

Studies in the Wilderness Areas of the Kenai National Wildlife Refuge: Fire, Bark Beetles, Human Development, and Climate Change

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Abstract—Wilderness areas comprise 65% of the 1.92 million acre Kenai National Wildlife Refuge, Alaska. Fire history studies indicate that fire frequency increased substantially in both white and black spruce forests after European settlement. Dendrochronology studies indicate that regional-scale spruce bark beetle outbreaks occurred in the 1820s, 1880s, and 1970s. None of these outbreaks was as intense as the 1990s outbreak, which has killed most of the large white and Sitka/Lutz spruce on the southern Kenai Peninsula. Strong climatic warming appears to have accelerated the recent outbreak, probably through drought-stress of large trees. Logging of once-remote beetle-killed forests on private lands on the southwestern flank of the Refuge is shrinking available brown bear habitat and making protection of the wilderness areas more crucial.

The Kenai National Wildlife Refuge is the most popular and most heavily visited of Alaska's sixteen National Wildlife Refuges. It lies on the highway system within a two to three hour drive of Anchorage, and is a popular recreation destination for hunting, fishing, skiing and snow machining. The Refuge was established in 1941 by President Roosevelt as the Kenai National Moose Range, in response to hunting and conservation organizations seeking to preserve the so-called "giant Kenai moose," then considered a separate subspecies of moose. The name was changed from "Moose Range" to "Wildlife Refuge" in 1980 under the Alaska National Interest Lands Conservation Act (ANILCA), and more territory was added to bring the acreage up to ~2 million acres. ANILCA also established the wilderness areas of the Kenai NWR (fig. 1).

Thirty-five percent of the Refuge is more or less road accessible and is not classified as wilderness. The remaining 65% (1.3 million acres) is accessible only by foot, horseback, boat, snowmachine or plane and is classified as wilderness. Snowmachine use is allowed in the wilderness areas below treeline, and outside of certain special set-aside areas, such as the Canoe System which is reserved for dogmushers and skiers. Floatplane landings are permitted on a small number of lakes in the wilderness areas, and limited helicopter landings are allowed for scientific purposes.

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Practically speaking, only a tiny fraction of the Kenai Peninsula's residents and tourists ever get back into the wilderness areas, so direct human impact is fairly low in these areas. The general proximity of the wilderness areas to urban centers, however, makes them excellent candidates for field studies that require large areas of land with relatively minor human impact. Animals with large home ranges, such as wolves and brown bears, can be studied here over a period of years or decades, as can ecological and climatic processes that affect animal populations and their habitats on landscape and regional scales.

Even though the wilderness areas are large and relatively isolated from the road system, this does not mean that they are timeless and unchanging, or unimpacted by human activity on adjoining lands. In my six years as the Refuge ecologist much of my work has focused on documenting the long-term changes in these wilderness areas, specifically as regards fire, spruce bark beetles and climate change.

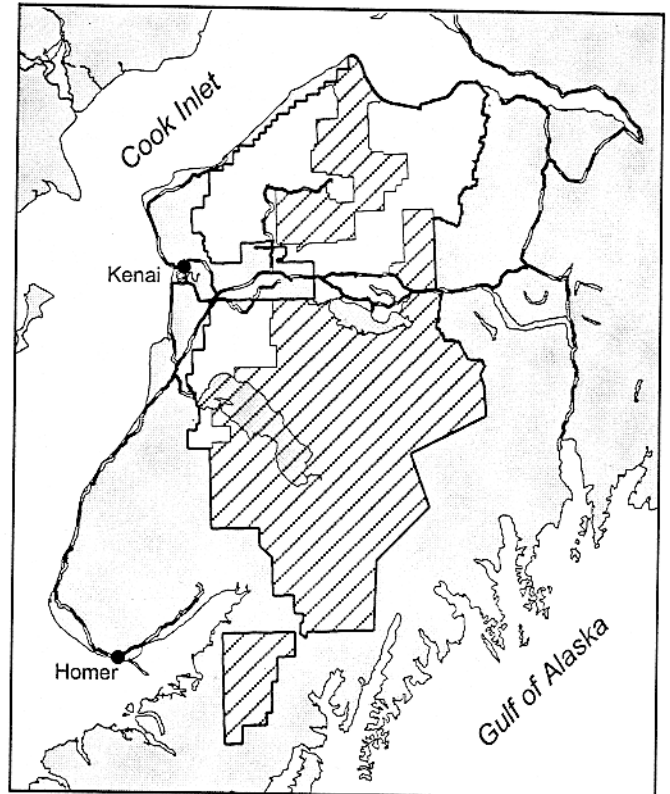


Figure 1—Map of the Kenai National Wildlife Refuge. Wilderness areas are shown with dotted lines.

Fire

In the 20th century, the Refuge has experienced many small fires and two large fires, most of which have been human-caused. Unlike Interior Alaska the Kenai Peninsula experiences very little lightning, so we have been curious to know whether fire was common before European settlement in mid-19th century. We have addressed this with separate fire history studies in white spruce and black spruce, and with charcoal studies in lake sediments.

The white spruce study examined mature white spruce forests using age-class analysis. We found nine “even-aged” polygons (homogeneous stands) with an initial cohort of recruits formed after a disturbance (presumably fire), with dates from the 1830s to the early 1900s. We found 11 older polygons with broad age distributions, indicative of continuous gap-phase recruitment. Virtually every stand had charcoal fragments in the soil, indicating that the stand had burned at least once in the 9,000 years that spruce forests have existed on the central Kenai since deglaciation (Ager 1983, S. Anderson, pers. comm. 1999).

In the black spruce study, Andrew DeVolder used tree-rings to cross-date burn poles and fire scars within the 310,000-acre 1947 burn. He dated 12 fires in the period 1708 to 1898; nine of these fires occurred after 1828, suggesting a substantial acceleration in fire frequency associated with European settlement (DeVolder 1999).

The lake sediment studies turned up remarkably little charcoal. A pulse of charcoal from the 1947 burn was visible in two sediment cores, but no other distinct peaks appeared in the ~1,000 years represented in the sediment cores. The level of background charcoal in the sediments was considered to be an order of magnitude less than that of a typical boreal forest lake in Interior Alaska, according to Jason Lynch and Jim Clark of Duke University (pers. comm.).

In the summer of 1998, Scott Anderson of Northern Arizona University pulled a 9 m core from one of our deeper lakes. This core has a bottom date of 13,170 years in glacial mud. The pollen has been analyzed at 10 cm intervals, and provides a full record of the revegetation history of the Kenai lowlands since deglaciation. Anderson is also doing a centimeter-by-centimeter measurement of the charcoal abundance in the upper layers to confirm or deny that presettlement fire frequency was as low as our earlier studies suggest. Thirty-nine tephra (volcanic ash) layers in the core are being analyzed by microprobe by Jim Beget of the University of Alaska - Fairbanks. This should provide the longest tephra chronology for eastern Cook Inlet and will be a valuable tool for dating a variety of stratified deposits in the region.

Spruce Bark Beetles

In the 1990s the white and Sitka/Lutz spruce forests of the Kenai Peninsula have been severely damaged by a record outbreak of the spruce bark beetle (*Dendroctonus rufipennis* Kirby), with red-needle acreage peaking at ~480,000 acres in 1996 (fig. 2). We have used dendrochronology to examine 13 stands throughout the peninsula for evidence of earlier outbreaks, using analysis of stand-wide growth releases. That is, when a stand is thinned by mortality of the overstory trees, the suppressed understory trees are released from

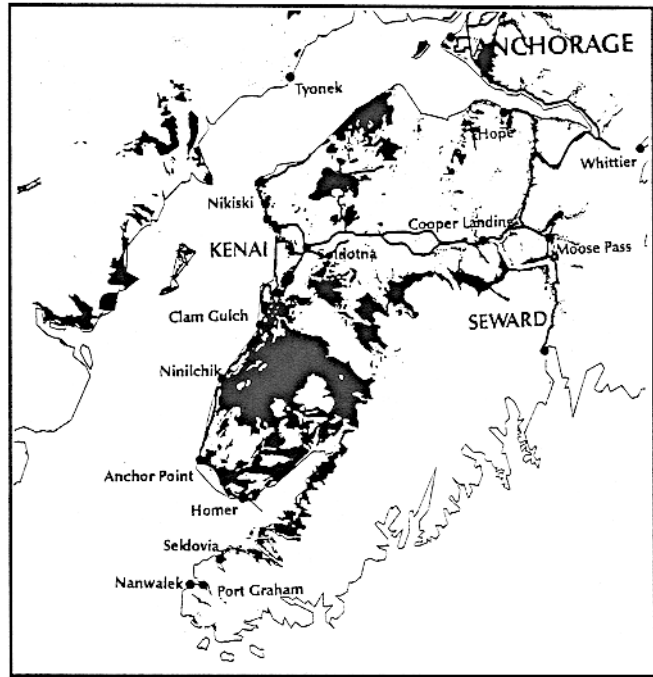


Figure 2—Spruce bark beetle red-needle acreage 1989-1997 (USDA Forest Service, State and Private Forestry annual surveys).

competition, and their annual growth rings become wider. This growth pulse typically lasts for about 70 to 90 years until the canopy closes and competition again intensifies. To detect growth pulses we measure the annual rings to 0.01mm accuracy and look for a doubling of the forward 10-year mean ring-widths over the previous 10-year mean. If the ratio of these means exceeds 2.0, we call this a release and graph the number of releases in an entire stand to get a picture of the thinning history of the stand (figs. 3 and 4).

When a number of stands are graphed together, we can see the regional pattern of thinnings (figs. 5 and 6). This approach reveals that the white and Sitka/Lutz spruce forests

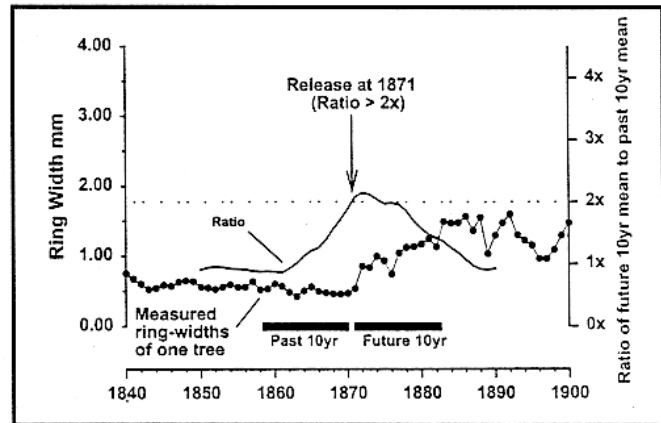


Figure 3—Definition of a release as a doubling (2x) of 10 year mean ring widths.

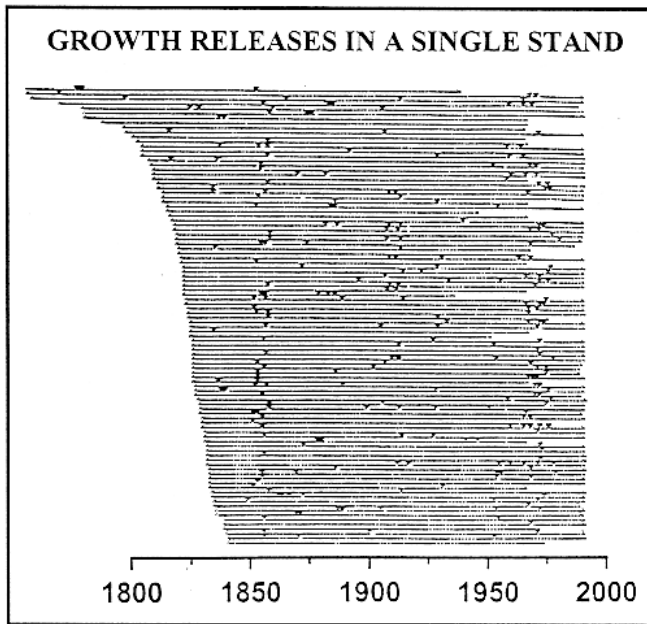


Figure 4—Release patterns in a very mature white spruce - birch stand. Each line represents a separate tree, with releases shown as black triangles. Many trees died in the 1970s, and most survivors released. Earlier releases can be seen in the 1850s and 1920s. (Graphic by C. Fastie).

on the Kenai have indeed experienced regional episodes of thinning: in the 1820s over most of the peninsula, in the 1880s in the southern peninsula, and in the 1970s in the central and northern peninsula. In some stands, we can see as many as three episodes of thinning, indicating persistent low levels of beetle infestation with periodic flare-ups. Even so, in most cases, the magnitudes of the past outbreaks are well below the magnitude of the present outbreak (Fastie and others, in review).

In earlier beetle outbreaks, Kenai Peninsula spruce forests recovered beetle-killed basal area within a few decades, either through released growth of survivors or through seedling recruitment; stand composition probably remained essentially unchanged (Fastie and others, in review). In the present outbreak, however, some stands lack adequate advanced regeneration (i.e., suppressed understory individuals), perhaps because of previous thinnings and releases. The death of mature overstory in these stands will mean the loss of seed sources for seedling regeneration. In mixed stands, this will mean a shift to more hardwood and less spruce; in pure spruce stands, we expect that heavy grass [*Calamagrostis canadensis* (Michx.) Beauv.] will dominate local sites for many decades. Some foresters have predicted that the Kenai Peninsula will become a “spruce savannah,” at least in the upland areas, but our studies of past beetle outbreaks show that on a scale of decades, white and Sitka/Lutz spruce stands have a remarkable capacity to perpetuate themselves, both through release and seedling regeneration, and we don’t subscribe to the spruce savannah prediction.

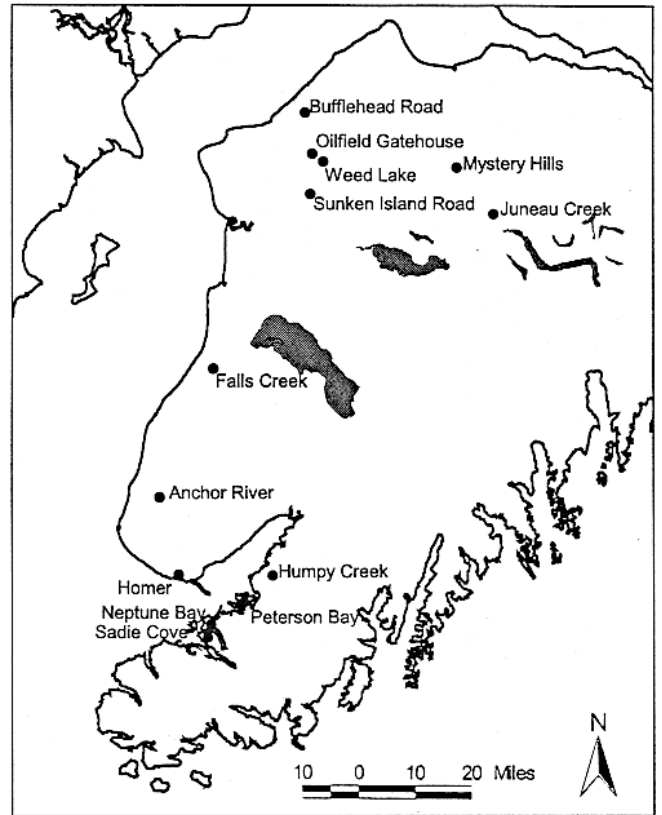


Figure 5—White and Sitka/Lutz spruce study sites for spruce bark beetle history.

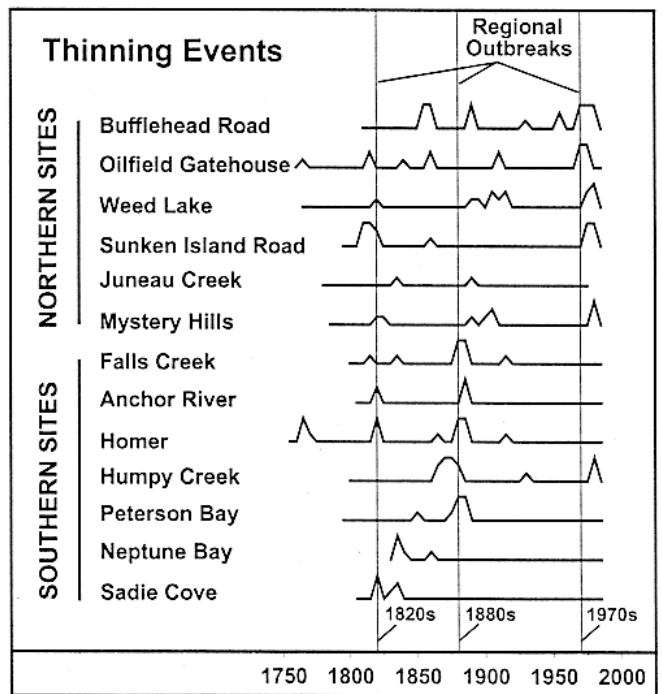


Figure 6—Summary of release pulses and inferred spruce bark beetle outbreaks in white and Sitka/Lutz spruce. High peaks are significant at $p < 0.001$, medium peaks at $p < 0.01$, small peaks at $p < 0.05$.

Human Development

The population of the Kenai Peninsula has increased at an annual rate of 2.2% in recent years. The impact of this increase is felt most heavily on the non-wilderness parts of the Refuge because of the good road access to popular fishing spots, moose hunting and campgrounds. The presence of the recreational infrastructure serves as an extremely valuable buffer for the wilderness areas. The most serious impact of off-Refuge development, so far, is the extensive network of logging roads initiated by the spruce bark beetle outbreak. The beetle outbreak has greatly accelerated timber harvest on private lands, as owners race to extract value before the trees rot on the stump. Chronic heartrot and beetle-borne blue stain fungus set time limits of several years on saw timber from beetle-killed trees, and much of the harvest is now simply being chipped for pulp. Approximately 85,000 acres have been harvested on the western Kenai since 1990, according to Alaska Department of Fish and Game, Habitat Division.

Extensive logging has occurred on Native corporation lands on the southwestern side of the Refuge right up to the wilderness boundary. The logging roads are considered permanent because the Native corporations want access to the land for their members' use and for income generated by sales or leases of recreational property. In the past, this area was remote undeveloped land that served as a buffer for brown bear habitat in the wilderness areas. The brown bear population numbers 250 to 300 individuals and is considered the most sensitive species on the Kenai. Brown bears are our "canary" in the coal mine. The increasing human population is raising the number of "defense of life and property" killings of brown bears to five to seven per year; these killings have severely limited the number of legally harvestable bears to about seven per year. Brown bears roam over large areas, and there is concern that their numbers should not fall below a threshold level from which they could not recover. Loss of habitat, regardless of ownership or land classification, is bad for bears, and the new logging roads definitely reduce the suitability of many square miles of bear habitat on the Kenai Peninsula.

Climate Change

The Kenai Peninsula, and indeed much of Alaska, has been warming up, probably at an accelerating rate. The Kenai airport shows a 2.9°F/50 years increase in mean annual temperature since the mid-1940s, and the Homer airport shows a 3.9°F/50 years increase in the same period. Much of this increase occurs in warmer Decembers (~9°F/50 years) and Januarys (~7°F/50 years), but summer temperatures are up 2.5°F/50 years in Kenai and 4.1°F/50 years in Homer., according to National Weather Service records. These are extremely strong gradients. We used tree-rings to reconstruct summer temperatures back to 1706 and found a general rise of about 3°F in summer temperature at treeline from a low in the 1810s (DeVolder 1999).

The effects of this warming are multifold. Glaciers are retreating rapidly (Wiles and Calkin, 1994), treeline is rising and water tables are falling as the landscape dries.

Precipitation is highly variable on the Kenai, and it appears that the drying phenomenon is primarily due to increased evapotranspiration associated with the warming. We see black spruce invasion of wetland perimeters due to gradual lowering of the water table. Many kettle ponds that held water in 1950 are now grassy pans with spruce and willow invasion. These ponds are important breeding habitat for wood frogs, our only amphibian species.

The warming trend, and more specifically its attendant droughtiness, appear to have triggered the present spruce bark beetle outbreak. There are two direct temperature effects for the beetles, in that they need 60°F days in the spring to make their reproductive flight to new trees, and they can complete their normal two-year life cycle in one year during a long warm summer. Probably more important, however, is the secondary effect of temperature in creating drought-stressed trees. The beetles have evolved to attack the trees during the period of maximum drought stress in the spring, when the stomata are open on sunny days but the soil is still frozen and water uptake is retarded. Many large spruce show decreasing ring-widths over recent decades, partly due to canopy closure, but also due to the increased growing season droughtiness. This decreased annual growth in mature trees increases their susceptibility to beetle attack (Hard 1985, 1987).

Wilderness as a Laboratory

The Kenai NWR has "research and education" written into its statement of purpose, and the wilderness areas of the Refuge are indeed used for scientific research, as the above studies indicate. Wildlife monitoring flights are perhaps our most frequent visitation of the wilderness areas. We have acquired more than 12,000 radiocollar locations for lynx, marten, wolves, caribou, moose, trumpeter swans, bald eagles and bears since 1976, in both wilderness and non-wilderness habitats. We are assembling a vegetation GIS layer with which we hope to model wildlife habitat use and habitat change, propagation of wildfires and bark beetles outbreaks, and vegetation succession in response to disturbance of various kinds. This kind of data-intensive modeling requires considerable ground-truthing, and we deploy crews of seasonal technicians, graduate students and volunteers every summer to gather as much data as possible in our all-too-brief field season from May to mid-September.

Much of this work is done in the Wilderness areas, and it does create a certain level of human presence in these areas. The human presence intensifies in August when the moose and caribou hunters arrive. Even so, both scientific and hunting visitation is rather tightly controlled by Refuge managers through a permit system, and visitation could be scaled back if we judged the impacts to be significant. Snowmachine use in the winter, however, is not controlled by permits, and it could become a major problem if the present popularity of snowmachining on the Kenai Peninsula continues to accelerate. Snowmachine use in the Refuge Wilderness areas is allowed under a "traditional use" provision of ANILCA, and it is unlikely that Congress would revoke this provision in any foreseeable future.

Conclusions

The landscape of the Kenai NWR and its wilderness areas has changed substantially over the past 150 years. Human settlers and their fires have created more early successional hardwood vegetation and brought more moose into the forests. Climate warming is pushing back the glaciers, raising treelines and drying our wetlands. Bark beetles are hitting the spruce forests harder than they did in the past, and our previously undeveloped buffer zone on private land has been turned into a checkerboard of clearcuts. One can lament these changes, but the good news is that they provide a wonderful opportunity for an unlimited variety of ecological studies. We try to take full advantage of this opportunity, and we always invite interested researchers to contact us with proposals. Many graduate thesis studies have been done on the Refuge, because we have been able to provide logistical and financial support.

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