 9-4. Pollen diagram (summary) from Hidden Lake, central Kenai Peninsula. (From Ager and Sims, 1981b, and unpublished data.)

Appendix C

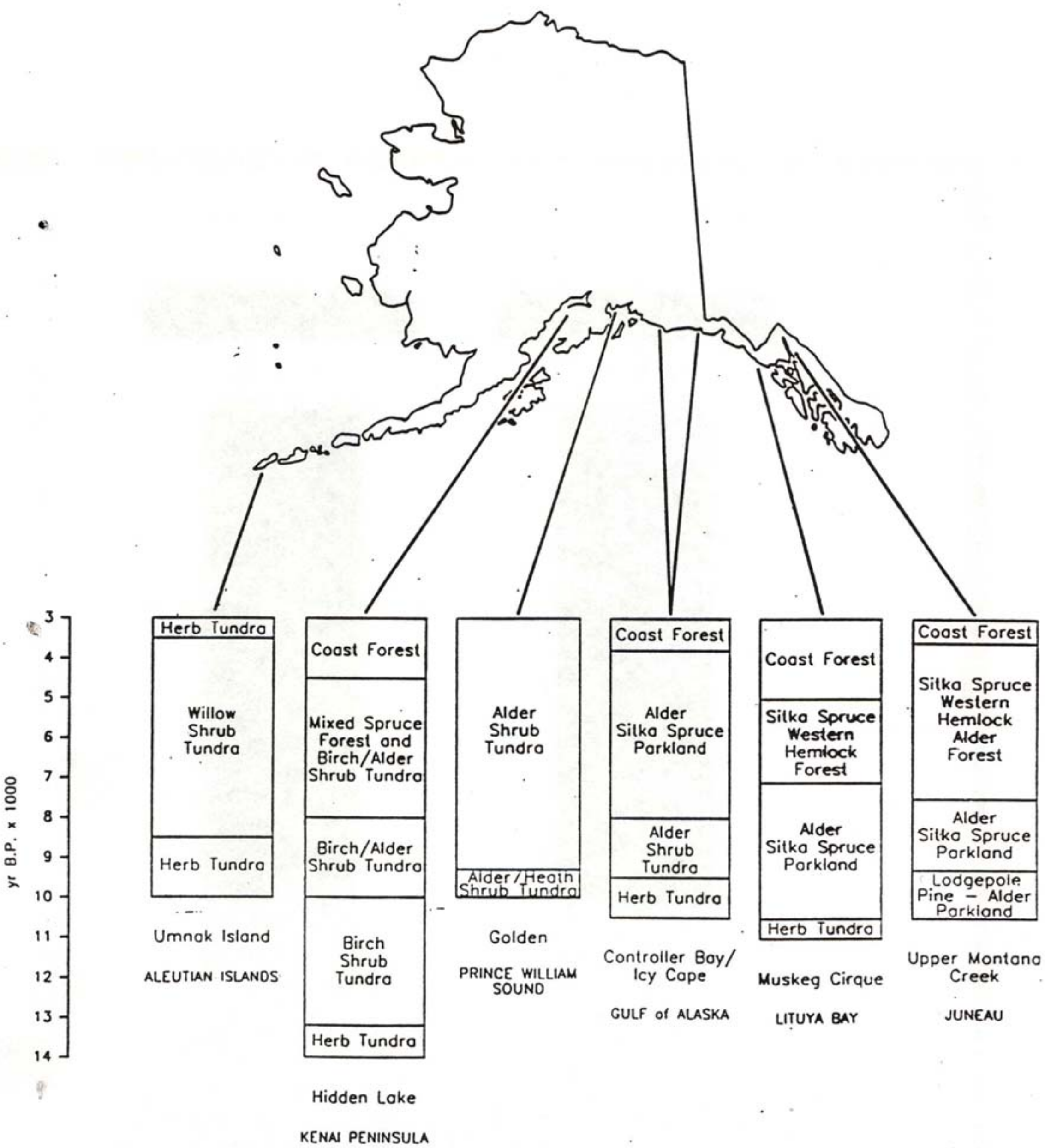


Fig. 153. Summary of vegetation history of southern Alaska.

Appendix D

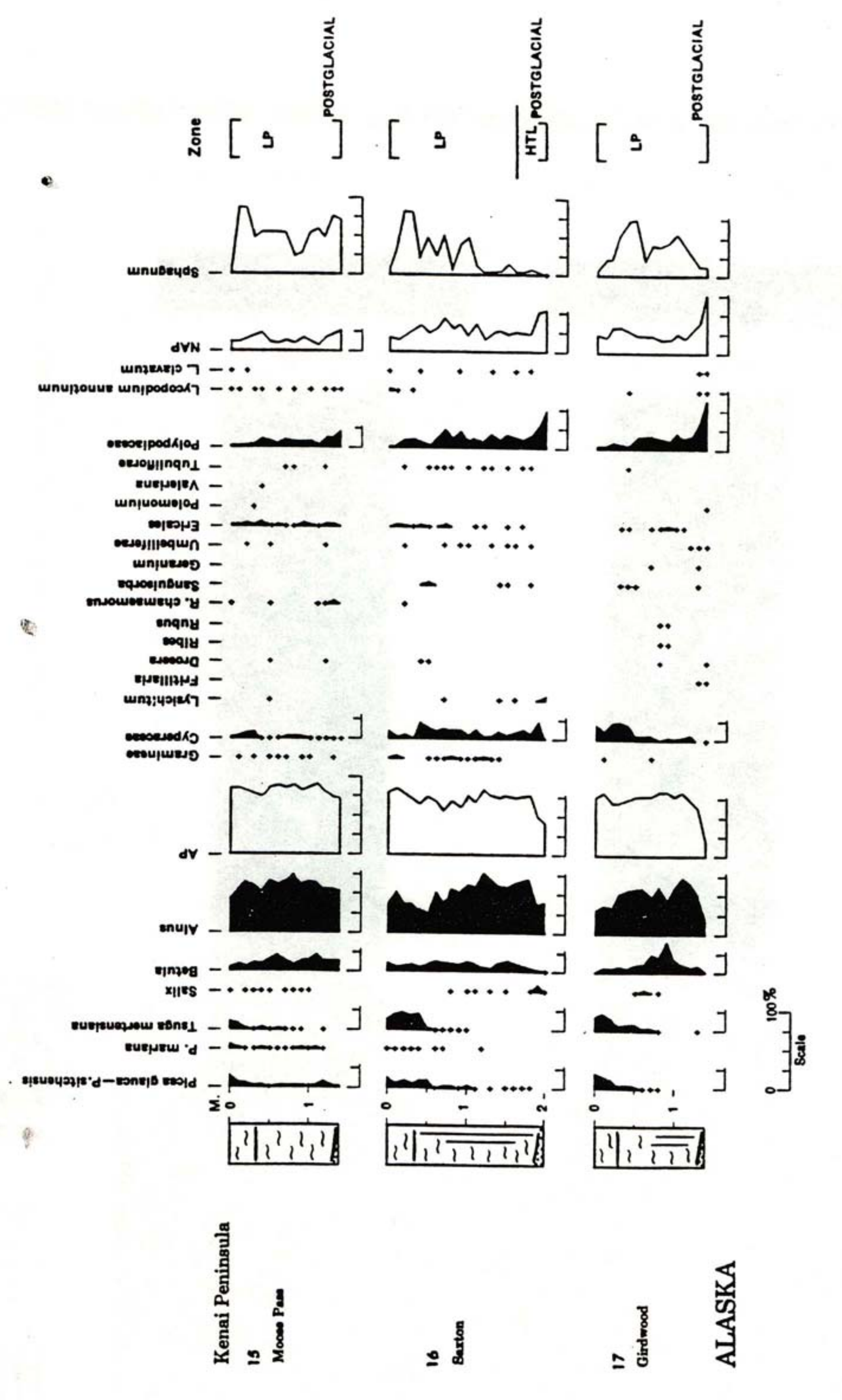


FIG. 18. Peat and pollen stratigraphy and zonation for sections from Moose Pass (15), Saxton (16), and Girdwood (17).

Appendix E

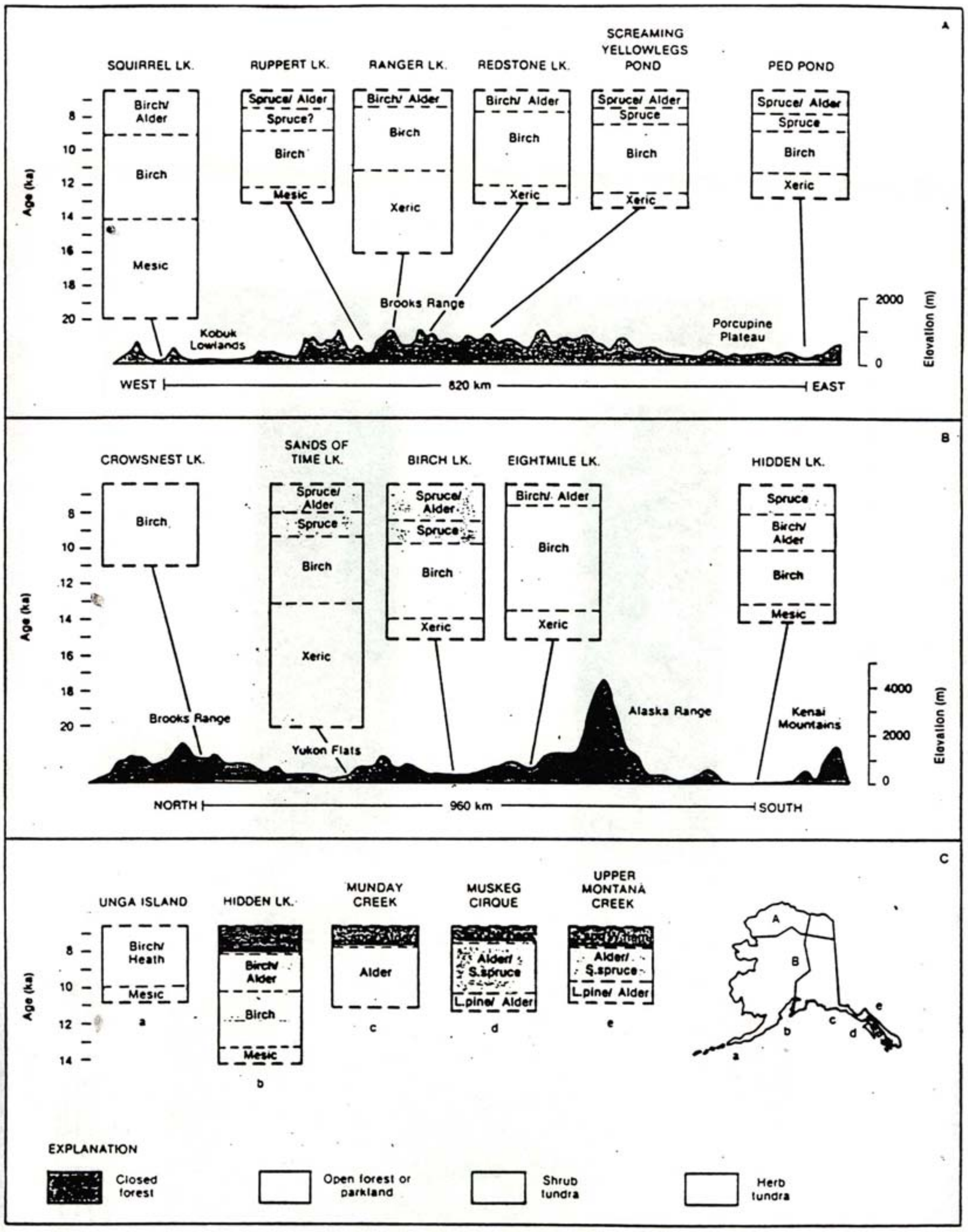


Figure 11. Vegetational changes through time inferred from three transects of pollen sites in Alaska. (Abbreviations: L. pine = lodgepole pine; S. spruce = Sitka spruce; W. hem. = western hemlock).

Appendix F

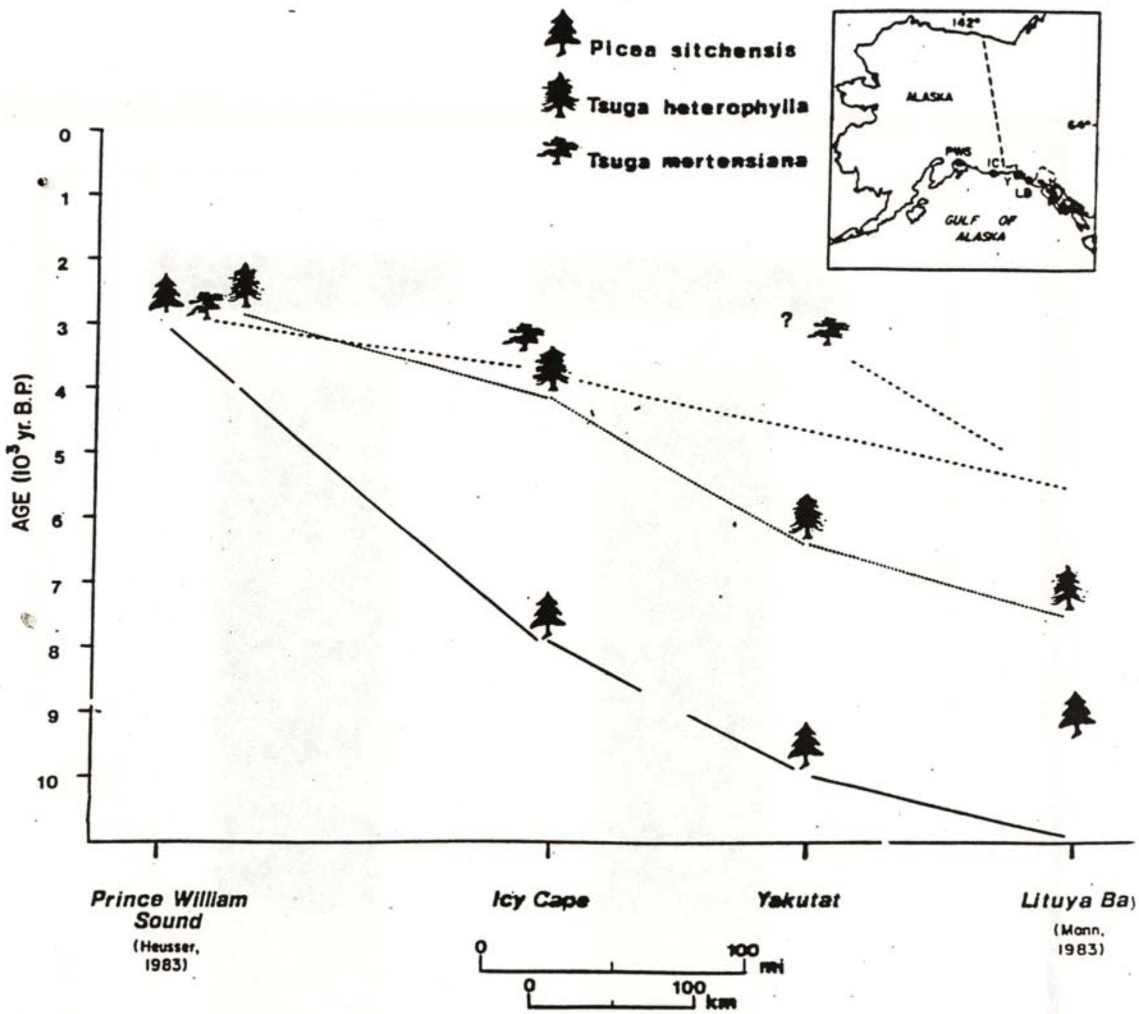


FIG. 9. Apparent Holocene conifer migration northwestward ~~b~~ased on first arrival between Lituya Bay and Prince William Sound.

Appendix G

(no appendix G in hardcopy)

Appendix H

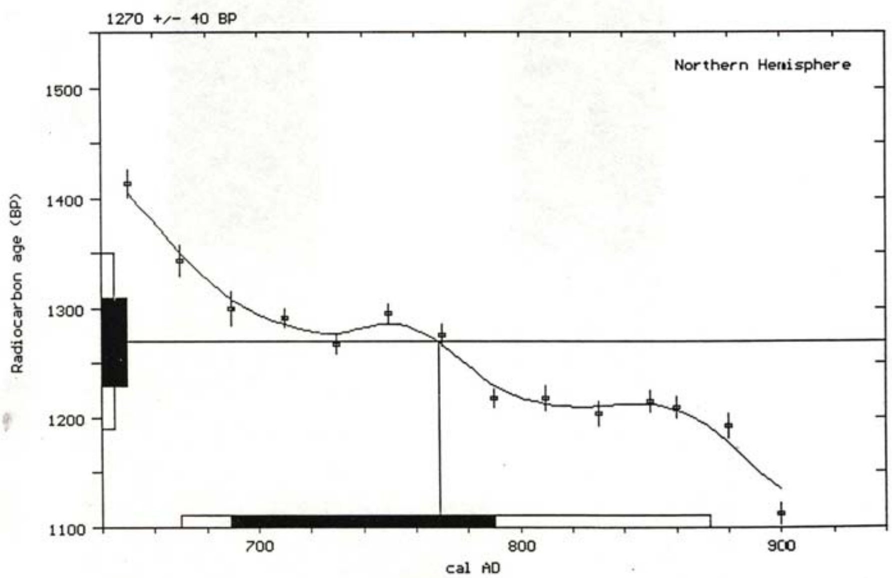
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables:C13/C12=-25.9:lab mult.=1)

Laboratory Number:	Beta-91346
Conventional radiocarbon age:	**1270 +/- 40 BP**
Calibrated results: (2 sigma, 95% probability)	**cal AD 670 to 875**

Intercept data:

Intercept of radiocarbon age with calibration curve:	cal AD 770
1 sigma calibrated results: (68% probability)	cal AD 690 to 790



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Pretoria Calibration Curve for Short Lived Samples
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A Simplified Approach to Calibrating C14 Dates
Talma, A. S. and Vogel, J. C., 1993, Radiocarbon 35(2), p317-322
Calibration - 1993
Stuiver, M., Long, A., Kra, R. S. and Devine, J. M., 1993, Radiocarbon 35(1)

Appendix I

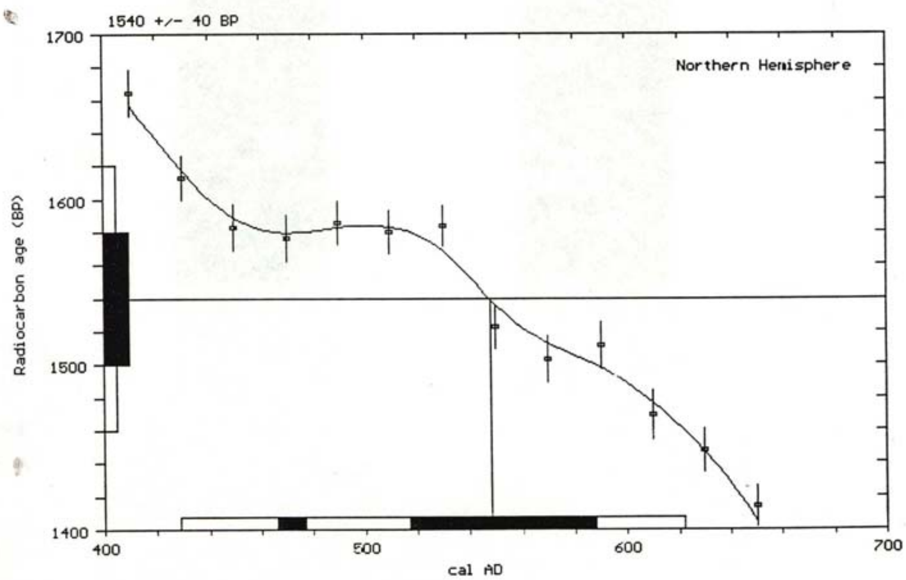
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables:C13/C12=-25.7:lab mult.=1)

Laboratory Number:	Beta-91344
Conventional radiocarbon age:	**1540 +/- 40 BP**
Calibrated results: (2 sigma, 95% probability)	**cal AD 430 to 620**

Intercept data:

Intercept of radiocarbon age with calibration curve:	cal AD 550
1 sigma calibrated results: (68% probability)	cal AD 465 to 475 and cal AD 515 to 590



References:

Pretoria Calibration Curve for Short Lived Samples
Vogel, J. C., Fuls, A., Visser, E. and Becker, B., 1993, Radiocarbon 35(1), p73-86

A Simplified Approach to Calibrating C14 Dates
Talma, A. S. and Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

Calibration - 1993
Stuiver, M., Long, A., Kra, R. S. and Devine, J. M., 1993, Radiocarbon 35(1)

Appendix J

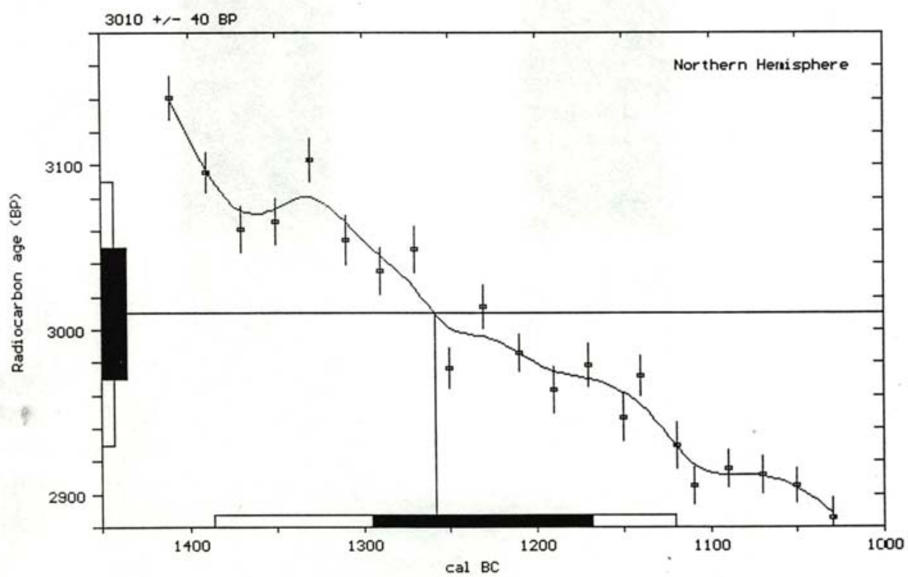
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables:C13/C12=-25.3:lab mult.=1)

Laboratory Number:	Beta-91342
Conventional radiocarbon age:	**3010 +/- 40 BP**
Calibrated results: (2 sigma, 95% probability)	**cal BC 1385 to 1120**

Intercept data:

Intercept of radiocarbon age with calibration curve:	cal BC 1260
1 sigma calibrated results: (68% probability)	cal BC 1295 to 1170



References:

Pretoria Calibration Curve for Short Lived Samples
Vogel, J. C., Fuls, A., Visser, E. and Becker, B., 1993, Radiocarbon 35(1), p73-86
A Simplified Approach to Calibrating C14 Dates
Talma, A. S. and Vogel, J. C., 1993, Radiocarbon 35(2), p317-322
Calibration - 1993
Stuiver, M., Long, A., Kra, R. S. and Devine, J. M., 1993, Radiocarbon 35(1)

Appendix K

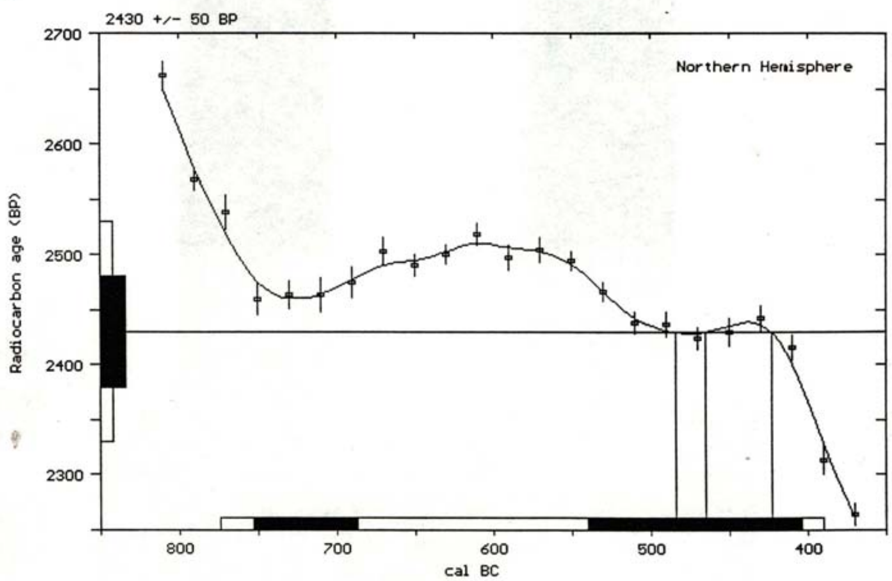
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables:C13/C12=-27.1:lab mult.=1)

Laboratory Number:	Beta-91343
Conventional radiocarbon age:	**2430 +/- 50 BP**
Calibrated results: (2 sigma, 95% probability)	**cal BC 775 to 390**

Intercept data:

Intercepts of radiocarbon age with calibration curve:	cal BC 485 and cal BC 465 and cal BC 425
1 sigma calibrated results: (68% probability)	cal BC 755 to 685 and cal BC 540 to 405



References:

Pretoria Calibration Curve for Short Lived Samples
Vogel, J. C., Fuls, A., Visser, E. and Becker, B., 1993, Radiocarbon 35(1), p73-86
A Simplified Approach to Calibrating C14 Dates
Talma, A. S. and Vogel, J. C., 1993, Radiocarbon 35(2), p317-322
Calibration - 1993
Stuiver, M., Long, A., Kra, R. S. and Devine, J. M., 1993, Radiocarbon 35(1)

Appendix L

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

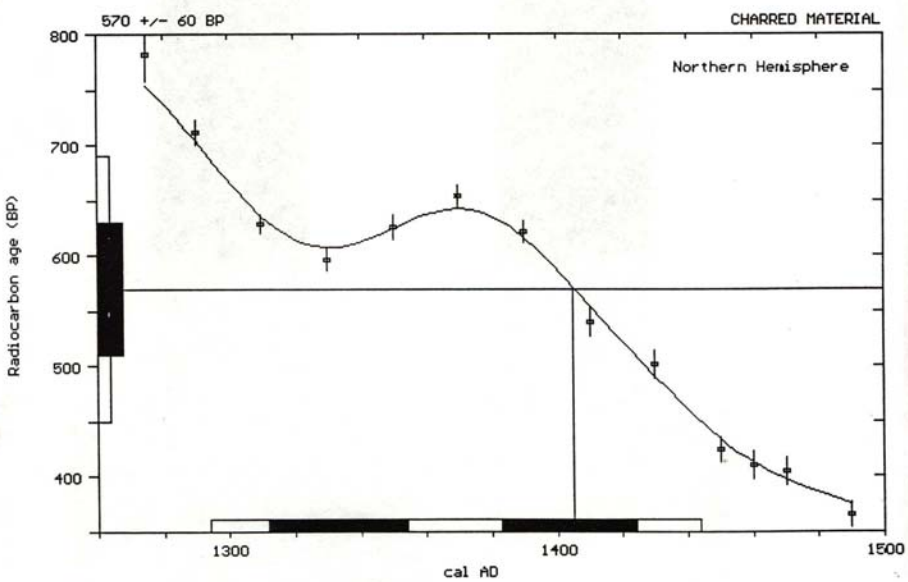
(Variables:estimated C13/C12=-25:lab mult.=1)

Laboratory Number:	Beta-91345
Conventional radiocarbon age*:	**570 +/- 60 BP**
Calibrated results: (2 sigma, 95% probability)	**cal AD 1295 to 1445**

* C13/C12 ratio estimated

Intercept data:

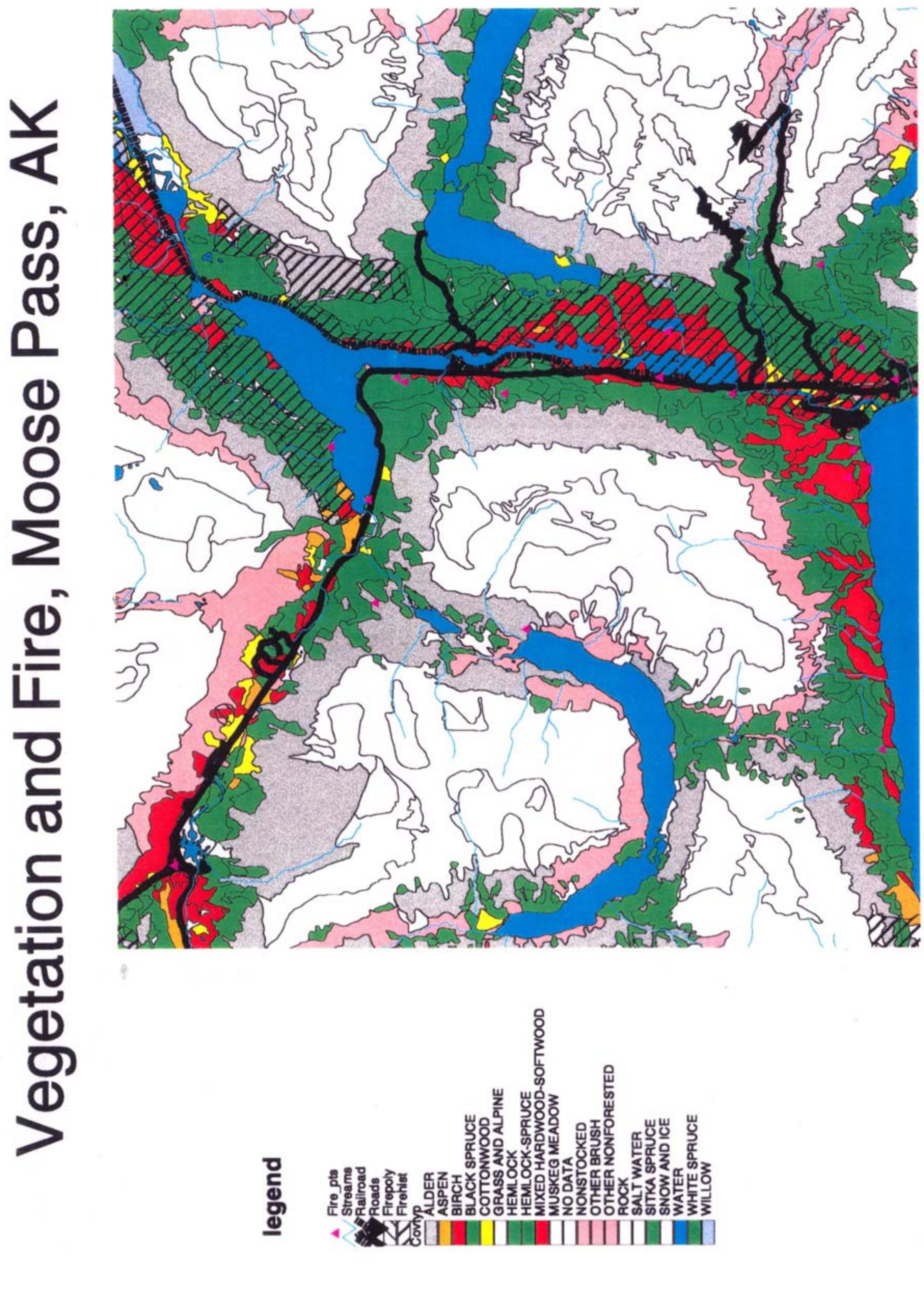
Intercept of radiocarbon age with calibration curve:	cal AD 1405
1 sigma calibrated results: (68% probability)	cal AD 1310 to 1355 and cal AD 1385 to 1425



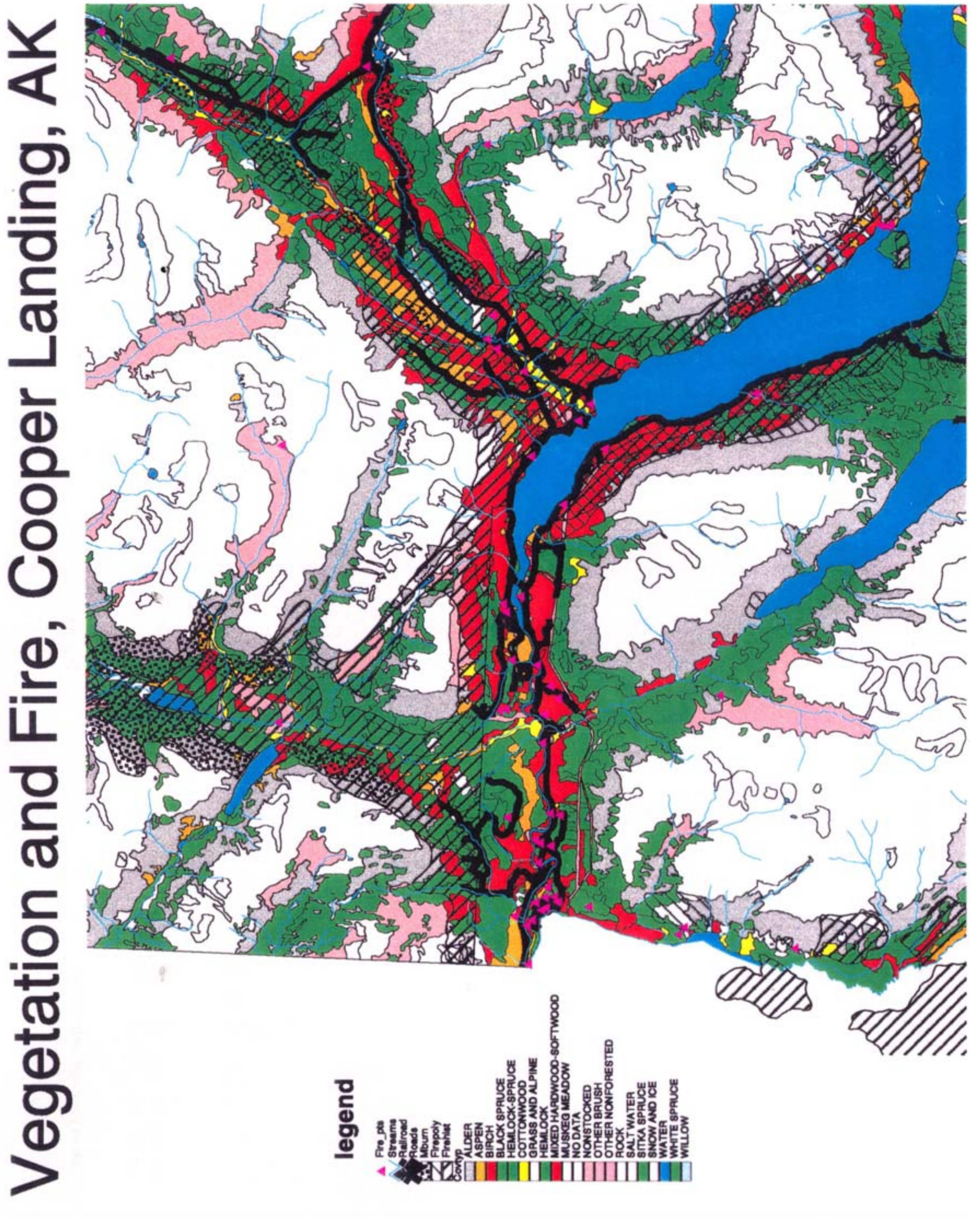
References:

Pretoria Calibration Curve for Short Lived Samples
Vogel, J. C., Fuls, A., Visser, E. and Becker, B., 1993, Radiocarbon 35(1), p73-86
A Simplified Approach to Calibrating C14 Dates
Talma, A. S. and Vogel, J. C., 1993, Radiocarbon 35(2), p317-322
Calibration - 1993
Stuiver, M., Long, A., Kra, R. S. and Devine, J. M., 1993, Radiocarbon 35(1)

Appendix M


Vegetation and Fire, Moose Pass, AK
legend
Fire_pts
Streams
Railroad
Roads
Firepoly
Firehist
Covtyp
ALDER
ASPEN
BIRCH
BLACK SPRUCE
COTTONWOOD
GRASS AND ALPINE
HEMLOCK
HEMLOCK-SPRUCE
MIXED HARDWOOD-SOFTWOOD
MUSKEG MEADOW
NO DATA
NONSTOCKED
OTHER BRUSH
OTHER NONFORESTED
ROCK
SALT WATER
SITKA SPRUCE
SNOW AND ICE
WATER
WHITE SPRUCE
WILLOW

Appendix M (cont.)



Appendix N

climate diagnostics center

Comparison of Different El Niños

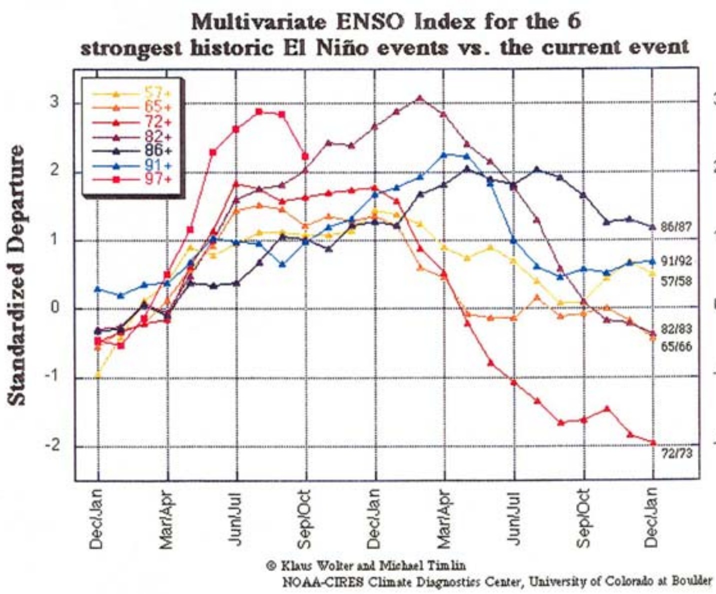
Animations of Past El Niño Events

(Using weekly Sea Surface Temperature data)

1: 1982-83 SST (JAN82 - JUL83)
2: 1991-92 SST (JAN91 - JUL92)
3: 1994-95 SST (JAN94 - JUL95)
4: 1997-98 SST (JAN97 - Present)

Comparison of 4 El Niño events (JAN - Present)

ENSO Index: Comparison of the current 1997 event with other events



CDC ENSO PAGES: Effects on Climate **Current Conditions** References Education Forecasts

NOAA-CIRES Climate Diagnostics Center
Document maintained by Cathy Smith (cas@cdc.noaa.gov)
Last updated: Nov 5, 1997
http://www.cdc.noaa.gov/ENSO/enso.different.html