SUSITNA
HYDROELECTRIC PROJECT

FEDERAL ENERGY REGULATORY COMMISSION
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HABITAT MANAGEMENT METHODS TO INCREASE MOOSE BROWSE PRODUCTION IN ALASKA: A REVIEW, SYNTHESIS, AND ANNOTATED BIBLIOGRAPHY OF AVAILABLE INFORMATION

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HARZA-EBASCO
SUSITNA JOINT VENTURE

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Report by
Harza-Ebasco Susitna Joint Venture

Prepared for
Alaska Power Authority

Final Report
September 1984

NOTICE

ANY QUESTIONS OR COMMENTS CONCERNING THIS REPORT SHOULD BE DIRECTED TO THE ALASKA POWER AUTHORITY SUSITNA PROJECT OFFICE

EXECUTIVE SUMMARY

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Construction of the Susitna Hydroelectric Project will eliminate or alter wildlife habitat in the Susitna River drainage, resulting in a decrease in carrying capacity. Mitigation for these habitat losses will include designating specific lands for habitat compensation and then increasing and/or maintaining moose carrying capacity on these lands through habitat management techniques.

In Alaska, there has been considerable testing and utilization of mechanical methods to increase moose browse. The majority of this work has been conducted in the Kenai National Wildlife Refuge (KNWR), commencing with an active habitat management program in 1954. This has since progressed in scope and geographical location to extensive habitat enhancement programs conducted throughout the state. Much of the available information relevant to increasing moose carrying capacity emphasizes the conversion of mature vegetation to early successional stages which produce more available moose browse and the factors which control the amount of browse produced.

Mitigation lands may be one continuous area, but are more likely to be multiple parcels which may be widely separated. Individual parcels and/or portions of large parcels should be regarded as management units, and a plan to achieve the mitigation objectives for the life of the project developed for each unit. The size of, location of, and vegetation types on mitigation lands are the primary factors which determine the appropriate management techniques required to increase and/or maintain a high carrying capacity.

The area of mitigation lands should be up to ten times larger than the area of early successional vegetation needed at any given time to replace browse lost by construction of the Susitna Hydroelectric Project. Moose as well as other species may benefit from a mixture of early successional vegetation for both browse and cover. Additionally, prescribed burns require more acreage than what will actually be burned, with consideration for visual

impacts also requiring larger areas. Browse production can be increased in all sites where vigorous growth of willow, alder, birch, poplar, and/or aspen is possible. However, increases in browse production are achieved more easily and cheaply on sites with a high density of willow or aspen which has become decadent, grown too tall for moose, and/or is overbrowsed.

Crushing is recommended to increase carrying capacity in riparian habitat in the lower Susitna valley, and may be used in accessible areas where there is a high density of browse plants which are overbrowsed or growing out of reach of moose.

Prescribed burning is the preferred habitat management technique to increase the carrying capacity of most areas for moose. It is the most cost-effective method for most areas and may be the only cost-effective method for remote areas. The major drawback of prescribed burning within the area of potential mitigation lands is the need for flexibility in habitat management planning in that specific weather and fuel conditions are required.

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1.0 INTRODUCTION

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The Alaska Power Authority (APA) has submitted a license application to the Federal Energy Regulatory Commission (FERC) for a two-dam project at the Devil Canyon and Watana sites on the upper Susitna River. Mitigation for permanent losses of wildlife habitat resulting from impoundment and facility construction will include compensation through enhancement of other lands.

Dams, reservoirs, spillways, and damsite borrow areas of the proposed developments will permanently cover about 50,000 acres of vegetated land and water within the middle Susitna Basin. Habitat within the affected area will no longer be available to moose, and displaced moose will compete for food and space on surrounding lands, potentially reducing browse quality and thus the carrying capacity of these adjacent ranges. Preliminary estimates of carrying capacity for all project facilities indicate that wintering habitat loss will affect an estimated 340 moose (Acres, 1983). The reduced carrying capacity of the immediate project area may produce a long-term deceasing trend in the number of moose present. The loss of moose carrying capacity likely to result from the project can be mitigated through increasing the moose carrying capacity of other lands.

Much information has been collected relative to moose habitat enhancement in Alaska and many studies are currently underway. However, much of these data have not been published and to date no systematic review of the subject has been made. The purpose of this report is to collect, review, and synthesize habitat enhancement information pertinent to the Susitna River Basin to provide information on the cost and effectiveness of habitat enhancement techniques for use in refining the mitigation plan for the Susitna Hydroelectric Project. The specific objectives of the study are to:

1. Briefly describe moose winter habitat;

2. Describe the types and effects of habitat modification on winter moose forage;

3. Generally describe the types and effects of habitat modification on other resources; and,

4. Evaluate the effectiveness and cost efficiency of types of habitat modification for the Susitna River Basin.

This report is based on existing information, and focuses on information from Alaska and adjacent parts of Canada with similar environmental conditions. The data base covers the range of moose.

A complete list of the references reviewed is provided in the Reference Section at the end of the report, which includes the literature cited in this report. The methodology for this review included a thorough literature search and review of published and unpublished data, and a synthesis of this information. The literature review included computerized literature searches, reviews of references collected by Alaskan game researchers and managers, and review of the literature cited in publications on hand. Unpublished data and information were acquired via site visits to logged/burned areas and interviews with Alaskan resource managers and researchers, including the Alaska Department of Fish and Game (ADF&G), U.S. Fish and Wildlife Service (USFWS), U.S. Forest Service (USFS), and U.S. Bureau of Land Management (BLM).

In addition to a review and synthesis of published and unpublished information, an annotated bibliography of all pertinent literature can be found in Appendix A. Articles critiqued in this bibiography include articles concerned with natural and/or assisted moose habitat enhancement; articles covering south-central or interior Alaskan moose or adjacent Canada; "landmark" articles frequently referenced from any area on moose habitat, general fire effects or related topics; and articles which are the only source of information on subjects such as fertilization to increase browse, browse on transmission lines and other rights-of-way, economics of moose habitat enhancement, and effects of moose habitat enhancement on other species which occur in Alaska, i.e., caribou. Of 205 articles referenced in the bibliography, 82 of these articles have been annotated.

Also included in the Appendix is a table of common and scientific names of plants and animals cited in the annotated bibliography and in the text of this report (Appendix B). An update of the status of planned prescribed burns within the state is presented in Appendix C.

The report itself opens with a summary of General Moose Ecology, followed by two sections entitled Fire and Mechanical Habitat Enchancement. The Fire section includes discussion of wildfire history and regimes; the state's interagency fire management plans; ecological effects of fire on soils, vegetation, wildlife and site-specific factors controlling the effect of fire on moose carrying capacity; and prescribed burning. The Mechanical Habitat Enhancement section includes discussion of indirect methods such as agriculture, mining, and logging, and direct methods, such as crushing. The report closes with recommendations.

2.0 GENERAL MOOSE ECOLOGY

2.0 GENERAL MOOSE ECOLOGY

Moose (Alces alces) are present throughout the boreal forest in North America. Moose distribution and abundance in Alaska have been and continue to be very dynamic. Moose increased steadily through the 1950's and early 1960's in response to recurrent wildfires, and stabilized or declined in the following 15 years in southcentral and interior Alaska due to a series of severe winters, complicated by deteriorating range conditions, changing hunting pressures and predation (LeResche et al. 1974).

Major habitats important to moose in Alaska include both seral and non-seral communities, as discussed in LeResche et al. (1974), and summarized below. Non-seral habitats include treeline and wetland shrub communities. Treeline shrub communities are characterized by dwarf birch and willow, with heath and forb understories. These habitats are used most intensively in summer and autumn, but are utilized year round by moose in some areas. Wetland shrub communities (bog areas) occur on the broad alluvial plains common south of the Brooks Range. These are important during spring and winter, and support concentrations of moose during calving. Seral communities, including those created by fire and by glacial or fluvial action, are key winter ranges in much of Alaska. Fire-created habitats support the greatest population increases and among the greatest densities of moose in the state.

The importance of early successional stages to moose is well documented (Lutz 1960, Spencer and Halaka 1964, Krefting 1974 and Kelsall et al. 1977). Early seral stages of plant succession, especially those areas rich in aspen, birch and willow support many moose (Kelsall et al. 1977). As forest succession advances, the quality of the habitats and the numbers of moose decrease because at maturity the boreal forest shades out the understory browse, and the overstory trees grow beyond the reach of moose (Krefting 1974). In mature coniferous forests moose numbers are few and are entirely dependent on the quantity and quality of deciduous, browse-producing shurbs and trees along forest edges (Kelsall et al. 1977).

In interior Alaska, as in many northern areas, moose undergo regular seasonal movements or migrations. Migration of moose appears to be an adaptation to optimize seasonal use of forage habitats (Coady 1982). In the middle Susitna Basin as in interior Alaska, moose spend the summer at low elevations, move to high elevations during fall and remain there throughout most of the winter (Bishop 1969). Lowland and upland climax shrub communities are heavily utilized during summer and fall. By early winter moose commonly move to upland and lowland seral communities. During winters of deep snow, upland seral communities are abandoned in favor of lowland areas. As the winter advances, moose gradually move from the more open stands to denser cover (Krefting 1974). Weather conditions, particularly snow depth and structure are among the most important factors associated with moose migration (Coady 1974, LeResche 1974).

Moose populations are ultimately limited by the quantity and quality of winter range (Coady 1982), which is critical to moose survival only during severe winters (Coady 1974, LeResche et al. 1974). High quality winter range of moose is characterized by (1) abundant trees and shrubs that are most preferred by moose as winter browse; (2) consistently low snow depths in relation to surrounding areas, and (3) good interspersion of young seral growth (for forage) and older aged forest stands (for cover) (LeResche et al. 1974, Peck 1974). Shrub communities, particularly riparian willow stands provide high quality winter range. Because riparian habitats are frequently disturbed by alluvial action, they provide permanent seral habitats. The nutritional quality of browse (e.g., amounts of crude protein, fats and carbohydrates, digestibility, total calories) is also important in determining the quality of winter range (Oldemeyer 1974).

It has been well established that moose are primarily a browsing species, feeding predominantly on deciduous woody browse during winter months and on emergent and herbaceous plants as well as leaves and leaders of shrubs and trees during the summer (Peck 1974). A thorough review of moose food habits in North America is summarized in Peek (1974) and a number of studies have focused on Alaska (Spencer and Chatelain 1953, Spencer and Hakala 1964, Milke 1969, LeResche and Davis 1973, Cushwa and Coady 1976, Machida 1978). Although general conclusions are that willow, birch, aspen and poplar are primary food sources, local and seasonal variations in forage preferences are important. Food habits of moose are strongly influenced by browse availability, therefore there are some differences in the importance of various browse species to moose, with moose distributions closely associated with the distribution of commonly utilized browse species. Many preferred species appear characteristic of successional stages, with the importance of early successional stages to moose previously discussed. Winter forages vary according to conditions of winter range. The more persistent snows of interior Alaska require that taller browse species be available for moose in winter.

The minimum requirements of moose for winter food and cover appear to be satisfied by a great diversity of habitat types across North America, suggesting that moose are adaptable to a variety of conditions.
The quality of moose habitats are constantly changing as a result of forest succession, with populations fluctuating accordingly. Moose adapt favorably following alteration of vegetation by disturbance such as fire, with carrying capacity increased because of an increase in the quantity and quality of available moose browse. Cushwa and Coady (1976) report that, in Alaska, fire improved habitat through increased productivity and availability of deciduous woody plants, and that moose responded in reaction to improved habitat conditions. In general, moose utilization of optimum browse peaks 20 to 30 years following fire (Spencer and Hakala 1964, LeResche et al. 1974, Viereck and Schandelmeir 1980), and occasionally moose browse may be available for 60 to 70 years following fire (Spencer and Hakala 1964). Species composition, size of burn, rate of growth, diversity of communities, and ecotone created all determine the impact of a burn on moose activities (LeResche et al. 1974).

3.0 FIRE

3.0 FIRE

3.1 WILDFIRE HISTORY AND REGIMES

Fire has been a prehistoric and historic controlling factor in the circumboreal forests of Alaska (Barney 1971, Barney and Stocks 1983, Lutz 1956, Viereck 1973), Canada (Kayall 1968, Kershaw 1977, Rowe and Scotter 1973), Scandinavia (Uggla 1958) and Russia (Barney and Stocks 1983, Lutz 1956) The post-glacial fire record has been studied in sediment cores from many areas of boreal forest (Barney and Stocks 1983). For example, two cores from Finland cover the past 7000 years, and indicate that before permanent settlements were established in the sixth and seventh centuries, the "natural" mean fire intervals for this southern portion of the boreal forest were 78 years for pine forest and 159 years for mesic spruce forest [(Tolonen 1978, 1980 (cited in Barney and Stocks 1983)]. From time of settlement to the present, the mean fire interval has decreased. Similar cores from North American boreal forest sites have shown a fire history dating back thousands of years, with fire intervals of 70-100 years [(Terasmae and Weeks 1979, Nichols 1969 (cited in Barney and Stocks 1983)].

Approximately 220 million acres of Alaska's total area of 375 million acres are considered vulnerable to wildfire (Taylor et al. 1983). Barney (1971) estimated that before organized fire suppression began in 1940, 1.5 to 2.5 million acres burned annually. From this information, the mean fire interval for the total area vulnerable to fire can be roughly estimated as 110 years. Fire suppression has steadily decreased the number of acres burned each decade, and since 1969 the annual number of acres burned has decreased to a level of 375,000 to 625,000 acres, increasing the mean fire interval for the total area to 440 years (Taylor et al. 1983).

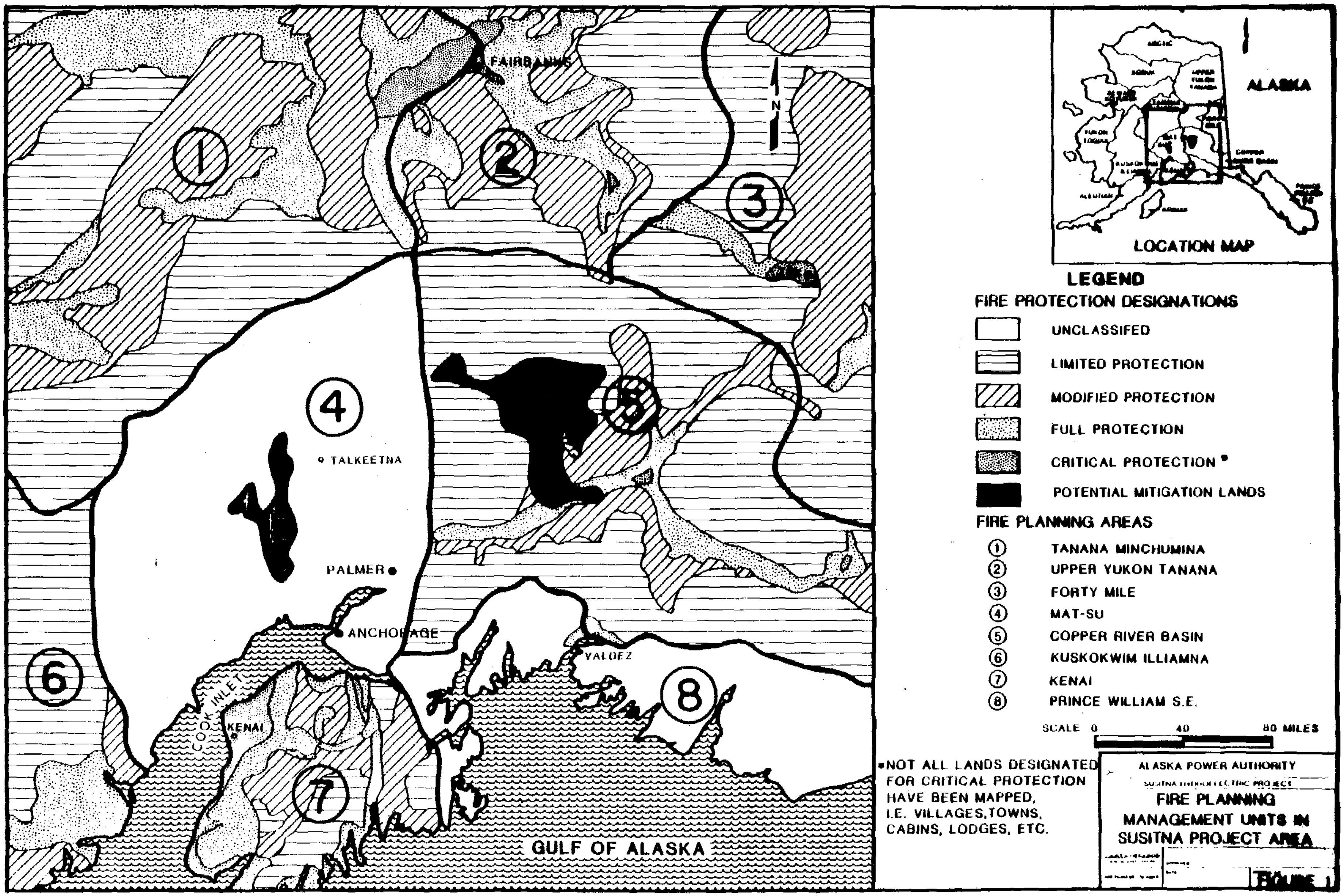
Exceptional fire years are characteristic of the taiga, and may be synchronized over large areas. The year 1865 has been reported as a big fire year in the Mackenzie Valley (Northwest Territories, Canada), Jasper

Park (Canada), Montana, and Minnesota (Viereck and Schandelmeier 1980). The years 1893, 1915, 1937, 1941, 1950, and 1969 were major fire years in both Alaska and the Mackenzie Valley. In Alaska from 1940 to 1978, 6 years (1940, 1941, 1950, 1957, 1969, and 1977) accounted for 63% of the area burned during this 28-year period. Data from Alaska and Canada on area burned show a rough correlation of annual area burned to a 9- to 11-year time interval, but neither the existence nor the cause of periodic patterns in major fire years has been established.

Fire regimes vary in different parts of Alaska (Figure 1), depending on climate. The Tanana/Minchumina fire planning area (see Section 3.2 for discussion of fire planning areas) has a severe fire climate, with low precipitation, relatively high summer temperatures, and a high frequency of lightning which is not accompanied by heavy rainfall. During the 25-year period for which statistics are available from 1957-1981, approximately 9% (2.8 million) of the 31 million acres in the planning area burned (ALUC 1982). There were 1716 fires, but only 4% (64) of the fires burned 94% of the acreage. Lightning caused 52% of the fires and burned 86% of the acreage.

The Copper River Basin fire planning area (Figure 1) has a different fire regime. Climate and fuel types are similar to the Tanana/Minchumina area, but the incidence of lightning-caused fires is much lower and the interval between fires appears to be much longer (ALUC 1984). During the 23-year period for which statistics are available (1956-1978), approximately .06% (12,000) of the 19.7 million acres in the planning area burned. Of 584 fires, 1% burned 84% of the total burned acreage. In contrast to the Tanana/Minchumina area, only 6% of the fires were lightning-caused, and these burned only 8% of the total burned acreage.

Specific data is available for the Susitna Dam project area from the Copper River Basin fire management plan. In the management unit bordered by the Talkeetna Mountains, the Oshetna River, the Susitna River, and the Alaska Range, only 13 acres of the total area of 2 million acres burned between 1956 and 1978. There was one lightning-caused fire and two man-caused fires.


FAIRBANKS
N
TALKEETNA
PALMER
ANCHORAGE
VALDEZ
COOK INLET
KENAI
GULF OF ALASKA
ALASKA
LOCATION MAP
LEGEND
FIRE PROTECTION DESIGNATIONS
UNCLASSIFED
LIMITED PROTECTION
MODIFIED PROTECTION
FULL PROTECTION
CRITICAL PROTECTION *
POTENTIAL MITIGATION LANDS
FIRE PLANNING AREAS
1 TANANA MINCHUMINA
2 UPPER YUKON TANANA
3 FORTY MILE
4 MAT-SU
5 COPPER RIVER BASIN
6 KUSKOKWIM ILLIAMNA
7 KENAI
8 PRINCE WILLIAM S.E.
SCALE 0 40 80 MILES
*NOT ALL LANDS DESIGNATED FOR CRITICAL PROTECTION HAVE BEEN MAPPED, I.E. VILLAGES,TOWNS, CABINS, LODGES, ETC.
ALASKA POWER AUTHORITY
FIRE PLANNING MANAGEMENT UNITS IN SUSITNA PROJECT AREA
FIGURE 1

The management unit to the east and south of the project area is bordered by the Susitna River, the Alaska Range, the Richardson Highway, the Glenn Highway, Lake Louise, and the Tyone River; and includes the Alphabet Hills area and other areas considered for Susitna mitigation lands. In this area only 342 acres of the total of 3.2 million acres burned during the same time period. There were 4 lightning-caused fires and 54 man-caused fires, and man-caused fires were responsible for 75% of the burned acreage. The two management areas described above are within the lightning belt, but the thunderstorms are usually accompanied by enough rainfall to prevent fires from starting and/or spreading (F. Malotte. 1984. Pers. comm.).

Vegetation in the Copper River Basin however, clearly shows that the general fire pattern is similar to other areas of Alaska. Accounts of early explorers, and limited fire records for the time period from 1900 to the start of organized fire suppression, document a number of large fires. Vegetation studies for the Susitna Hydroelectric Project have documented the importance of fire in determining the age, composition, and distribution of plant communities in the project area, and have identified more recently burned areas which provide good moose habitat. According to F. Malotte (1984. Pers. comm.), climatic conditions in this area result in fuels which are generally more moist than fuels in the Interior north of the Alaska Range, and fire frequency is lower. However, fuel accumulates, and in the occasional very dry year, large areas burn.

Detailed information on the fire history of the lower Susitna Valley is not presently available. Fuel loading and moisture conditions are suitable for burning (F. Malotte. 1984. Pers. comm.). However, there is very little lightning, and historically the area has not burned frequently. Man-caused fires are changing this pattern in the developed areas.

3.2 INTERAGENCY FIRE MANAGEMENT PLANS

Alaska land managers and wildfire protection organizations are in the process of changing fire suppression policies. Wildfire suppression is administered by the Alaska Department of Natural Resources, the Bureau of Land Management, and the National Park Service. To reduce organizational duplication, each agency protects its lands under a cooperative suppression agreement which is a contractor-client relationship. The Alaska Land Use Council (ALUC), which was authorized by The Alaska National Interest Lands Conservation Act (ANILCA) and included federal, state, and native land managers, established a fire-working group to develop the Alaska Interagency Fire Management Plan. The Alaska Interagency Fire Management Council was then established to develop fire management plans for wildfires. Objectives include (1) reducing fire suppression costs, (2) optimizing suppression resources in major fire years, (3) making fire suppression costs commensurate with the value gained by protecting the resource, with the recognition that wildfire is beneficial to many resources, and that suppression may be more damaging than fire.

The state has been divided into 14 fire planning areas (Figure 1), and the interagency fire management plan categorizes each area into four management options: critical, full, modified, and limited protection. The critical protection option is designed for specific sites where human life or habitation are present. These sites receive immediate, aggressive, and continued attack to minimize damage, and are the highest priority for suppression forces. The full protection option identifies areas of high natural resource value, which receive immediate and aggressive action to minimize areas burned. The modified action option provides for initial attack on all new fire starts during the severe burning portion of the fire season. Fires which escape initial attack are evaluated to develop a strategy that balances acres burned versus suppression expenditure. During the low risk period of the fire season, initial attack is not required and the fire may be allowed to burn, but is monitored and continually evaluated to determine if suppression is required. The limited action option is for areas where fire is desirable or where resources values do not warrant suppression expenditures. The behavior and spread of the fire is monitored, but suppression activity is limited to preventing the fire from escaping the designated area. Critical fire suppression areas are often small sites such as cabins or lodges. Suppression measures such as catlines are used to protect the site itself, not the surrounding land.

Nine completed plans and five presently being developed will cover the entire state by mid-1985. In the nine completed plans, approximately 25% of the land is under full protection, 25% is under modified protection, and 50% is under limited protection. Of that land under limited protection, 22% is subject to fire and the remaining 28% is non-burnable (F. Malotte 1984. Pers. comm.). Fire plans will be updated as necessary to accommodate changes in land use and ownership.

The upper Susitna drainage area is classified as limited action (Figure 1), with the exception of cabin and lodge sites. These facilities would be protected, but the surrounding vegetation would be allowed to burn. Although the lower Susitna Valley was not given planning priority as a fire-prone area, an interagency fire management plan will probably be developed in 1985. Because much of this area is presently utilized or is planned for residential sites, agriculture, and forestry, and because these land uses exist or are planned in a patchwork pattern, it is likely that most of the lower Susitna Valley will be designated for critical or full fire protection.

3.3 ECOLOGICAL ROLE OF FIRE

Excellent reviews and summaries of existing information on fire ecology in Alaska and other parts of the boreal forest are available, and this effort will not be duplicated in this report (ALUC 1982, Kayll 1968, Kozlowski and Ahlgren 1974, Ream 1981, Rowe and Scotter 1973, Viereck 1973, Viereck and Schandelmeier 1980, Wien and MacLean 1983, Yukon Wildlife Branch 1980). Pertinent information is summarized from these sources and additional papers cited in the text as background for a more detailed discussion of the relationship between fire and moose habitat.

3.3.1 Fire Behavior

Fire behavior is one of the most important factors in determining fire effects. "Fire intensity" is a technical description of the rate of energy transmission at the fire front. The term "fire severity" may be used to describe the overall effects of the fire on the ecosystem, but is usually confined to the effects of the fire on the forest floor. In terms of ecological effects, a high-intensity fire is a hot crown fire which consumes much of the aboveground vegetation, while a low-intensity fire may leave large amounts of live vegetation. Either type of fire may or may not burn deeply in the organic mat on the forest floor.

Forest floor fire severity is important, because the amount of organic material removed by the fire affects postfire succession, soil temperature, permafrost depth, and amount of available nutrients. Fire removes the forest floor unevenly, leaving a patchy mosaic. Because of the importance of this effect to the production of moose browse, classifications of severity are presented in detail. The four forest floor severity classes used in the Washington Creek experimental prescribed burns (Viereck et al. 1979) are as follows: (1) heavily burned-deep ash layer present, organic material consumed or nearly so to mineral soil, no discernable plant parts remaining; (2) moderately burned- organic layer partially consumed, shallow ash layer present, parts of woody twigs remaining: (3) lightly burned- plants charred or scorched but original form of mosses and twigs visible; (4) unburned- plant parts green and unchanged. These classifications are most useful to characterize microsites within a burn; Wells et al. (1979 (cited in Viereck and Scandelmeier 1980)) expanded the system to describe the mosaic of burn patterns in larger area as follows: (1) severely burned- more than 10% of the area has spots that are heavily burned, more than 80% moderately burned, the rest lightly burned; (2) moderately burned-less than 10% heavily burned, but more than 15% moderately burned; (3) lightly burned- less than 2% heavily burned, less than 15% moderately burned, the rest lightly burned or not burned.

3.3.2 Effects of Fire On Soils

3.3.2.1 Soil Temperature and Permafrost. Most of a fire's heat is lost to the air, and soils are a good insulator. Surface temperatures of 450° C have been demonstrated to have little effect below 5 cm depth. However, the removal of the organic layer, the change in surface albedo, and the removal of overstory vegetation result in warmer soil temperatures. In areas with continuous or discontinous permafrost, such as the upper Susitna drainage, the thickness of the active layer is increased. For example, at the 1971 Wickersham Dome wildfire, the thaw depth increased from 45 cm in 1971 to 183 cm in 1979 (Viereck and Dryness 1979). Comparisons of active layer thickness in a number of known-aged burns indicated that the active layer returns to its original thickness approximately 50 years after fire (Viereck 1973).

3.3.2.2 Soil Nutrients. Warmer soil temperature and greater active layer thickness increase nutrient turnover and availability of nutrients to vegetation, increasing site productivity after fire. Burning releases plant nutrients that were tied up in organic layers, particularly where deep forest floors have built up because of a slow decomposition rate. Northern soils tend to be acidic, and pH is dramatically increased by fire. Usually, exchangeable phosphorous, potassium, calcium, and magnesium also increase after fire. Considerable amounts of nitrogen are lost as gas through volatization during burning, but some of the soil nitrogen tied up in the lower organic layers and in the permafrost may become available to plants as soils warm and thaw after the fire.

3.3.2.3 Runoff and Erosion. Runoff and erosion do not increase following most Alaskan fires, due to the high waterholding capacity of the soil organic layers, rapid revegetation, the short thaw season, and low summer rainfall (Viereck 1973). However, serious erosion has resulted from some firelines, particulary those constructed on permafrost soils (Hagihara and Libscomb 1968, Lotspeich et al. 1970).

3.3.3 Effects of Fire on Vegetation

Forested areas in fire-prone regions of Alaska have been divided into two major site types to describe general patterns of succession following fire. On well-drained upland sites (frequently south-facing slopes) the mature forest vegetation is white spruce, paper birch, aspen, or some combination of these species. White spruce may gradually invade and eventually dominate hardwood stands; or if seeds and suitable seedbeds are available, spruce may establish immediately after fire and even-aged stands may develop. On wet, poorly drained sites, and/or uplands and lowlands underlain by permafrost, the mature forest vegetation is dominated by black spruce. Descriptions of succession are summarized from Foote (1983) but include additional information relevant to moose habitat.

3.3.3.1 Well-Drained Upland Sites. On well-drained upland sites, trees, shrubs, and herbs resprout within a few weeks after the fire, unless the fire is very late in the season. Aspen produces a high density of root suckers around each burned tree. Paper birch produces stump sprouts, but some sprouting ability appears to be lost with age, and not all stumps produce sprouts. Willows, even if old and decadent, sprout prolifically immediately after fire. Alder is more susceptible to complete killing by fire than is willow, and resprouting is less vigorous and prolific. Depending on the time of year of the burn, aspen, birch and willow shoots may be one to four feet tall at the end of the season. Rose, high bush cranberry, bluejoint, and fireweed resprout on lightly and moderately burned microsites. On moderately burned sites, raspberries, stink currants, geranium, and Corydalis spp. germinate from buried seed immediately after the fire (Densmore 1979).

From one to five years after fire, the site is dominated by the resprouted trees, shrubs, and herbs; and by herbs such as fireweed establishing from seed. Willows may reach a height of 10 feet within 3 years if not heavily browsed (Wolff 1978). Seedlings of aspen, birch, alder, willow, and (less frequently) white spruce begin to establish the first year after the fire, after seeds have dispersed to the burned site in the fall and spring.

From 6 to 25 years after the fire, tall willow and alder shrubs, and aspen and paper birch saplings dominate the stands and begin to shade out the herbs. From 26 to 45 years after fire, aspen and paper birch form a dense canopy, grow beyond the reach of moose, and begin to thin, and an understory of small white spruce develops. The most common upland willows, bebb willow and scouler willow, may grow to tree size, or be shaded out and decline. From 46 to 150 years after fire, mature aspen and birch stands, or mixtures of white spruce and aspen or birch are present. Highbush cranberry, rose, twinflower, and horsetails dominate the understory. Some tree-size willows may persist, but most die. From 150 to 300 years, mature white spruce dominates, with a few remaining hardwoods in younger stands.

3.3.3.2 Poorly Drained Permafrost Sites. On cold, wet sites dominated by black spruce, early successional stages are similar to well-drained sites, but later stages differ. Shortly after fire, willows and alder resprout, and willows grow rapidly. On lightly and moderately burned microsites, rose, blueberry, laborador-tea, cloudberry, bluejoint, fireweed, and horsetail resprout. Raspberries, stink currants, and *Corydalis* spp. germinate from buried seed. Black spruce has serotinous cones which survive all but the most intense fires, and seed dispersal may begin immediately after fire and continue for several seasons (Zasada et al 1979).

From 1 to 5 years after fire, resprouted shrubs and herbs dominate, and seedlings of black spruce, aspen, paper birch, willow, and alder establish. From 5 to 26 years after fire, willows, alder, low shrubs, and hardwood saplings dominate, but the stand may be interspersed with young hardwood trees. The tall shrub layer of willow and alder begins to thin out, but the low shrub layer increases in cover. These stands are highly flammable and often burn.

From 51 to 100 years, black spruce and hardwoods mature, followed by a decline in vigor of hardwoods. Willows may die out. Many stands burn in this stage. From 91 to 200+ years after fire, mature black spruce trees, saplings, and seedlings dominate the stand, most hardwoods die out, and low shrubs may be reduced in vigor. During the last three stages, feathermosses invade and grow rapidly, and a thick organic layer develops. This layer ties up available nutrients, creates colder soil temperatures, and results in the return of a thin active layer on permafrost sites.

3.3.4 Effects of Fire on Tundra and Wetlands

Barney (1971) stated that 42% of the acreage burned in Alaska between 1950 and 1969 was tundra. The term tundra in this case probably encompasses all vegetation types not dominated by trees, including shrub- and graminoid-dominated wetlands and forest-tundra areas dominated by shrubs. These vegetation types are important to moose, and are generally described as "non-seral" habitat. It is important to realize that this non-seral habitat can and does burn, even if burns are not as frequent as in forest vegetation.

Fire is probably important in increasing nutrient availability and browse productivity in these important moose habitat types. Fire frequencies in wetlands are relatively low; fires usually occur in very dry years, and most of these fires burn only the surface organic soils (Wien 1983). Regeneration through resprouting of shrubs, forbs, and graminoids is generally so rapid that fire effects are visible only for a short period of time. In forest-tundra, isolated individuals of spruce occur in a matrix of shrub tundra dominated by dwarf birch, laborador-tea, blueberry, cranberry, willow, and lichens. These areas are susceptible to fire due to presence of lichens and ericacious shrubs (Auclair 1983). In western Alaska and on the south slopes of the Brooks Range, fire occurs frequently in treeline areas (Viereck and Schandelmeier 1980). As discussed above under fire history, past burns in forest-tundra are evident in the project area and provide good moose habitat, but fire is not frequent. Shrubs rapidly resprout, but lichens and spruce may be slow to re-establish (Auclair 1983).

3.3.5 Effects of Fire on Wildlife Other Than Moose

Although this topic is very important, a duplication of the existing excellent reviews and syntheses will not be attempted. Pertinent information briefly summarized in this section is from Viereck and Schandelmeir (1980) and Kellyhouse (1979) unless otherwise cited.

By their continued presence in the fire-prone Alaskan taiga, species are presumed to be adapted to or tolerant of fire. The problem addressed is the effect of the conversion of a portion of an area of mature plant community to an early successional plant community on the carrying capacity of wildlife species other than moose. Conclusions are based on assumptions that the maximum size for an area would be about 10,000 acres, that approximately 40% of the area would be left in mature vegetation, and mature plant communities would be interspersed to some degree with early successional plant communities. As will be seen in this report, these are necessary and reasonable assumptions for a state-of-the-art habitat conversion program.

Conversion to early successional stages is likely to increase the carrying capacity of a site for woodpeckers, flickers, alder flycatchers, tree swallows, savannah sparrows, orange-crowned warblers, dark-eyed juncos, sharp-tailed grouse (Mossop 1979), ruffed grouse, ptarmigan, geese, ducks, swans (Buckley 1968, Klein 1971), owls, eagles, falcons, most hawks (ALUC 1982), red-backed voles, meadow voles, muskrats (Kayll 1968), beavers, least and short-tailed weasels, wolves, and red foxes (Kellyhouse 1979) and other furbearers (Stephenson 1984). Habitat conversion which emphasizes a mosaic of young and mature stands is most likely to increase the carrying capacity for olive-sided flycatchers, western wood peewee, bohemian waxwings, snowshoe hares (Wolff 1978), lynx and black bears.

Carrying capacity is likely to be reduced for gray jays, black-capped chickadees, boreal chickadees, varied thrushes, ruby-crowned kinglets, golden-crowned kinglets, yellow-rumped warblers, Townsend's warblers, pine siskins, white-winged crossbills, brown creepers, Swainson's thrushes spruce grouse, sharp-shinned hawks (ALUC 1982), red squirrels, flying squirrels (Ream 1981), and caribou. Davis et al. (1978) felt that there was no obvious correlation between fires and caribou in the Nelchina herd, since many major fires occurred during the 1940's, yet during the late 1940's through the 1960's the population increased. Caribou populations over a large area may be controlled by factors other than food, but on a particular site, the later successional stages following fire or other disturbance are better habitat for caribou than the early successional stages of the first 25 to 30 years. Since this analysis discusses the effect of habitat conversion on the carrying capacity of a particular site, the effects on caribou are listed as negative. Carrying capacity for pine marten may not be altered in a mosaic where forest provides cover and dens, and the adjacent early successional vegetation provides an increased prey base (Archibald 1979).

3.2.6 Effects of Fire on Moose

It is generally recognized that fire increases the carrying capacity of an area for moose, especially in winter. In Alaska, moose maintain low populations in non-seral and riparian habitats; but creation of seral fire habitat, and its subsequent decline after 26 to 30 years, is the most important factor in steady increases or declines in moose populations (Bangs and Bailey 1980, Bailey 1978, Buckley 1968, Chatelain 1954, Coady 1973, Davis and Franzmann 1979, Krefting 1974a, Leoplod and Darling 1953a, LeResche et al. 1974, Rowe and Scotter 1973, Spencer and Hakala 1964). Carrying capacity is increased because quantity and quality of available moose browse increase after fire. The increase varies widely among sites, and may be affected by proximity to cover or time to regrowth of cover. The question of whether increased carrying capacity will be utilized by moose, and result in a population increase, is addressed in a separate report to be prepared by Alaska Department of Fish and Game.

In general, available moose browse is increased for 20 to 30 years following fire (Spencer and Hakala 1964, Viereck and Schandelmeier 1980), but occasionally more browse may be available for 60 to 70 years after fire (Spencer and Hakala 1964). Useful quantitative measurements of increase in available browse have been made in Alaska; some additional studies have measured parameters such as stem density, which cannot be readily utilized to estimate available browse biomass per unit area.

In the Kenai National Wildlife Refuge from 1971 to 1974, the mean available browse was 12 lb/acre in mature forest; while available browse in the 1947 burn ranged from 76 to 166 lb/acre, depending on the density of paper birch, which supplied almost all of the browse (Oldemeyer 1983). Oldemeyer et al. (1977) observed that prior to the 1970's, levels of available browse were higher, and willow and aspen constituted a larger proportion of the available browse. By 1979, available browse in the 1947 burn had declined to 36 lb/acre. The estimated moose population increased steadily from approximately 2000 moose in 1949 to a peak of 9000 moose in 1971, then crashed to 3500 moose in 1975 and stabilized around that level through 1980 (Bangs and Bailey 1980). The 1947 Kenai fire burned slowly over a period of several months, leaving a very large number of unburned inclusions and maximizing edge effect. The large, steady moose population increase from 1949 - 1971 has been attributed to this fire pattern, which produced large quantitites of available browse close to cover provided by mature forest (LeResche et al. 1974, Spencer and Hakala 1964). The sharp decrease from 1975 - 1981 has been attributed to a decline in browse quantity and quality as willows and aspen died and/or grew out of reach, combined with the effects of severe winters (Bangs and Bailey 1980, Oldemeyer et al. 1977).

The 1969 Swanson River burn in the Kenai National Wildlife Refuge was a hot fire that burned most of the vegetation over a large area, leaving few unburned inclusions. Moose densitites did not increase as rapidly as in the

1947 burn, and the difference was attributed to the lack of cover and poor available browse production (13 lb/acre 10 years after fire). However, by 1983 available browse had increased to 90 lb/acre, and moose densities and productivity were as high or higher than the 1947 burn at its peak (W. Regelin. 1984. Pers. comm.). It appears that the hot burn provided many suitable seedbeds for hardwood regeneration, and that once these seedlings had grown tall enough to provide both browse and cover, moose carrying capacity increased dramatically (W. Regelin in 1984. Per. comm.).

Wolff and Zasada (1979) measured available browse in several mature and early fire successional stands in the Tanana-Yukon uplands of interior Alaska. Aspen stands 35 and 50 years old had no available browse, while 1, 4, and 7 years after fire available browse in the form of aspen suckers was 198, 113, and 134 lb/acre. A 35-year-old mixed stand of white spruce, paper birch, and alder had no available browse. A burn in closed white spruce-paper birch forest had 66 lb/acre available browse 16 years after fire, and 60 lb/acre 19 years after fire; most of the browse was willow. Another site in the same preburn vegetation type in the same burn had 120 lb/acre of available browse 19 years after fire, approximately 75% paper birch and 25% willow. Mean available browse (all willow) in a 75-year-old mature black spruce forest was 8 lb/acre, while the burned portion of the same stand produced 16, 43, 45, 57, and 67 lb/acre of available browse (all willow) 3, 4, 5, 6 and 7 years after fire, respectively.

3.3.7 Site-Specific Factors Controlling the Effect of Fire on Moose Carrying Capacity

Moose browse following fire is produced by both vegetative (resprouting) and seed regeneration. The amount of moose browse produced by vegetative regeneration is controlled by what is present on the site before burning, or to put it even more plainly, "what you see is what you get".

3.3.7.1 Vegetative Regeneration. The post-fire browse production from resprouting of major browse species can be predicted with a fair degree of accuracy before the burn. Willows resprout vigorously from the root crown, and are rarely killed even by severe burns, so the number of resprouting willows will be approximately equal to the number present before the fire. Paper birch can regenerate by sprouting. However, the buds at the base of the parent tree, which are the source of sprouts, may be killed by fire; not all trees resprout even if buds are not killed by fire; and sprouts may be short-lived (Zasada 1971). Alder may occasionally be killed by hot fires, and does not resprout as vigorously as willow (Viereck and Schandelmeier 1980).

Aspen resprouts from dormant buds on the roots, which are in the mineral soil and protected from fire. The ability of aspen roots to produce suckers is great. In the 1971 Wickersham Dome fire, the density of aspen root suckers was 80,000 per acre the first year following fire (Viereck and Schandelmeier 1980). The May 1983 Rosie Creek fire produced 120,000 aspen root suckers per acre immediately after the fire, and some suckers grew to 5 feet in height within three months (Viereck 1984). Aspen suckers self-thin rapidly, but the survivors rapidly produce browsable side-twigs. For this reason, estimates of available browse based on stem counts are particularly inaccurate for aspen.

3.2.7.2 Seed Regeneration. Factors which control the amount of browse produced by seed regeneration of major browse species include seed availability, suitable seedbed area, and weather. Seed rain decreases with distance from the seed source, so the size and shape of the burn is important. Paper birch disperses for a distance of at least 2 to 3 tree heights, and is often carried further by the wind (Zasada 1971). Aspen and willow have light seeds adapted for long-distance dispersal by wind and may be dispersed for several miles, but seed rain is greater close to the parent plant. Alder seeds are usually dispersed for several hundred feet, but may be carried further by wind or water. Periodicity of maximum seed crops may also affect the level of seed rain. Paper birch produces large seed crops every 2 to 4 years; aspen every 4 to 5 years.

3.2.7.3 Forest Floor Fire Severity. Forest floor fire severity is the most important factor in determining the number of paper birch, aspen, willow and alder seedlings which will establish following fire. Studies of regeneration following logging have demonstrated that most paper birch seedlings establish on mineral soil seedbeds, and that aspen seedlings establish only on mineral soil seedbeds (Zasada 1971, Zasada and Grigal 1978). In areas of the Wickersham Dome fire where the pattern of forest floor fire severity was classified as light to moderate, very few willow seedlings had established four years after fire; and all of these seedlings were on mineral soil exposed by tree tip-ups and in heavily burned microsites at the base of trees. Forest fire severity on the adjacent "ALPS burn" was heavy over large areas, and numerous willow seedlings had established two years after fire. The area of heavily burned microsites and mineral soil exposed by tree tip-ups was much greater than on the adjacent Wickersham Dome fire. Densmore (1976) sowed seeds of two willow species along a 100 m transect in the 1975 "ALPS burn" and observed that seedlings established only in heavily burned microsites.

Zasada et al. (1983) conducted a thorough and detailed study of the relationship between forest floor fire severity and seed regeneration of all the major browse species. Studies were conducted in the Washington Creek Fire Ecology Experimental Area in an area of mature black spruce forest which was burned in a prescribed fire. Seeds of alder, paper birch, black spruce, aspen, balsam poplar, feltleaf willow, bebb willow, and scouler willow were collected locally and sown at time of natural dispersal in plots which contained unburned, lightly burned, moderately burned, and heavily burned forest floor microsites (for detailed descriptions of these forest floor fire severity classes, refer to the section on fire effects on soils). After three years, alder, black spruce, aspen, balsam poplar, and willow seedlings were present only on heavily burned microsites. About 99% of the paper birch seedlings were present on heavily burned microsites, and the remainder were on moderately burned microsites. It is evident that complete burning of the organic layer to mineral soil is required for seed regeneration of browse species.

3.3.7.4 Cover. Although available winter browse is one of the most important factors in determining the carrying capacity of an area for moose, other factors which are more difficult to quantify and less well understood are also important. One such factor is cover. As discussed above, the proximity to cover created by interspersion of numerous unburned stands has been considered to be a major factor in the relatively rapid moose population increase in the 1947 Kenai burn (LeResche et al. 1974). However, the 1969 Swanson River burn is now experiencing a similar increase in moose populations, although it was a large burn which provided relatively little cover for a number of years after the fire (Regelin, 1984 Pers. comm.). Heavy utilization appears to have delayed until the vegetation grew tall enough to provide cover, but the severity of the burn apparently provided many suitable seedbeds for establishment of browse species. The methods used in prescribed burns, as discussed below, generally do not produce large areas without cover, so the focus can remain on browse production.

3.4 PRESCRIBED BURNING

Prescribed burning has been defined by the U.S. Forest Service as the skillful application of fire to fuels in a definite area under exacting conditions such as weather, fuel moisture, and soil moisture, to accomplish certain planned objectives. Prescribed burning has been used in most National Forests and many National Parks throughout the contiguous United States to manage vegetation and wildlife, duplicating the effects once achieved through natural wildfire.

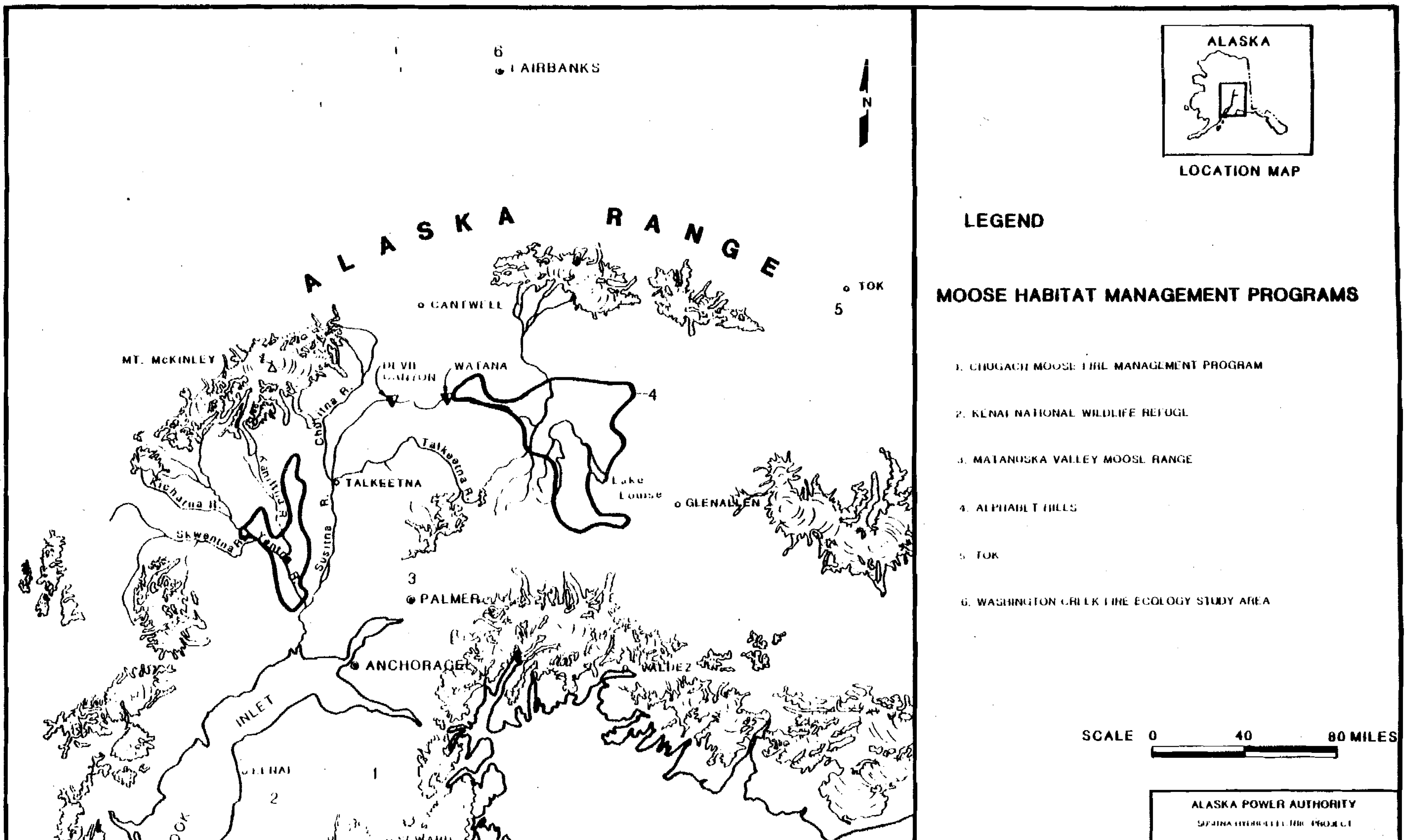
In British Columbia, prescribed burning has been used extensively since the 1970's to increase production of wildlife on remaining habitat, as mitigation for the loss of critical big game winter range to settlement, utility corridors, impoundments, and coal exploration and development (Eastman 1978). Prescribed burning has been emphasized over other techniques because it is regarded as the most economical and ecologically beneficial. Prescribed burning has been conducted to increase carrying capacity for moose, elk, stone sheep, bighorn sheep, mule deer, and white-tailed deer. Most prescribed burns were spring surface fires in nonforested or early successional stages. Burns most applicable to Alaska have been those in northeastern British Columbia, where 100,000 acres have been burned in the alpine spruce ecotone, aspen stands, and seral shrub-grasslands for the benefit of moose, stone sheep, and elk. Prescribed burning in the Yukon Territory for wildlife management is still in the experimental stages (Larson 1980).

In Alaska, prescribed burning has progressed rapidly through experimental stages to an economical and effective program for moose habitat improvement in Chugach National Forest. 1984 is an important year, as prescribed burning for wildlife habitat management is planned for several areas in the State. If these prescribed burns are carried out successfully, prescribed burning will make a giant leap toward becoming an established wildlife management technique for all of the Alaskan taiga. Figure 2 shows the locations of past and planned prescribed burn programs in the state.

Small-scale experimental prescribed burns were conducted in a mature black spruce forest in the Washington Creek Fire Ecology Study Area near Fairbanks in 1976 and 1978. Fire behavior and forest floor fire severity effects on soils and vegetation were studied in detail, and the results have been discussed in section 3.2 (Friedman 1982, Dyrness and Norum 1983, Van Cleve and Dyrness 1983, Zasada et al. 1983).

3.4.1 Chugach Moose-Fire Management Program

The Chugach Moose-Fire Management Program was initiated in 1977 with the preparation of an Environmental Impact Statement (USDA Forest Service 1977). The management objective is to maintain and improve habitat for moose, since, due to lack of wildfire, carrying capacity for moose habitat is decreasing in the Kenai portion of the forest. Of the important browse species, scouler willow, paper birch, aspen, and cottonwood have grown too tall to produce much forage, and barclay willow is decadent and unproductive. Over a 10-year period which began in 1977, a total of approximately 10,000 acres of National Forest land in moose winter range



LOCATION OF BURNS

FIGURE 2

will be treated by prescribed burning, approximately 6% of the forested land on the Kenai portion of the forest (Figure 2). Approximately 3500 acres have been burned from 1978 to 1983, and an additional 6500 acres have been selected for burning from 1984 through 1987. Most of the vegetation in prescribed burn areas is mature stands of white spruce and hardwoods, with an understory of willow, other shrubs, and grass.

The procedure for planning and conducting the prescribed burn program is described as follows (R. Moore. 1984. Pers. comm.). Selection of areas and fire planning for each site was conducted with an interdisciplinary team, starting with examination of aerial photos and continuing with field evaluations. Biologists selected areas likely to produce good moose habitat after a burn. The fire expert then determined whether the selected areas would burn, and if they could be burned safely and economically. Factors considered included types of fuel, continuity of fuel, access, fuel moisture content, location of natural control features, and proximity to facilities. About 50% of the areas selected by the biologists turned out to be unsuitable for burning, which was the reason for the reduction from the 20,000 acres proposed in the Environmental Impact Statement to the present goal of 10,000 acres.

A fire plan was prepared for each burn unit. A discrete area was marked out as the actual proposed area for burning. Then a larger surrounding area with natural fire boundaries was marked out. This is the area within which it would be acceptable for the fire to burn in case it should go beyond the initial selected boundaries. Natural fire boundaries included avalanche tracks, ridgetops (especially those which have tundra and/or rock), other rock areas, rivers, streams, existing trails and roads, and similar features. The planned burn area was usually laid out so that it was bordered as much as possible by fuel continuity breaks, such as a shift from coniferous to deciduous forest, to control the rate and extent of fire spread. The fire plan included weather and fuel moisture criteria for burning; method, pattern, and timing of ignition; and control methods. A profile of the burn was developed which gave the biologists and other resource managers a description of what the results of the burn would be; how much of the area would be lightly burned, heavily burned, or not burned, and what the forest floor fire severity would be.

Weather forecasting to determine when weather and fuel conditions will meet prescription criteria has been a major task of prescribed burning, and daily observations were necessary. On sites not accessible by road, a remote area weather station which transmits information has been utilized. Changes in strategy or tactics have commonly occurred because of changes in the weather.

Fires in the Chugach National Forest were conducted on areas with cut slash prior to 1981. These areas were either commercial timber sales or public firewood cutting areas. Remaining slash (mostly white spruce too small for timber or unwanted by public for firewood) was cut. According to Robert Moore (1984. Pers. comm.) it was important to plan before cutting or crushing exactly how it would be done to optimize burning conditions. Slash lay in one direction, parallel to the slope, with as much fuel continuity as possible. Fire control was more difficult in slashed or crushed areas, but 80 to 100% of the areas burned and some of the forest floor was heavily burned.

Most areas in the Chugach National Forest have been burned with standing undisturbed vegetation. The carrier fuel in the Chugach is grass, and burning has been done very early in the spring. Even large birch trees were killed, because at this time of year above-ground plant portions are very dry as transpiration removes water while the ground is still frozen. These fires have been light fires, with about 50% of the planned area actually burned, and with the forest floor only lightly burned.

Nelson and Weixelman (1983) described preburn vegetation, fuel loading, and fire effects; counted numbers of seedlings and sprouts; and calculated available browse biomass and increase in moose carrying capacity for three slashed and two non-slashed prescribed burns (Table 1). Although the

Table 1

Seedling establishment, increase in browse production as compared to control, and preliminary calculation of increase in potential and actual moose carrying capacity for prescribed burns with and without slashing in the Chugach National Forest.

Unit	Year Burned	Fuel Treatment	Seedling/ ha	Browse Increase (kg/ha)	Available Use (Moose days/ha1/)	X Area (ha)	Available Use (Moose days)	Actual Use (Moose days)2/
Juneau 1	1983	None	4,000	34.4	6.9	500	3450	1522
Juneau 5	1982	None	700	26.0	5.2	535	2782	1196
Quartz Creek 34a	1981	Slashed	23,000	131.0	26.2	147	3851	1656
Quartz Creek 6	1979	Slashed	21,000	169.3	33.8	19	656	282
Quartz Creek 13a	1979	Slashed	9,000	67.0	13.4	58	779	335

1/ Average daily consumption rate of woody browse per adult moose estimated as 5 kg.

2/ Average utilization 43% overwinter.

difference in the age of the burns makes comparisons difficult, it is apparent that in units Quartz 34A and Quartz 6, which were heavily burned, slashed sites in well-drained areas, a large number of seedlings established and grew rapidly to provide a large proportion of the browse biomass within a few years after fire. The moderately burned, slashed Quartz 13A, had fewer seedlings, and the lightly burned, unslashed sites have apparently regenerated primarily from sprouts, although more seedlings may establish in future growing seasons. These plots are being monitored on a yearly basis, providing the best data now available in Alaska on the relationship between prefire vegetation; fire intensity and severity; and source, species composition, and rate of postfire browse production.

The prescribed burning program in the Chugach has shown a steep positive learning curve, correlated with a steep negative curve in cost per acre burned. The learning curve applies not only to the fire experts and biologists in the U.S. Forest Service, but apparently also to other involved governmental agencies and the public. Early burns were (1) small in size, (2) utilized a large amount of labor and heavy equipment for preparation, ignition, and fire control, (3) observed by a large number of interested persons, (4) regarded with skepticism in regard to burnability and benefits, and with anxiety in regard to fire control, and (5) very expensive. In contrast, a 1000 acre unit was burned in 1983 with a helitorch and hand control, and nobody paid much attention. Only 5 people were required in the entire burning procedure, and the cost per acre was less than $3.00. The cost does not include the direct and indirect costs of planning the burn, monitoring weather conditions, and monitoring fire effects and browse production after the burn. Similar learning and cost curves may be experienced in prescribed fire programs in other areas of the state, but will be ameliorated by experience to date, the efforts of the four or five fire behavior and use specialists now present in the state, and the changing attitudes of the agencies and the public.

3.4.2 Planned Prescribed Burning Programs

3.4.2.1 Kenai National Wildlife Refuge. The U.S. Fish and Wildlife Service has planned a prescribed burning program for the Kenai National Wildlife Refuge similar to the Chugach program. (M. Hedrick. 1984. Pers. comm.). This program is included in and would be viable under all of the alternatives presented in the Kenai National Wildlife Refuge Draft Comprehensive Conservation Plan, Environmental Impact Statement, and Wilderness Review (U.S. Fish and Wildlife Service 1983). Approximately 500,000 acres would be included in a prescribed burning program (Figure 2). This area contains the best moose habitat, including 70,000 acres in the 1969 Swanson River burn, 300,000 acres in the 1947 burn, and 150,000 acres that are presently at low carrying capacity for moose and have a potential for conversion to higher carrying capacity.

At any given time in a 20-year cycle, approximately 10% of this area would be maintained in an early seral stage, and a balance would be maintained between early successional habitat and more mature forest. Approximately 5000 acres might be managed each year, primarily with prescribed burning. The primary use of crushing would be in certain areas where burning is not possible, and for preparation of firelines. Objectives of the program also include fuels management. Carefully prescribed burns which are backfired will protect private property and residential development from burning in a wildfire, particularly in areas where fuels are allowed to build up under critical or full fire suppression management. So far, the plan has received virtually no opposition from the public or governmental officials, and seems to have moderate support.

A prescribed burn in April or May 1984 is planned for the 1700 acres crushed this past winter in the Kenai National Wildlife Refuge by the Alaska Department of Fish and Game (see below under crushing for further discussion). Objectives of the prescribed burning include heavy burning of the forest floor to create suitable seedbeds for establishment of browse species, release of nutrients, improvement of the visual quality of the area, removal of living spruce stumps with protruding branches which may inhibit establshiment and growth of seedlings, and destruction of residual spruce seedlings and small saplings (M. Hedrick, 1984. Pers. comm.). The overall goal is to increase the amount of forage plants in this area, since crushing provides only as many browse plants as were present before crushing, and some parts of the crushed area do not have an adequate number of browse plants to provide much browse after crushing. To maximize benefits, the forest floor must be heavily burned (Section 3.3.2) and burning of uncrushed islands may occur, but this is not considered to be a problem. Hedrick also stated that Bob Moore, fire management officer for the Chugach National Forest, had visited the site to develop the fire plan. Moore expressed concern that fuel conditions may not be suitable to achieve the desired level of burn severity, since the crushed material was flattened down to the ground and the heavier logs were crushed.

3.4.2.2 Matanuska Valley. A prescribed burn is also planned for this summer (1984) for an area of the moose range north of Palmer which was chained in 1982, and then opened for public firewood cutting, as part of an Alaska Department of Fish and Game program for increasing the carrying capacity of the area for moose (Section 4.1.2). The agency managing the burn will be the Alaska Division of Forestry, and the objectives are the same as those listed above for the Kenai crushing area. A successful burn in this area would be important, because site conditions are similar to areas being considered for mitigation lands in the lower Susitna Valley, and because the area is relatively close to private land and to proposed and existing residential development (Figure 2).

3.4.2.3 Alphabet Hills. A prescribed burn is planned for the Alphabet Hills area, located between the upper end of the Watana dam impoundment area and the Richardson Highway (Figure 2). The burn will be conducted by the Bureau of Land Management, and was planned in cooperation with the Alaska Department of Fish and Game. The objectives of the burn include maintaining the carrying capacity of the area for moose (R. Toby. 1984. Pers. comm.). The 10,000 acre designated burn area is located within natural fire boundaries. The natural boundaries encompass 50,000 acres, and this area could be allowed to burn if the fire spread beyond the designated burn area.

This area was scheduled for burning in 1982 and 1983; a burn was attempted and failed in 1982. According to Robert Moore and F. Malotte (1984. Pers. comm.), the fire plan has been altered to make a successful burn more likely. Criteria for weather and fuel conditions have been modified, and the designated burn area now includes a larger extent of more continuous conifer fuel types. However, as described in the fire management plan (see above) this area appears to have a low natural fire frequency, and burns extensively only when unusually dry weather conditions occur. Prescribed burning in this area will eventually succeed, but may require patience and long-term planning.

Preburn vegetation and soil data have been collected by the U.S. Forest Service-Institute of Northern Forestry and the University of Alaska-Palmer Agricultural Experimental Station. Because of the relevance of the data for mitigation planning for the Susitna Hydroelectric Project, the Alaska Power Authority has provided logistical support and funding for part of this work.

3.4.2.4 Tok. A summer prescribed burn is also planned near Tok (Figure 2) for a 500 acre area of mixed white and black spruce which presently contains almost no browse (D. Kellyhouse. 1984. Pers. comm.). The objective of the burn is to convert the vegetation type in this area from a closed mature conifer stand to a hardwood stand with more available moose browse. The fire plan has been prepared by Rod Norum, fire management specialist at the Institute of Northern Forestry. The burn site is bordered by existing roads and the Tok River, and one small fireline has been constructed. The area has been partially logged, so sufficient slash is present for a heavy burn which will provide seedbeds for establshiment of browse species. The willow stands along the adjacent Tok River will provide an ample seed source. Preburn vegetation plots have been established by the Institute of Northern Forestry, and postfire succession will be studied.

If the prescribed burns described above are carried out, much more information will be available on the feasibility, benefits, and cost of prescribed burning in the areas proposed as mitigation lands for the Susitna Hydroelectric Project.

4.0 MECHANICAL HABITAT ENHANCEMENT

4.0 MECHANICAL HABITAT ENHANCEMENT

The conversion of less productive mature plant communities to early succesional plant communities, which produce greater quantities of winter moose browse, can be accomplished indirectly or directly by mechanical means. Indirect methods include logging and land clearing for such purposes as agriculture, mining (including gravel), buildings, trails, roads, and transmission lines; while direct methods include crushing and chaining.

4.1 INDIRECT METHODS

4.1.1 Agriculture, Mining and Construction

In Alaska, for most of this century, homesteading laws have provided an impetus for mechanical removal of mature forest and the organic mat, and preparation of an excellent (often fertilized) mineral soil seedbed for establishment of willows and hardwood tree seedlings. The result has frequently been productive winter moose habitat, contributing significantly to moose populations in the Matanuska Valley, the Tanana Valley, and the Kenai Peninsula (LeResche et al. 1974). Wolff and Zasada (1979) measured moose winter browse production on a homestead 30 miles north of Fairbanks 11 years after agriculture was discontinued. Production of willow, birch, alder and aspen browse was 207 kg/ha, a 25-fold increase over the 8 kg/ha in the surrounding undisturbed 80 year old black spruce forest.

Placer mining created dense, productive seral plant communities along many streams and probably increased moose populations in the Kuskokwim Mountains and the Yukon-Tanana Uplands (LeResche et al. 1974). However, revegetation has been so slow on some dredged areas that these areas have not provided habitat for several decades (Holmes 1981). Transmission lines are maintained in early successional plant communities by clearing, and may provide a small but sustained production of winter moose browse. Roadsides and inhabited areas have provided habitat in the same way, but the damage to people and moose from moose-vehicle collisions has usually outweighed any benefits (LeResche et al. 1974).

4.1.2 Logging

To date, logging has not had a major impact on moose habitat in Alaska, but has become a major factor in moose population dynamics elsewhere. In the southern portion of the boreal forest in the United States and Canada, logging is now the principal means by which stands of the older age classes are removed and young browse-producing stands created, and is considered to be the major ecological influence on large ungulates in most of this area (Krefting 1974, Stelfox 1974, Telfer 1970, Telfer 1972, Telfer and Darphine 1981). However, particularly in Canada, there has been concern about the lack of integration of forestry and wildlife management (Telfer and Darphine 1981). A major concern is the size and shape of clearcuts, as studies have indicated that moose utilization of winter forage in clearcuts decreases with distance from cover, and that some areas may not be utilized due to lack of cover (Eastman 1974, Hamilton et al. 1980, Hunt 1976, MacLennan 1975, Stelfox 1974, Thompson and Vukelich 1981).

To date, only a very small area has been logged in Interior Alaska and the Susitna Valley. Until the 1970's most logging was selective cutting of white spruce, with some poplar taken for houselogs in the Susitna Valley. Most recent logging in the Susitna Valley has been state timber sales for selective cuts of white spruce stands and poplar stands for house logs and saw timber, and clearcuts of paper birch for firewood (J. Page. 1984. Pers. comm.). Most recent timber sales have been small, from 20 acres to a maximum of 400-500 acres.

Most timber sale contracts for the past several years have specified that the contractor leave residual spruce under 9 inches diameter at breast height (dbh), and that the areas be scarified to provide mineral soil seedbeds for regeneration. Current forestry management techniques are designed to minimize white spruce regeneration, since it is a non-browse, competitive species. However, the requirement for scarification will increase moose browse production on logged areas. The same scarification technique has been successful in increasing hardwood regeneration from seed in interior forests (Zasada 1980) since willow, aspen, and poplar required mineral soil seedbeds for establishment, and regeneration of paper birch from seed is greatly enhanced where mineral soil seedbeds are available (Zasada 1971).

Quantitative information on moose browse production on logged taiga sites is limited. Wolff and Zasada (1979) measured winter browse production and utilization in a one year old scarified clearcut in an upland mixed stand of paper birch, white spruce, and aspen near Fairbanks, and in 35 and 50 year old unlogged stands of similar composition. The unlogged stands had no available browse; the one-year old clearcut produced 16 kg/ha, of which 81% was utilized by moose.

Available browse and utilization were also measured in an unscarified 4 year old poplar clearcut at the confluence of the Susitna and Chulitna Rivers (Zasada et al. 1981). The uncut balsam poplar forest had no available browse; while 2, 3, and 4 years after clearcutting available browse was 5, 9, and 16 kg/ha respectively, mostly balsam poplar root sprouts. Browse consumed was approximately 2 kg/ha each year, in spite of the increase in available browse. Seedlings and root sprouts were most abundant where the organic mat was disturbed and mineral soil exposed. In April 1984, the site, which had not been scarified, was dominated by grass and alder (J. Page. 1984. Pers. comm.). Regeneration of poplar, birch and willow was limited, and these species produced little browse. However, almost all available browse had been utilized by moose, including highbush cranberry and rose.

Logging, in the form of public firewood cutting areas, is currently being used as a moose habitat enhancement technique in the Matanuska Valley, an area north of Palmer, which is managed by the Alaska Department of Fish and

Game (ADF&G) as moose range (N. Steen. 1984. Pers. comm.). Since moose browse production is a primary goal, classifying this project as an indirect method is somewhat arbitrary.

The area is characterized by glacial morraine ridges covered with mature forest, dominated by paper birch with some spruce. The understory is mostly grass with little or no moose browse. ADF&G, in cooperation with the Alaska Division of Forestry, has an ongoing program to convert mature forest to productive browse habitat. Long-term management plans are to maintain a proportion of this moose range in early successional plant communities. For the past several years, access has been created from Fishhook Road to areas designated for public firewood cutting. The public cut and removed all the birch and aspen; the spruce, which is not popular as firewood, was then cut down by forestry technicians. Resprouting of stumps and scattered shrubs produced some browse, which is heavily utilized. In the summer of 1983, a bulldozer was used to expose mineral soil seedbeds throughout the firewood cutting areas. Since the scarification was done after seedfall, most seedlings were raspberries germinating from buried seed. However, birch seeds were abundant on the plots and many seedlings should establish in 1984.

Since waiting for the public to cut the timber took about 1.5 years, ADF&G experimented with speeding up the process by chaining 150 acres in 1982. The public removed the downed deciduous timber, but a number of residual spruce saplings are still standing. The chaining process produced mineral soil seedbeds where large trees were tipped over. After one growing season, mineral soil areas had numerous raspberry and currant seedlings from buried seed, but few birch seedlings were evident, probably because the growing season was very dry. Responsibility for management of the area and creation of hardwood browse has been turned over to state forestry personnel. The area is scheduled for prescribed burning in June to remove residual spruce, reduce slash, and create more mineral soil seedbeds (J. Page. 1984. Pers. comm.). Fuel continuity, however, may not be sufficient for the hot burn which is desired.

State forestry personnel plan to monitor sprout and seedling regeneration, in both scarified and burned areas.

4.2 DIRECT METHODS

Most mechanical plant control has been conducted in the western United States to improve livestock grazing ranges, by removing plant competition or controlling shrub growth to allow desirable forage plants to become established or to rejuvenate browse species. Considerable effort has been expended to develop effective equipment and techniques (USDA 1982). Methods include cables and chains pulled by bulldozers, bulldozer adaptations to facilitate tree removal, and brush cutters and choppers. Two chain variations have been developed to increase vegetation chopping and uprooting and soil scarification during vegetation removal. These are the chain swivel, which allows the chain to rotate, and the Ely Chain, which has metal bars on the chain links. The methods used for livestock range improvement have also been applied to increase browse for wildlife on dry shrub habitats in the western United States (Scotter 1960, Yoakum et al. 1980).

4.2.1 Kenai National Wildlife Refuge Crushing Program

In Alaska, there has been considerable testing and utilization of mechanical plant control methods to increase moose browse. The majority of this work has been conducted on the Kenai National Wildlife Refuge (KNWR).

4.2.1.1 Early Crushing Programs. Active habitat management in the KNMR began in 1954. Mechanical methods began in 1956 with cutting of pole-sized stands using chain saws. During the 1960's, tractors with chains, rakes, angle blades, Crossville blades, and Fleko rolling choppers were used to knock down larger stems. A total of 2400 ha (5760 acres) were mechanically treated from 1955-1968 (Oldemeyer and Regelin 1980). Crushing was done in small plots 200 to 1000 acres in size, mostly with the rolling choppers (W. Regelin. 1984. Pers. comm.). No quantitative measurements of moose browse production or utilization were made, and most records of location, timing, methods, and observations for these areas have been lost (W. Regelin 1984. Pers. comm.). Limited recorded observations state that the Skilak Lake crushed area "has responded unbelievably well", and verbal recollections describe very high moose use of these areas (Oldemeyer and Regelin 1980, W. Regelin. 1984. Pers. comm.).

<u>4.2.1.2 1966 Crushing Program</u>. Close to the KNWR, at Quartz Creek in the Chugach National Forest, 35 acres of mature spruce birch forest were crushed in November 1966 using Fleco rollers and a D-8 caterpillar (Culbertson 1976). Results were compared to the 1959 Kenai burn, but the author stated that conclusions should be qualified due to problems in data collection, and the value of the data was also limited because the only parameters measured were the number and height of plants. Conclusions of the study were as follows: (1) spruce and birch re-established or were released on a crushed or burned site within 2-5 years, (2) within 5 years, density of birch plants had increased 10 fold on the crushed site, (3) after 10 years, white spruce, grass, and forbs dominated the crushed site, (4) spruce attained greater height in less time on crushed sites than on burned sites, probably because crushing released residual spruce while burning killed them, (5) a calculated projection indicated that spruce on the crushed site would attain the same densities as on the burned site given an equal amount of growing time, but the densities of paper birch would be 4-5 times higher in the burn and (6) birch densities in the crushed area were probably lower because less mineral soil was exposed in the crushed site as compared to the burn, since crushing was done in winter on snow and frozen ground, and the equipment rode over the top of trees and brush.

<u>4.2.1.3 1975-1978 Crushing Program</u>. Three 40-ton LeTourneau tree crushers were purchased and used to crush burned timber on 9720 acres of the 1969 Swanson River burn for erosion control and aesthetic impact amelioration. Effects of this operation on browse regeneration in the 1969 burn are not known. From 1975 to 1978 the tree crushers were used for moose habitat enhancement on 6,720 acres of the 1947 burn. Immediately after crushing was completed in the winter of 1976, high densities of moose were observed

browsing on the downed vegetation, particularly where mature birch and aspen had been knocked down. A dramatic increase in calf survival over that of nearby areas was documented as an important short-term effect of the project (Sigman 1977).

The Willow Lake area responded very rapidly within two years, but in other areas results were less promising (Oldemeyer 1978). Four growing seasons after crushing, browse production had increased in 8 of the 10 plots at Willow Lake, 3 of 7 stands at the South Moose Research Center, and 5 of 15 stands at Mystery Creek (Oldemeyer and Regelin 1980). Overall biomass values for available browse were 5 lb/acre for mature forest, 36 lb/acre for the 1947 burn, and 37 lb/acre for the crushed areas. Low values were due in part to the fact that the study was designed to test hypotheses on the crushing response of a wide variety of vegetation types; including those which were considered unlikely to respond favorably, such as black spruce stands with a low density of hardwoods. In the analyses, stands were grouped by site and were not described and compared by pre-crushing vegetation type. This resulted in an underestimation of the amount and rate of browse production which would occur in a well-designed crushing program where only stands likely to produce browse would be selected for crushing (W. Regelin. 1984. Pers. comm.).

The area was re-evaluated in 1983 and quantitative estimates were made of browse production (W. Regelin. 1984. Pers. comm.). Some of the areas which were not producing browse in 1979 showed a five-fold increase in browse production, as compared to the levels which existed before crushing. The response on these areas has been delayed, and apparently in some vegetation types as long as 8 years were required for a substantial increase in browse production to occur. Also, because the 1947 burn has decreased in production since the crushing program was started, the comparison now between the uncrushed 1947 burn and the crushed areas may be much more favorable than it was in 1979; a twenty-fold difference in browse production is now likely. Browse production has dropped very rapidly in the 1947 burn. In 1971, it was approximately 100 lb/acre; by 1980 it had dropped to 30 lb/acre and is now probably considerably lower. Effects of crushing may last for as long as 50 years (W. Regelin. 1984. Pers. comm.). Al Franzman, biologist with ADF&G at the KNWR, stated that the crushing program was a great success (1984. Pers. comm.). He also commented that judging on the basis of tracks and browsing, moose utilization in crushed areas was very intense, and much higher than in adjacent uncrushed areas.

Oldemeyer and Regelin (1980) suggested the following guidelines for crushing programs for moose habitat enhancement: (1) the area to be crushed should be no smaller than 750 acres to insure adequate dispersal of moose, (2) the width of the crushed area should be no greater than 400 yd to allow adequate seed dispersal for hardwood regeneration, and (3) the browse/spruce ratio for the entire area should be greater than 4:1 prior to crushing. Wayne Regelin stated recently that moose have overutilized 1500 acre crushed areas, and suggested that the minimum size for sites to be managed for moose habitat should be 10,000 acres, with 60% of the area crushed and the remainder left undisturbed to provide cover for moose and a seed source for regeneration (1984. Pers. comm.). Al Franzman stated that time of crushing was important; winter crushing snapped off black spruce trees, while fall crushing often just bent them over (1984. Pers. comm.).

<u>4.2.1.4 Winter 1983-1984 Crushing Program</u>. This past winter (1983-84), crushing for moose habitat enhancement in the KNWR was resumed by the ADF&G, utilizing the LeTourneau tree crushers. The crushing program was managed and conducted by Ted Spraker and Al Johnson of ADF&G. Information on this winter's crushing was obtained from discussions with Al Franzman, Wayne Regelin, and Mike Hedrick, Deputy Manager of the KNWR for the USFWS, and from a field trip to the crushing site with Hedrick on March 22, 1984. Approximately 1700 acres were crushed near the south end of Skilak Road. The cost of the program was approximately $60.00 an acre (M. Hedrick. 1984. Pers. comm.). Most of the crushing was done in a part of the 1947 burn which had grown up into dense young black spruce but which contained overbrowsed willow, birch, and aspen. Most of the browse plants were small and very decadent, or dead. The area was crushed in an irregular shape,

crushing only those areas which had been burned in the 1947 burn. Islands and areas of mature forest which had been burned or which had been lightly burned were left uncrushed to serve as seed source for hardwoods and provide cover for moose. Consideration for visual impact was also a factor; the irregular contours attempt to fit the conformation of the area's natural geographic features, islands of uncrushed vegetation are left, and there is a visual barrier between the crushed area and the road. The entire crushed area was covered with a layer of black spruce branches to a depth of about 6 inches to 1 foot. The main trail used by the tree crushers, and the depressions in the organic mat created by the cleats of treecrushers may provide mineral soil seedbeds.

A prescribed burn is scheduled for the crushed area to create mineral soil seedbeds for hardwood seedlings, release nutrients, improve the visual quality of the area, remove living spruce stumps with protruding branches which may inhibit establishment and growth of seedlings, and destroy residual spruce seedlings and small saplings (Section 3.3.2.1).

4.2.1.5 Planned Crushing. The 1983-1984 winter crushing project on Skilak Road is the first phase of a draft project plan for management of early seral vegetation for moose on the northern Kenai lowlands that has been developed by ADF&G (Holderman 1983). The management goal of this program is to maintain 50,000-60,000 acres of moose winter range, exclusive of the 1969 burn, in early seral vegetation. This will be accomplished by crushing 3000 acres of unproductive range in the 1947 burn per year over a 20-year period of rotation. Four areas have been selected on the basis of winter utilization by moose, potential of existing vegetation to respond favorably to crushing, suitability of the terrain for operating crushers, and land management status within the refuge.

Specific criteria have been developed for planning crushing within each area. Areas with steep terrain, where crushers cannot operate, will not be crushed. Critical wildlife features which may be adversely impacted by crushing, such as nesting and denning sites essential to rare or endangered species of wildlife, will be identified and avoided. A minimum 300 foot buffer of undisturbed vegetation will be maintained around the perimeter of all lakes 12 acres or larger and on either side of major streams. Vegetation buffers of at least 300 feet will also be kept along public roads and trails. As described above for this past winter's crushing, vegetation will be crushed in irregular patterns following natural geographic and vegetation patterns. Vegetation will be classified into crush potential and low crush potential. The crush potential category will include forest stands with a high proportion of any combination of aspen, birch, and willow and a low proportion of spruce. The amount of crush potential vegetation should be 60% of the area to be managed, a criterion met in all four selected habitat areas. Habitat areas will be managed to provide a combination of feeding areas, cover, and edge habitat for moose, and to provide adequate seed sources for hardwood regeneration. Crush units of 750-1500 acres will be considered adequate to avoid overbrowsing, and maximum width of crush units will be 400 yards.

4.2.2 Tok Crushing Program

A crushing program for moose habitat enhancement has been conducted and is being expanded near Tok, in the same area as the planned prescribed burn. Information on this program was obtained from discussions and a field trip to the site with Dave Kellyhouse, ADF&G biologist, in March 1984. In the Tok Valley, moose utilize nonseral treeline habitat until snow becomes too deep. They then move down to riparian habitat along the Tok River, and this habitat may become limiting in severe winters. The crushing program is concentrated on willow stands along the Tok River. These stands are dominated by mature feltleaf willow up to 20 feet tall, and are producing very little browse which is not out of reach of moose. The stands occur in linear areas along old sloughs and point bars. To plan the crushing program, aerial photos were taken of the riparian habitat along the Tok River during the fall, when color changes clearly indicate the presence of different types of vegetation. Stands and scattered plants of willow could be easily seen, and tall stands of feltleaf willow in areas suitable for crushing were selected.

In the winter of 1981-82, 30 acres were crushed along an old slough. Work was done with a JD-450 caterpillar tractor, which was effective but too small to be efficient. Cost per acre was approximately $35.00. The first growing season after crushing, willows resprouted rapidly with a high productivity of large shoots. Deep snow came relatively early in the winter of 1982-83, and moose moved down to the river in November and December. Almost all of the new shoots produced in the crushed area were browsed. During the second growing season, productivity increased, with many large shoots up to 1 m long. This winter, moose did not come down to the Tok River riparian habitat until February, so at time of observation in early March utilization was not as intense as the previous winter. Although qualitative observations were made, no quantitative studies comparing browse production and utilization in crushed and uncrushed areas have been conducted. During the site visit, available and browsed twigs were counted on 4 m^2 plots, one each in uncrushed and crushed areas. The uncrushed plot had 43 available twigs, none browsed. The crushed plot had 290 available twigs, with 30% browsed, suggesting a five-fold increase in available twigs 2 years after crushing. Since the twigs in the crushed area were much larger than those in the uncrushed area, the increase in browse biomass in the crushed area, estimated visually, was probably greater than ten-fold.

Since the crushing was done in narrow strips, following the natural contours of the willow stands, the aerial and ground visual impact was minimal, although the crushed areas stayed greener later in the fall.

The crushing program has been expanded, and an additional 300-400 acres of mature feltleaf willow stands were to be crushed in March. A larger tractor was to be used to snap off willows more easily. In future programs, Kellyhouse is considering crushing more mature stands which contain both balsam poplars and willows. This crushing program appears to be producing a very high quantity and quality of moose browse with minimal effort. Almost all of the browse produced is of feltleaf willow, a species highly preferred by moose.

5.0 RECOMMENDATIONS

Construction of the Susitna Hydroelectric Project will eliminate or alter moose habitat in the Susitna River drainage, resulting in a decrease in carrying capacity. This impact will be mitigated in part by designating lands within or adjacent to the Susitna drainage for which the major land use objective will be increasing the carrying capacity for moose and other species. This report has presented much of the available information relevant to managing habitat to increase and maintain moose carrying capacity. The emphasis has been on the conversion of mature vegetation to early sucessional stages which produce more available moose browse, and on the factors which control the amount of browse produced. This information can be utilized in both the selection of mitigation lands and the development of habitat management plans.

5.0 GENERAL MITIGATION CONCEPT

The general concept being considered for mitigating moose habitat losses resulting from the Susitna Project is to designate specific lands as habitat compensation lands and then to increase and/or maintain moose carrying capacity on these lands through habitat management techniques. The habitat management techniques discussed in this report are relevant to this approach. The entire area being considered for mitigation lands has a low frequency of wildfire, and the lower Susitna drainage has and will have full suppression fire management. Unless the mitigation lands of high current moose carrying capacity include mostly non-seral habitat and/or seral riparian habitat, habitat management techniques will most likely be required to maintain the high carrying capacity of these areas for the life of the project. Similarly, if mitigation lands with low current, but high potential, moose carrying capacity are selected, habitat management techniques will be required to create and maintain high carrying capacity.

5.2 Habitat Management Unit Approach

The areas being considered for mitigation lands for moose are located within the upper Susitna drainage, the area east to the Richardson Highway, and the lower Susitna drainage. Mitigation lands may be one continuous area, but are more likely to be multiple parcels which may be widely separated. Individual parcels and/or portions of large parcels should be regarded as management units, and a plan to achieve the mitigation objectives for the life of each project developed for each unit. The selection of mitigation lands is actually an important part of the habitat management plan, since the size, vegetation type and location of mitigation lands determine the appropriate management techniques; and these parameters are also the interrelated factors which control the carrying capacity of mitigation lands for the life of the project.

5.2.1 Size

The acreage set aside for mitigation lands should be larger than the acreage to be managed for productive winter browse habitat for several reasons, including;

1. Moose benefit from (but probably do not require) a mixture of mature forest which provides cover, and early successional habitat which produces a large amount of available browse. Recommended proportions are 40% mature vegetation and 60% early successional vegetation for a given habitat management unit, and the maximum recommended width for a mechanically cleared area is 400 yards (Oldemeyer and Regelin 1980).

2. Species other than moose may benefit from a mixture of mature and early successional vegetation. For some, the benefits of the edge effect ameliorate the loss of mature forest; for other species, carrying capacity will be reduced by the loss of part of the mature forest, but preserving part of the forest within a

management unit may at least maintain a smaller population of these species.

3. Proximity of mature vegetation insures a good seed source for regeneration of browse species such as paper birch and aspen.

4. Areas with a high potential for regenerating to productive moose browse are often patchy. Since mechanical clearing has a high cost per acre, an irregular clearing pattern which leaves areas of low browse regeneration potential undisturbed may be desirable. Prescribed burning may be conducted in small units to achieve the same effect, or the size of the burn unit may be increased to include many patches.

5. Prescribed burns require more acreage than what will actually be burned. A prescribed burn is conducted within a designated area surrounded by natural fire boundaries thus encompassing a larger region within which burning would be acceptable if the fire escaped the designated area. Also, most prescribed burns in unslashed vegetation do not burn the entire area, but leave inclusions and fingers of unburned vegetation.

6. Consideration for visual impacts may require larger areas. Visual barriers of mature vegetation may need to be maintained, and irregular boundaries which follow natural contours reduce the visual impact of mechanically cleared areas and slashed prescribed burns.

7. The period for increased production of moose browse usually lasts for 20 to 30 years following disturbance, but the mitigation for loss of habitat is desired for a longer period of time. Therefore the same area can be mechanically cleared on a 20-year rotation, but sufficient fuel for repeated prescribed burning may not accumulate on such a short rotation cycle. It may be more

desirable to have habitat management units which are large enough that only 10 to 20% needs to be managed as early successional habitat at any given time, thus allowing for a longer rotation cycle or at least more freedom in determining the best rotation cycle for individual sites within the unit.

In summary, the area of mitigation land should be 2 to 10 times larger than the area of early successional vegetation actually needed at any given time to replace browse lost by construction of the Susitna Hydroelectric Project. The size depends on the habitat management technique; twice as large may be adequate wnere repeated crushing is planned, 10 times as large would be optimal for prescribed burning in remote areas.

Mitigation lands may be geographically scattered in different management units, but to insure adequate dispersal of moose and avoid overbrowsing, the minimum area of early successional habitat at a given time within a management unit should be 750 acres (Oldemeyer and Regelin 1980), and an area greater than 1500 acres is preferred (Regelin personal communication).

5.2.2 Vegetation

Browse production can be increased in all sites wnere vigorous growth of willow, alder, birch, poplar, and/or aspen is possible. However, increases in browse production are achieved more easily and cheaply on sites with a high density of willow or aspen which has become decadent, grown too tall for moose, and/or is overbrowsed. These species will resprout vigorously after a lignt prescribed burn or crushing. If these species are absent or present only in low densities, more difficult and/or expensive techniques may be required to remove the forest floor and produce mineral soil seedbeds.

5.2.3 Habitat Management Techniques

5.2.3.1 Agriculture. Clearing for short-term agriculture has been an important factor in increasing carrying capacity for moose within the area being considered for mitigation lands. Agricultural clearing is continuing on a large scale, and may increase or decrease the overall carrying capacity of the area during the life of the project, but is basically an uncontrolled factor which cannot be integrated into habitat management planning.

5.2.2.2 Logging. In contrast to agriculture, logging can be regarded as a technique to increase carrying capacity for moose if there is coordination between wildlife managers and foresters. Such coordination has resulted in successful moose habitat enhancement programs in the Chugach National Forest and the Matanuska Valley. Browse production depends both on pre-logging vegetation and on post-logging site preparation. Willows, paper birch, and poplar will resprout after logging. Seedlings of these species require mineral soil. Post-logging scarification to produce mineral soil seedbeds is now required on state timber sales in the Susitna Valley. The effectiveness of post-logging scarification in producing browse is currently being evaluated in the Matanuska Valley. Prescribed burning of slash has been very effective in increasing browse on logged areas in Chugach National Forest, and the combination of logging and prescribed burning is recommended as a technique to increase carrying capacity on project mitigation lands. Some potential mitigation lands in the lower Susitna Valley include merchantable timber stands for which state foresters have high hopes of commercial timber sales during the life of the project (J. Page. 1984. Pers. comm.). Current plans include several thousand acres of timber sales in road-accessible areas.

Some of these sales could be included in mitigation plans. However, the timing and extent of sales in more remote areas is uncertain. For any habitat management units in these areas, it may be necessary to develop a mitigation plan which would produce an adequate increase in carrying capacity without logging of merchantable timber, and add habitat management plans for logged areas opportunistically.

5.2.3.3 Transmission lines. Browse production on transmission line corridors tends to increase where mature forst is replaced with saplings, shrubs, and herbs for the life of the project. The amount of browse produced is dependent on a number of factors, including the number of resprouting willows and hardwood trees, extent of mineral soil seedbeds created for establishment of seedlings of browse species, and the frequency of line vegetation maintenance.

5.2.3.4 Chaining and crushing. Crushing or chaining are strongly recommended as techniques to increase carrying capacity in riparian habitat in the lower Susitna Valley. Riparian shrub stands, particularly willow stands, which have grown too tall for moose and/or become decadent can be crushed or chained during the winter. Resprouting the following growing season produces a rapid and large increase in available browse which should last for 10 to 20 years, after which the crushing or chaining may be repeated. Compared to other techniques, this technique in riparian vegetation has the most predictable results and is likely to produce the most browse per unit area.

In addition to the riparian shrub type, chaining and/or crushing is most likely to be effective in other vegetation types where there is a high density of browse plants which are over-browsed or growing out of reach of moose. Such situations include existing burns, abandoned homestead fields, and possibly non-seral habitat. After fire has been used to establish good densities of browse plants on mitigation lands, chaining or crushing 10 to 20 years later may be useful to maintain carrying capacity since fuel loading may not be sufficient to allow reburning. Crushing or chaining may also be used to improve fuel conditions for effective ground fire in non-merchantable timber.

Chaining and/or crushing has several major limitations. First, the technique often does not create suitable seedbeds for browse species and therefore, for predictably good results, is best used only where resprouting will produce adequate browse. Second, chaining or crushing is estimated to be 5 to 10 times more expensive than prescribed burning. Third, additional costs and difficulties of transporting catapillar tractors or crushers to remote areas probably limit this technique to areas within a few miles of existing roads.

5.2.3.5 Prescribed burning. Prescribed burning is the preferred habitat management technique to increase the carrying capacity of most areas for moose. It is the most cost-effective method for most areas and may be the only cost-effective method for remote areas, since properly planned prescribed burns can utilize natural fire boundaries and do not require heavy equipment.

Prescribed burning will not be effective if fuel loading and continuity are not adequate, and this should be considered when mitigation lands are selected where burning is the desirable or only feasible technique to increase carrying capacity. The major drawback of prescribed burning within the area of potential mitigation lands is the need for patience and flexibility in habitat management planning. The weather and fuel conditions for an effective prescribed burn may not occur when desired; for example, ideal conditions in some areas may occur only once in every three years. However, given that the habitat is to be managed over the life of the project, mitigation goals could be effectively achieved.

5.3 POLICY CONSIDERATIONS

Some Alaskan resource managers differ on whether prescribed burning or crushing is the best approach to increase carrying capacity for moose. For example, one agency has a prescribed burn program planned for the Kenai National Wildlife Refuge (Section 3.3.2.1); another has a crushing program planned (Section 4.2.1). Managers generally agree that burning is more desirable but they differ in their assessment of the feasibility of prescribed burning. Feasibility concerns include negative attitudes toward prescribed burning from government sectors and private citizens who are used to suppressing fire, not using it; and the uncertainty and delays which often result from waiting for optimal fuel and weather conditions. These concerns may be reduced if planned prescribed burns are successful.

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APPENDIX A

Appendix A

MOOSE HABITAT ENHANCEMENT

ANNOTATED BIBLIOGRAPHY

Ahlgren, I.F. and C.E. Ahlgren. 1960. Ecological effects of forest fires. Bot. Rev. 26: 483-533.

This paper is a literature review concerning the extent of forest fires and their effects on soil and various forms of life, including lower plants, plant diseases and pests, bacteria, invertebrates, vertebrates and plant succession; grasses, shrubs, and trees. Only tree species characteristic of the northern boreal forest, including jack pine, white pine, red pine, paper birch, aspen, black spruce and white spruce are discussed. The author concludes that each combination of region, climate, forest tree association, soil type, and plant species must be considered individually to determine the effect of fire. In general, fire has been frequent in forests and has been a major factor in determining the direction and rate of plant succession. Fire frequently results in an increase in moss, lichen and liverwort cover, and definite patterns of post-fire plant succession exist. A vigorous regrowth of herbs, grasses, and shrubs occur frequently following fire and the effect of fire on tree reproduction varies with species.

Alaska Cooperative Wildlife Research Unit. 1963. Effects of fire on Alaskan Wildlife. Alaska Coop. Wildl. Res. Unit, Univ. Alaska, College (Fairbanks). Quarterly Progress Report, ACWRU, 14(3):13-29.

This report presents data accumulated over a 10-year period (1951-1961) on the 529,000-ac Porcupine River Burn in north-central Alaska. The objectives of this study were to determine qualitative and quantitative effects of various intensities of burning on populations of wildlife vertebrates; to study vegetative composition in relation to the preceding objectives; and to determine the seral stages and rates of succession following the burn. The quantitative results corraborate qualitative observations: a progressive change in both vegetation and animal populations occurs. The original white spruce vegetation was replaced by a shrub stage with a marked increase in grass cover. In 1961 aspen and willow were the dominant shrubs, indicating a gradual succession into a sub-climax forest. Mammal populations (including moose) slowly increased, apparently in proportion to the increased development of the shrub layer. Little or no soil change occurred since the 1950 burn; the A_0 horizon was still absent from the soil profile.

Asherin, D.A. 1973. Prescribed burning effects on nutrition, production and big game use of key northern Idaho browse species. Ph.D Thesis, Univ. of Idaho, Moscow. 96pp.

The objectives of this study were to determine the effects of prescribed burning on browse yield and the nutritive value of key browse species, and to compare big game use of burned and non-burned sites in three spring burns in southern and central Idaho. Nutrient analysis of mountain maple, serviceberry, redstem ceanothus and willow indicate species specific responses to spring burning. Overall, there was a temporary increase in browse quality on burned compared to nonburned sites as determined by chemical analysis of crude protien, fat, crude fiber, ash, nitrogen-free extract, calcium, phosphorus and moisture. Total production of the four browse species in the burn far exceeded control plant production by the end of the study. Pellet group and utilization counts substantiate higher summer and winter use of burned compared to nonburned sites by big game (white-tailed deer and elk). Burning scattered areas of a range appears more beneficial than burning one area of the same acreage, as nonburned land seems to receive a regrowth stimulus from adjacent burns.

Bailey, T.N. 1978. Moose populations on the Kenai National Moose Range. Proc. N. Amer. Moose Conf. Workshop 14: 1-20.

This paper reviews and summarizes information on moose numbers, population composition, productivity, mortality, physiological condition, and migratory behavior on the Kenai National Moose Range (KNMR). Habitat manipulation for moose includes logging, prescribed burning, and mechanical crushing. Logging, as a management tool, has been difficult to implement. Prescribed burning has been unsuccessful, although the technique appears to have considerable potential. Mechanical tree crushing by 40-ton Le Tourneau tree crushers has been the most effective habitat management tool to date on the KNMR. Harvest control, in addition to these habitat manipulation techniques, is also used to manage moose. A vigorous range rehabilitation program may be complicated by increased energy costs, establishment of wilderness areas, potential public opposition to vegetation manipulation programs, and an increasing demand to consider other species influenced by habitat management.

Ballard, W.B., K.P. Taylor, S.H. Eide, T.H. Spraker, and A. Franzmann. 1980. Upper Susitna valley moose population study. Alaska Dept. Fish and Game Fed. Aid in Wildl. Restoration Final Rep. Proj. W-17-9, W-17-10 and W-17-11, Job 1.20R. 102pp.

The purpose of this study was to determine population identities and seasonal movement patterns of moose in the Upper Susitna River Valley, and to determine potential impacts of the Susitna River Hydroelectric power development on moose. Results showed that some cows traveled to areas outside their normal winter and summer ranges for breeding. Most, however, remained within or near their wintering areas. Some cows also had movements that did not fit typical migration patterns exhibited by others. Approximately 94% and 82%, respectively, of the mortality to collared and uncollared calves occurred by July 19 of each year. During the 3 years of this study, adult cow mortality averaged 6%. Four discrete populations of moose were identified: Clearwater Mountains-Western Alphabet Hills; Upper Susitna River; Upper Nenana-Brushkana; Susitna River. Moose commonly cross the Susitna River in winter. It is possible that the Devil Mt. area is only used by moose during relatively severe winters.

Bangs, E.E. and T.N. Bailey. 1980. Interrelationships of weather, fire and moose on the Kenai National Moose Range, Alaska. Proc. N. Amer. Moose Conf. Workshop 16: 255-275.

This study examines the effects of weather on moose, especially the effects of severe winters on moose population density, reproductive rates and food availability. This paper also reviews the history of moose populations and the influence of fire on moose population dynamics within 688,000 ha of the Kenai National Moose Range in south-central Alaska, much of which has been repeatedly burned since the 1900's. Spring calf counts, composition counts and winter density and distribution counts were conducted with aerial surveys from 1949 through 1979. Several successive years of severe winter weather slowed population increases and accelerated the rate of decline, while mild winter weather accelerated population increases or dampened their decline. Weather appears to modify population structure, although habitat quality probably determines population density and reproductive rates. Data indicate a positive response in moose productivity and density to disturbance by wildfire.

Barney, R.J. 1971. Wildfire in Alaska - some historical and projected effects and aspects. Pages 51-59 in C.W. Slaughter, R.J. Barney and G.N. Hansen, eds. Fire in the northern environment - Proceedings of a symposium. April 1971, Fairbanks, Alaska. USDA For. Serv., Pacific N.W. For. and Range Exp. Stn., Portland, Oregon.

This paper discusses some of the historical aspects of wildfire in interior Alaska, focusing from 1940 to the present, and includes discussion of known impacts of fire and speculated and projected impacts of wildfire. Effects of fire surpression efforts are discussed in terms of economy, ecology and management objectives. Annually, approximately 1 million acres were burned from 1940 - 1969. In 1969, fire losses were in excess of $16 million, with "business" lost due to smoke created by fires. Although fire should be excluded from choice white spruce sites because of its commercial value, fire can also increase site quality and production by destroying the insulation moss and organic layer. Current technology exists to control wildfires, to exclude wildfire in Alaska or to allow fires to burn.

Bendell, J.F. 1974. Effects of fire on birds and mammals. Pages 73-133 in T.T. Kozlowsky and C.E. Ahlgren, eds. Fire and ecosystems, Academic Press, New York.

Numerous species of birds and mammals are discussed in relation to topics such as reactions to fire, long-term effects of fire, species change after fire, change in density and trend after fire, wildlife effects of fire, speciation in flammable habitats, and adaptations of birds and mammals to flammable habitat. Moose are discussed in relation to a case history comparison of fire and moose abundance on the Kenai Peninsula. It was concluded that moose abundance was not related to forest fires in any simple fashion. Some of the causes of variation in relationships between fire and moose may have been due to changes in local distribution of moose, the variable response of vegetation to burning, and intrinsic properties of the stock that influenced population growth.

Buckley, J.L. 1958. Effects of fire on Alaskan wildlife. Proc. Soc. Amer. Foresters 58: 123-126.

This short paper discusses the effects of fire, both direct and indirect on hydrology, vegetation (including plant succession following fire), and wildlife in Alaska. Fire causes melting of permafrost which allows surface water to percolate into the ground, lowering the water table. Although this water recession reduces available habitat, open areas left behind by fire attract waterfowl. Fire produces thaw ponds which become colonized by peat-producing vegetation, leading to the formation of bogs. Fire produces favorable habitat for most animals, especially moose, and reduces habitat necessary for caribou. Wildlife are affected by changing hydrologic relations and vegetative composition resulting from fire.

Coady, J.W. 1973. Evaluation of moose range and habitat utilization in interior Alaska. Pages 1-25 in J.W. Coady, Interior moose studies, Vol. 1. Alaska Dept. Fish and Game Fed. Aid in Wildl. Restoration Prog. Rep. Proj. W-17-4 and W-17-5.

The purpose of this study was to make a vegetation map and characterize the botanical composition and soil conditions of major vegetation types in the Tanana Flats, evaluate browse preference by both moose and hares, and to analyze moose rumen for various nutritional data. Results show that in the Tanana Flats moose commonly feed in herbaceous bogs from spring thaw to late summer, however, greatest use appeared to be in early to midsummer. During late summer moose may feed more frequently on herbaceous and woody browse in heath bog and tall shrub communities. The Tanana Flats do not appear to be good winter moose range, and observations of large scale emigration confirms this. However, fires have created some suitable winter habitat especially where the permafrost has been reduced, which has resulted in an increase in palatable species (willow, poplar, and paper birch). Moose rumen data show that spruce does not constitute a major portion of its diet, and that spruce is not used as an emergency food.

Coady, J.W. 1974. Evaluation of moose range and habitat utilization in interior Alaska. Pages 1-12 in J.W. Coady, Interior moose studies, Vol. II. Alaska Dept. Fish and Game Fed. Aid in Wildl. Restoration Prog. Rep. Proj. W-17-6.

This report is part of a longer study to identify major vegetation types in Tanana Flats and adjacent portions of Game Management Unit 20 B to evaluate browse use and preference, and to monitor seasonal distribution and composition of moose populations. Eight aerial surveys and a radio-collar survey were conducted over a 260 sq. km. count area from July 1, 1973 through June 30, 1974. Aerial surveys over the Tanana Flats area showed a gradual decline in total moose from 196 in June to 51 in January and an increse by 106 in May, suggesting an emigration from the flats between mid-summer and late fall and a return between late winter and early summer. Radio collar studies indicated greater usage by coniferous and deciduous habitats throughout the year than aerial surveys indicated. It is suggested that bulls prefer less dense low shrub and tall shrub areas than do either lone cows or cows with calves.

Cowan, I.McT., W.S. Hoar and J. Hatter. 1950. The effect of forest succession upon the quantity and upon the nutritive values of woody plants used as food by moose. Can. J. Res. Sec.(D) 28:249-271.

This study investigated 3 stages of forest succession growing under nearly identical conditions of soil and climate. The quantity of available moose browse, and carotene and ascorbic acid content of 17 palatable and unpalatable trees and shrubs was determined. Values for moisture, protein, carbohydrate, ether extractives, and total mineral content were also determined. These analyses were conducted primarily during winter. The study site was located adjacent to the airport at Quensel, British Columbia. The results of this study confirm earlier reports that nutrients available from plants are at their lowest point during winter (plant dormancy). Thus, the group of trees and shrubs available as moose browse in the study area were uniformly of low nutritive quality. Exceptions included high protein values of Sheperdia spp. twigs and Populus tremuloides bark; high ether-etractive values of Abies spp., Populus trichocarpa, and bark of P. tremuloides; and a high carbohydrate rating of Usnea spp. Nutritive quality and palatability are not necessarily related. It was concluded that the most desirable winter range for moose will be one well diversified as to species composition and age of stands but predominantly of new growth following deforestation. The authors suggest that moose are adapted to living upon lower quality nutrients than are domestic ungulates.

Culbertson, J.L. 1976. Mile 43 moose range crushing 10 year analysis and comparison to the effects of the 1959 Kenai Lake fire. Progress Rep. Chugach National Forest. 8pp.

This paper is a 10 year progress report discussing the results of mechanically crushing a spruce and hardwood forest to induce sprouting, seeding, and new growth of browse plants. This project occurred about 2 miles NE of the Sunrise Inn west of Quartz Creek. The project was successful; the cost-benefit ratio was favorable. After the forest canopy was removed, spruce competition for light was reduced and birch increased on the site by a factor of 1/3 in 2 years, and by a factor of 10 by 5 years. Birch establishment on south facing slopes was 4-5 times more dense than on north slopes. Spruce and grass-forb growth appeared to have become dominant within 10 years. Problems occurred with breakdowns of the equipment, and it was difficult operating equipment on rolling and steep terrain.

Cushwa, C.T. and J. Coady. 1976. Food habits of moose (Alces alces) in Alaska: A preliminary study using rumen contents analysis. Can. Field-Nat. 90:11-16.

This study attempted to quantify moose food consumption over a one-year period of four seasons: winter (Nov-Mar), spring (Apr-May), summer (Jun-Aug), and fall (Sep-Oct). Moose rumen samples were collected from the Fairbanks and Kenai Peninsula areas. The greatest number of samples for Fairbanks and Kenai were obtained during the winter. Winter habitats of moose near Fairbanks consist primarily of shrub and deciduous tree communities. Winter habitats of moose on the Kenai Peninsula consist primarily of shrub and deciduous tree communities. In the winter, moose in the Fairbanks area most frequently ate willow, birch, and aspen in decreasing order; spruce was not consumed near Fairbanks. On the Kenai, birch , aspen, and willow are most frequently eaten in the winter. This difference is attributed primarily to food availability, not to differences in preference. The overall results for all four seasons indicate both seasonal and regional variation in moose-habitat interactions. However, the small sample size obtained within season and location precluded a formal statistical analysis. Nevertheless, these preliminary data are in basic agreement with similar rumen content studies previously conducted in the Susitna region.

Davis, J.L., and A.W. Franzmann. 1979. Fire-moose-caribou interrelationships: A review and assessment. Proc. N Amer. Moose Conf. Workshop 15: 1-18.

Extirpation of caribou from the Kenai Peninsula in the early 1900's and the subsequent increase in moose numbers is frequently cited as a classic example of a faunal change which resulted from fire-initiated plant succession. This paper reviews the validity of such cause and effect observations, and concludes that factors other than fire were most likely responsible for past declines in caribou; also, creating or enhancing moose habitat by burning is not necessarily detrimental to caribou. Hunting mortality was suggested as the cause of caribou decline from the Kenai Peninsula. Evidence shows that moose have been present on the Kenai since at least the earliest recorded times, despite claims that moose did not appear here until the 1870's.

DeWitt, J.B. and J.V. Derby. 1955. Changes in the nutritive value of browse plants following forest fires. J. Wildl. Manage 19: 65-70

Studies were conducted to determine chemical composition and nutritive value of four species of plants used as deer browse, and to determine the effects of low- and high-intensity fires upon chemical composition of the browse. These studies were conducted at the Patuxent Research Refuge, Maryland and consisted of comparing burned and nonburned (control) plots. Results showed that protein contents of roundleaf greenbriers, red maple and flowering dogwood foliage were significantly higher in the season following a low-intensity fire, but no effects could be determined in the second year. The high-intensity fire produced significant increases in protein contents of roundleaf greenbrier, red maple, flowering dogwood, and white oak; effects were still apparent two years later.

Eastman, D.S. 1974. Habitat use by moose of burns, cutovers and forests in northcentral British Columbia. Proc. N. Amer. Moose Conf. Workshop. 10: 238-256.

Overwinter use of burns, logged and unlogged forests by moose was studied in eight study sites in the sub-boreal spruce zone within 50 miles of Prince George, British Columbia from 1971 - 1973 for dry, modal and wet environments. Habitat use was revealed by post-winter pellet group surveys and tagged twig transects, with the averge moose density 1/sq. mile. Recent clearcuts were least used, with developing vegetation providing little browse when snow depths were greater than 3 feet. Partially logged stands 11-20 years old were the preferred winter habitat type at most sites, providing both browse and shelter. The two burns showed greater winter pellet group densities than those in forested and clearcut areas and equaled those in most partial cutovers. In all habitat types, winter use was greatest at the ecotones. Conflicting data of hign pellet group densities and low rates of browsing indicate that forests provide for non-feeding activities, sucn as shelter in late winter, with burns and cutovers important feeding areas in early winter. This conflicting data demonstrates the need to assess habitat use by more than one method.

Eastwood, D.S. 1977. Habitat selection and use in winter by moose in sub-boreal forests of northcentral British Columbia, and relationships to forestry. Ph.D. Thesis, University of British Columbia, Vancouver.

The paper reviewed herein was the Abstract from the thesis. This study of winter habitat selection was conducted in an 11,000 Km^2 area of northcentral British Columbia. Wintering moose used partial cutovers and burns more than coniferous forests; deciduous forests and recent clearcuts were used least. Winter use increased from near zero after a recent disturbance, to a peak sometime between 10 and 25 years later; use then declined to low levels between 25 and 90 years, and seemed to stabilize in the mature forest stage at slightly higher levels. Moose had catholic diets but ate primarily deciduous browse most of the year. Selection of bedding sites by moose varied with snow depth; in deeper snows moose bedded closer to larger trees in the denser canopies of forest stands. Snow acts to trigger migration. Moose management recommendations are discussed in the thesis but are not covered in the Abstract.

Euler, D. The economic impact of prescribed burning on moose hunting. J. Environ. Manage. 3: 1-5.

This paper provides a preliminary estimate of the monetary benefits which can be realized as a result of the favorable habitat created for moose due to pescribed burning. Three studies in eastern North America (Hansen, Krefting and Kurmis, 1973; Spencer and Hakala, 1964; Williamson, 1972) where moose populations have increased following fire are used to estimate benefits provided by moose through hunting. An assumption of 20% harvest of standing crop is used. Estimated revenues ranged from $0.17 to $4.31 per acre per year for 32 years, with 0.01 to 0.04 days per acre per year for 32 years provided in days of recreation provided to the hunter. Costs of burning vary form $0.25 per acre to several hundred dollars per acre. It is concluded that if the cost of burning exceeds the benefits, other values will have to justify burning.

Foote, J.M. 1983. Classification, description and dynamics of plant communities after fire in the taiga of interior Alaska. USDA For. Serv., Pacific N.W. and Range Exp. Stn., Portland, Oregon. Res. Pap. PNW-307. 108pp.

This study describes plant communities in the taiga of Alaska, and orders these community types into successional patterns for white spruce and black spruce sites. 130 forest stands ranging in age from 1 month postfire to 200 years, located in interior Alaska south of the Yukon river were sampled. Succession was divided into six developmental stages; newly burned, moss-herb, tall shrub-sapling, dense tree, hardwood (or hardwood-spruce) and spruce. Patterns of change in the two successional series are described and compared. In addition, 12 mature forest community types were identified and described. While white spruce sites are characterized by well drained soils and a lack of permafrost, black spruce sites have poorly drained soils and an abundance of permafrost. Fire is more common on black spruce sites.

Franzmann, A.W., P.D. Arneson, R.E. LeResche, and J.L. Davis. 1974. Development and testing of new techniques for moose management. Alaska Dept. Fish and Game Final Rep. Fed. Aid in Wildl. Restoration Proj. W-17-2 to W-17-6, Job 1.6 R. 54pp.

This paper provides a detailed summary of numerous types of moose management techniques such as drugs, marking devices, telemetric tracking, aerial-count census evaluation studies, and pellet counts. However, no specific information regarding moose habitat enhancement is given.

Grenier P., B. Bernier, and J. Bedard. 1977. The effect of forest fertilization on crude protein content, growth, and use by moose (Alces alces) of paper birch (Betula papyrifera) in Laurentides Park, Quebec. Proc. N. Amer. Moose Conf. Workshop 13: 258-278.

Experiments were conducted to determine the effect of fertilization on the crude protein content, growth, and use by moose of paper birch. Although an increase in the protein content of paper birch was noted following application of ammonium nitrate and urea, the results did not show an increase in vegetative growth or in browsing by moose. The lack of a preference by moose for foraging on fertilized vegetation versus non-fertilized vegetation does not agree with results reported by others. The results may have been a consequence of the poor influence of the fertilizers on the quality and quantity of forage produced. This may be due to the N being leacned by a 2.7 cm rain falling shortly after treatment, or because paper birch did not need additional N in this environment.

Hamilton, G.D. and P.D. Drysdale. 1975. Effects of cutover width on browse utilization by moose. Proc. N. Amer. Moose Conf. Workshop 11: 1-12.

Two clear-cuts in the Dog River area of Thunder Bay District were studied to examine the relationship between browse utilization by moose and distance from cover. Moose density, hunting pressure, browse preference and abundance, snow depth and distance from cover were assumed to influence browse utilization, with all factors held constant except distance from cover. Moose densities in two cutovers of 200 and 75 areas respectively were approximately 0.8 moose/sq. mile, with utilization determined by the presence of browse stems. Distance from cover exceeded 200 meters in the larger cut-over and were less than 100 meters in the smaller cut. In the clear cut portion of the larger cut-over, utilization declined significantly with increased distance from cover, especially beyond 40 meters, and dropped to zero at 100 meters. There were no significant changes in use with respect to distance from cover in the smaller cut-over. Cut-overs less than 200 meters in width are too small to alter moose usage patterns, with the maximum distance from cover possibly limiting browse utilization.

Holdermann, D.A. 1983. Draft project plan: Management of early seral vegetation for moose on the northern Kenai lowlands. Alaska Dept. Fish and Game, Division of Game, Juneau, Alaska. 16pp.

This paper discusses a draft plan to initiate moose habitat enhancement through the use of three 40-ton LeTourneau tree crushers on the Kenai National Wildlife Refuge. The goal of the crushing program is to maintain 50,000-60,000 acres of moose winter range, inclusive of the 1969 burn, in early seral vegetation. This is to be accomplished by crushing 3,000 acres/yr of unproductive range at 4 different locations in the 1947 burn over a 20 year period of rotation. A 20 year rotation was chosen because experience suggests that maximum browse production occurs 15-20 years after crushing, and that production and availability begin to significantly decline after 25 years. Sixty percent of the surface area in each habitat area will be designated for crushing, and the remaining 40% of the area will be allowed to follow a course of natural succession. Habitat areas will be managed to provide a beneficial combination of feeding areas, cover, and edge habitat for moose. Irregular, convoluted patterns will be crushed; square, rectangular, and repeating patterns will be avoided.

Johnson, A. 1975. History of fires on the Kenai moose range. Canadian-Alaska fire seminar, Oct. 7, 1975, Unpubl. Rep. 4pp.

This paper is based on a seminar presentation. The 1947 Burn on the Kenai Range is regarded as the biggest factor in increasing moose to their highest levels in historic time. About 310,000 acres burned in all types of the interior forest. Vegetational changes relevant to moose include: white and black spruce are common and began to regenerate immediately after the burn; there was heavy revegetation of aspen from stump sprouts and later from seedlings; birch covered nearly 1/5 of the burn area, mostly from reseeding; willow reproduction varied in intensity of growth throughout the burn, and showed evidence of heavy browsing. Vegetation following a burn is determined by the previous stand but tends to favor hardwoods; a mixed stand of hardwoods is more favorable for moose forage than a pure stand; after perhaps 20 years the stand will have a tendency to go to spruce; under suitable conditions the most favorable period for moose forage occurs from 5 to 20 years post fire. Besides fire, moose habitat enhancement is being tested by timber sales to remove old growth trees and by mechanical crushers.

Joyal, R. 1976. Winter foods of moose in La Verendyre Park, Quebec: An evaluation of two browse survey methods. Can. J. Zool. 54: 1765-1770.

Winter foods of moose inhabiting mixed forest areas in La Verendyre Park, Quebec were determined by estimating browse units, which identified key species in the diet, and by twig counts, which gave the proportion of each species browsed by weight. The two methods are compared. A total of 21 species offered available food, but only 12 were browsed. Mountain maple, the most important species in the diet, was eaten proportionally to its availability. Moose preferred willows and trembling aspen, which showed the highest availability: utilization ratio. Succulence and palatability control preference, with the color of needles influencing palatability. In conclusion, browse estimations were accurate enough to find and rank key species reliably as to availability and use.

Kelleyhouse, D.G. 1980. Fire/wildlife relationships in Alaska. Pages 1-35 in M. Hoefs and D. Russell, eds. Wildlife and wild fire; proc. of a workshop. Nov. 27-28, 1979. Yukon Wildlife Branch, Whitehorse, Yukon, Canada.

This report attempts to summarize and compare existing knowledge concerning the effects of fire on wildlife. The effectiveness with which man is controlling fires in interior Alaska has resulted in fewer fires which is seen as a threat to greater wildlife diversity because of a lack of habitat diversity. Wildfire effects on populations of herbivores (small rodents, hares, birds, waterfowl, muskrat, beaver, moose, and caribou) and carnivores are discussed. The relationship between numbers of moose and increased forage production is noted. The use of burns is dependent on the amount of cover available near and within burns. The effects of fire on moose also depend on their historical use patterns of traditional summer and winter areas, and migratory corridors. The effects of fire upon caribou are controversial, and the assumption that the correlation between fires and caribou population declines is a cause and effect relationship is inaccurate. The author concludes with a discussion predicting wildlife response to fire and evaluating a fire for probable effects upon wildlife.

Kelsall, J.P., E.S. Telfer and T.O. Wright. 1977. The effects of fire on the ecology of the boreal forest with particular reference to the Canadian north: A review and selected bibliography. Can. Wildl. Serv. Occas. Pap. 32. 58pp.

This review analyzes literature relevant to the effects of fire in the boreal forest, and on its related wildlife resources, with particular reference to the Canadian north. Alaska publications were also reviewed. It was concluded that fire is the most important factor influencing the ecology of the northern boreal forest; that fire and the resulting forest mosaic are natural features of long standing; and that the boreal forest can be characterized as a fire-dependent ecosystem. The flora and fauna of the forest have evolved in response and adaptation to the frequency, extent, and intensity of fire. With some possible exceptions, a mosaic of varied successional stages in the boreal forest provides a richer habitat for a more varied and abundant fauna than does the monotypic spruce forest characteristic of unburned areas. Specific attention is given to the effects of fire on soil, hydrology, vegetation, and wildlife. The wildlife review includes a 3-page discussion on moose in the Canadian north and Alaska, covering moose distribution as it relates to successional stage, population fluctuation, and moose habitat and forest succession. The effects of fire on vegetation, types of forest burned, forest succession, and the mosaic effect is further discussed in the vegetation review. The authors conclude that the optimum successional stages for moose occur between 11 and 30 years after burning.

Kershaw, K.A. and W.R. Rouse. 1976. The impact of fire on forest and tundra ecosystems Final Report 1975. Arctic Land Use Res. Program, Dept. Indian Affairs and North. Develop. ALUR Rep. 75-62-63. 54pp.

This study examined the chronological development of vegetation, soil properties, and microclimate following fire in the southern Northwest Territories, east of Great Slave lake. Open spruce-lichen woodland is the dominant vegetation type. The study was restricted to black spruce-lichen woodland dominated drumlins due to their relatively constant size, shape and orientation. The study area is within the winter foraging range for large numbers of caribou. It is concluded that in the absence of forest fires the spruce-lichen forest would develop into a spruce-moss woodland. Burning is accompanied by a hotter soil and a hotter, drier atmosphere for a period of 50 years. If large areas are burned, this will exert a strong desiccating influence on non-burned areas downwind, which will greatly increase evaporation from ponds and small lakes.

Komarek, E.V. 1969. Fire and animal behavior. Proc. Annu. Tall Timbers Fire Ecol. Conf. 9: 161-209.

This article is a general discussion of the reaction and behavior of animals to fire, smoke and the resulting burned ground. The author makes the following observations: in the wild, animals have no innate fear of fire and in most cases effectively avoid any injury from fires; many animals seek out recently burned areas since fire ash is high in calcium, potash, phosphate and trace minerals; regrowth in burns are sought out by wildlife because of higher protein and nutrients in the re-establishing vegetation.

Krefting, L.W. 1974. Moose distribution and habitat selection in north-central North America. Naturaliste can. 101: 81-100

This paper reviews the available information pertaining to moose distribution and habitat selection in Manitoba, Ontario and the Lake States, with a discussion of present and historic status of moose, and factors affecting their range and habitat selection. Moose populations are constantly changing because of forest succession, with the highest moose densities associated with subclimax forests. Factors promoting second-growth forests include fire, defoliation of mature forests by the spruce budworm, and logging activities. Factors that decrease the availability of browse include overbrowsing by moose, fire surpression activities, and forest succession; with climax species shading out browse species. Summer and winter home ranges for moose require different kinds of habitats. In winter, movements and habitat selection are influenced by the depth and quality of snow. As winter advances, moose gradually move from open stands to more dense cover. The author concludes that there is a lack of information on moose distribution and habitat, with further documentation needed concerning burns, logging, and their effect on moose.

Larson, D. 1979. General comments on prescribed burning and moose management in the Yukon. Pages 175-176 in M. Hoefs and D. Russell, eds. Wildlife and wildfire; Proc. of a workshop. Nov. 27-28, 1979. Yukon Wildlife Branch, Whitehorse, Yukon, Canada.

This brief paper discusses how moose should be managed in the Yukon. While the author acknowledges the documented benefits of prescribed burning (as in Alaska), he feels that not enough is known of the ecological relationships between moose and its habitat (as in the Yukon) to warrant this method of treatment at the present time. A recommended course of action would include: consideration of prescribed burning as part of an overall resource management plan for all species, resources, and various user groups; forgo active burning at the present time because of a lack of baseline data and financial constraints; try to curb present fire suppression policies; use prescribed burning on specific populations with specific objectives only after baseline data are collected.

Leopold, A.S. and F.F. Darling. 1953. Effects of land use on moose and caribou in Alaska. Trans. N. Amer. Wildl. Conf. 18: 553-562.

This article discusses the ecological requirements and the factors that influence the population dynamics of moose and caribou. Past and present game management practices in Alaska are described, and recommendations to achieve "optimum" sized herds are included. While moose inhabit sub-climax successional stages of vegetation, caribou range consists of climax forests. Human influences, most importantly fire, have caused significant increases in moose populations, while these same influences coupled with wolf predation and the introduction of reindeer in Alaska have caused a decrease in caribou. Predator control methods have helped moose populations. It is suggested that management programs provide for both moose and caribou by conducting experimental burns of designated moose ranges while excluding fire from the remaining caribou ranges.

LeResche, R.E. and J.L. Davis. 1973. Importance of nonbrowse foods to moose on the Kenai Peninsula, Alaska. J. Wildl. Manage. 37:279-287.

This paper describes the observations made on food intake of three tame moose at the Kenai Moose Research Center to quantify the observed "catholic" food tastes of moose for nonbrowse foods. It had previously been observed that they consume, especially in spring and summer, forbs, grasses, mushrooms, lichens, and practically all other floral components of their environment. Bite sizes were classified in four categories for summer and winter observations. Forty-six percent of 28,423 bites taken by the moose in July and August consisted of birch leaves; 5% were of willow species; 4% were leaves and twigs of dwarf birch. Thus, during summer, 65% of all bites taken were parts of woody browse. The remaining forage consisted of forbs (25%), grasses (3%), sedges (4%), and aquatics (3%). Alder, aspen, lowbush cranberry, lichens, and mushrooms (mostly Boletus spp.) were taken in trace amounts. A total of 50 nonbrowse species were recorded as eaten by moose. In winter, moose on normal range consumed 72% birch stems, 21% lowbursh cranberry, and 6% willow and alder. On depleted range, moose ate only 23% browse; the remainder consisted of lichens (mostly Peltigera spp.) and cranberry. The availablility of understory forage species during part of the winter is probably an important factor in supporting the very high moose densities found on the Kenai Peninsula.

LeResche, R.E., R.H. Bishop and J.W. Coady. 1974. Distribution and habitats of moose in Alaska. Alaska Dept. Fish and Game. Fairbanks, Alaska.

This review decribes past and present distribution of moose in southeast, southcentral and nothern Alaska, including the upper and lower Susitna Valleys, and also discusses the major habitats important to moose. Four major climax community habitat "types" are discussed in general terms, including upland willow or birch dominated communities, lowland bog areas, and seral communities, including those created by fire and by glacial or fluvial action. Fire-created habitats support the greatest moose population explosions and among the greatest densities of moose in the state, but are the least permanent of the habitats discussed. Species composition, size of burn, rate of growth, diversity of communities and ecotone created determine the impact of a burn on moose populations. Moose increased steadily through the 1950's and early 1960's in response to recurrent wildfires, and in southcentral and Interior Alaska have since stabilized or declined due to a series of severe winters, complicated by deteriorating range conditions, changing hunting pressures and predation.

LeResche, R.E., R.H. Bishop and J.W. Coady. 1974. Distribution and habitats of moose in Alaska. Naturalist can. 101: 143-178.

This paper is the slightly condensed version of the above referenced LeResche, Bishop and Coady paper put out by the Alaska Dept. Fish and Game, 1974.

Lotspeich, F.B., E.W. Mueller and P.J. Frey. 1970. Effects of large scale forest fires on water quality in interior Alaska. USDI, Federal Water Pollution Control Administration, Alaska Water Laboratory, College (Fairbanks), Alaska. 115pp.

The purpose of this study was to develop information on the relationship of forest fires and water quality of Alaskan streams, and to understand the requirements necessary to implement measures to control stream erosion, e.g. revegetation, erosion prevention, etc. The study showed that there was no statistically significant change in the benthic fauna of the streams that could be attributed to the effects of fire. Fire control methods may cause more serious, long-lasting damage to the aquatic ecosystem within the burned area than the fire itself. No significant detrimental effect was noted for burned soils; very little mineral soil was exposed by burning, possibly due to the thickness of the organic layers. Only the organic layer is useful in diagnosing the change in soil chemistry.

Lutz, H.J. 1956. Ecological effects of forest fires in the interior of Alaska. USDA For. Serv., Alaska For. Res. Cent. Tech. Bull. 1133. 121pp.

This study discusses the effects of fire on forests in the interior of Alaska; including effects on trees, subordinate forest vegetation and succession after fire; soils, including humus layers, physical and chemical properties; hydrology; wildlife, including fur-bearers, moose and caribou; and economic development. From 1949 to 1952, data on 103 sample plots, 11 transects and 860 milacre quadrants were recorded and analyzed. The effect of fire on white spruce, black spruce, paper birch, quaking aspen and balsam poplar, and the following succession are discussed in detail. As a result of fire, the climax white spruce stands on moderately well drained sites have been replaced by stands of paper birch and quaking aspen. Fires have less effect in changing forest composition of black spruce stands situated in low lying areas. Fire has a positive influence on some properties of soils, including the mobilization of some plant nutrients. Fire exhibits a negative impact on fur-bearing animals and caribou, but provides favorable habitat for moose. Widespread uncontrolled fire destroys valuable timber and surpresses tourism, but prescribed burning of appropriate areas can produce desirable ecological effects.

Lutz, H.J. 1960. Fire as an ecological factor in the boreal forest of Alaska. J. Forestry 58: 454-460.

Boreal forests are by their nature flammable, and several lines of data indicate that fires were a part of the boreal forest environment long before the advent of earliest man. This paper discusses the effects of fire on boreal vegetation and soil. However, these data are not directly relevant to the issue of moose habitat enhancement. The author notes that in other regions, including the boreal forest of northern Europe, the techniques of controlled burning as a management tool have been worked out and successfully applied. He therefore advocates the use of fire as a tool to favor establishment of new vegetation and to effect game management. No special conclusions are reached regarding the relationship between controlled fires and enhancement of moose habitat.

Macnida, S. 1978. Preferential use of willow by moose in interior Alaska. Alaska Coop. Wildl. Res. Unit, Univ. Alaska, Fairbanks. Unpubl. Rep. 28pp.

The purpose of this study was to evaluate whether between-species or within-species food preference occurred among willow species in a burn regrowth area. The relationship of protein content to food preference was also investigated. The study area was located at the Wickersham Fire Ecology Study Site, 20-mile Elliot Highway, in Interior Alaska. Mean browse production and utilization varied from 0 to 37.7 percent for the 1976-77 winter, and from 0.8 to 50.2 percent during the 1977-78 winter. Observations show that overall, Salix alaxenis is most preferred, S. planifolia is next, and S. hastata and S. scouleriana are least preferred. These results compare favorably to other studies conducted in Interior Alaska. Within-species preference patterns suggest a preference by moose for stems browsed yearly, and avoidance of those stems not browsed previously. The same preference pattern was found to exist between plants of the same species. Protein content was unrelated to patterns of between-plant preference. The author concluded that range evaluation studies need to take into account with-species preferences, and the habitat improvement work such as controlled burns and mecnanical crushing need to take into account which browse species will grow back and in what quantity.

Martin, R.E., C.T. Cushwa and R.L. Miller. 1969. Fire as a physical factor in wildland management. Proc. Annu. Tall Timbers Fire Ecol. Conf. 9: 271-287.

This paper discusses some physical factors of importance in the use of fire. The stages of fuel combustion, moisture of fuels, fuel removal, fire temperatures and lethal temperatures (to plants) are discussed. The importance of duff or soil layers in protecting living tissues is demonstrated by rough calculations. The significance of needle scorch due to prescribed burning during moist fuel conditions is discussed.

McNicol, J.G. and F.F. Gilbert. 1980. Late winter use of upland cutovers by moose. J. Wildl. Manage. 44: 363-371.

The utilization of mixed-species cutovers by moose during late winter was examined to determine the relationships between browse, coniferous cover, and edge within and bordering these cutovers. Biweekly aerial track counts and ground examinations were carried out on sixteen upland cutovers, 10 to 15 years in age, near Thunder Bay, Ontario, ranging in size from 49 to 2,830 ha. Paper birch, willow, mountain ash, pin cherry and trembling aspen constituted about 80% of the total recorded browse consumed by moose. The scattered-residual cover type was preferred by moose and provided the most diverse browsing opportunities over the dense-conifer, open and open-planted cover types. Use of these habitats is regulated by snow conditions. The edge between residual conifer and open areas within cutovers seemed to be more important to moose than the peripheral edge around cutovers. The number of use areas/ha increased with decreasing size of cutover, regardless of hunting pressure or snow conditions on the cutover.

Milke, G.C. 1969. Some moose-willow relationships in the interior of Alaska. MS. Thesis, Univ. of Alaska, Fairbanks. 79 pp .

This paper examined moose-willow relationships on several moose ranges in interior Alaska. Study sites included the Dry Creek study area (S. portion of Tanana Flats), Paxson Lake (Alaska Range), Little Clearwater Creek (54mi. W. of Paxson, AK.), Gunn Creek Flat (13 mi. N. of Paxson, AK.), Taylor

Highway (200 mi. SE. of Fairbanks), Wood River (30 mi. E. of Mt. Mckinley National Park) and Tanana River (1 mi S. of Fairbanks). Salix interior, S. alaxensis, S. arbusculoides, and S. pulchra were found to be most preferred by moose. S. alaxensis and S. pulchra are probably the most important browse species due to their high palatability, wide distribution and high abundance. Moderately palatable willow species were eaten to a greater degee when occurring with highly preferred species. Neither the relative abundance nor density of a species noticeably affects its degree of use. Although the degree of browsing that is sustained by a given species appears correlated with plant height, preferability is probably influenced more by inherent palatability. Moose management implications are that only the amount of browsing sustained by the highly and moderately preferred willow species should be considered when assessing moose range conditions or the relationship of moose density to food supply. When environmental manipulation becomes possible, only the growth of preferred species should be considered.

Nelson, K.J. and D. Weixelman. 1983. Moose-fire vegetation surey progress report for 1983. USDA For. Serv. Chugacn National Forest, Seward District, Alaska. Unpubl. Rep. 37pp.

This vegetation survey is a continuation of previous years' surveys of the Chugach Prescribed Burn Program in the national forest portion of the Kenai Peninsula. Hardwood moose browse production was measured in five prescribed burn units and two wildfire sites and was compared with production in adjacent control sites. Browse production averaged 71.8 kg/ha in the non-slashed burn units and 41.1 kg/ha in the control units, a 1.74 fold increase (174%). Browse production in slashed and burned units averaged a 2.94 fold increase over control units for the three areas surveyed. Production in the two older wildfire sites averaged a 16.56 fold increase in the burn vs. control, 14 and 24 years post burn. Slashed burns in each case produced more seedlings per hectare and incurred higher tree kill than nonslashed burns, thus influencing the post burn succession to a greater degree. Both slashed and nonslashed burns were effective at stimulating trunk sprouting of hardwood browse species. Potential moose carrying capacity realized by burning the five units surveyed was estimated at 11,600 moose-days vs approximately 4,991 moose-days as indicated by browse percentages. A log-arithmic relationship was established between percent grass cover in the preburn state and resulting burn coverage for the nonslashed burn unit surveyed.

Oldemeyer, J.L. 1983. Browse production and its use by moose and snowshoe hares at the Kenai Moose Research Center, Alaska. J. Wild. Manage. 47: 486-496.

The effect of different moose densities on paper birch production and use was studied for 4 years at the Moose Research Center (MRC) on the Kenai National Wildlife Refuge (KNWR), Alaska. Production and use of quaking aspen and willow were also estimated, and the impact of snowshoe hares on paper birch evaluated. The study was conducted in four 2.6 km^2 enclosures within a 125,500 ha area burned in 1947, where moose densities ranged from 1,237 to 5,851 moose-days/pen/winter from 1971-1974. 5 vegetative types important for browsing; including dense, medium, and thin birch-spruce regrowth; spruce-birch regrowth; and thin mature hardwoods; showed a significant difference in per-plant production the first 3 years. By 1973, different moose densities influenced plant production, which ranged from 3.7 g/plant (pen 3) to 6.9 g/plant (pen 1). Birch produced an average of 102 kg/ha in the 4 pens while willow and aspen combined produced 3.7 kg/ha in 1974. Birch use by moose and hares ranged from 31.8 to 83.3% of current annual production. Birch plants were subdivided into those browsed only by moose, only by hares, and those browsed by both. During the 4 years, hares browsed a greater percentage of tagged plants than did moose. Browsing levels of aspen in the fall and spring were 40.7 and 57.8% respectively with browsing of willows 55 and 70% respectively. It is indicated that willow and aspen are less tolerant of browsing than birch.

Oldemeyer, J.L., A.W. Franzmann, A.L. Brundage, P.O. Arneson, and A. Flynn. 1977. Browse quality and the Kenai moose population. J. Wildl. Manage. 41:533-542.

This study was the first to report on all of the major components of wild ungulate nutrition. Characteristics used to describe browse quality included _in vitro_ dry-matter disappearance (IVDMD), fiber content, protein content, and the concentration of 18 mineral elements. This study was conducted on the Kenai National Moose Range at the Kenai Moose Research Center, which is located in the NW lowlands of the Peninsula. Five major summer and winter browse species were investigated: paper birch, aspen, willow, alder and lowbush cranberry. Dwarf birch was also tested. The results show low winter levels of protein in all plant species, and low levels of manganese and several other trace elements. Seasonal differences in mineral concentrations were striking. During summer, alder and lowbush cranberry were significantly more digestible than the other four plant species. In winter, aspen and lowbush cranberry were the most digestible, willow and paper birch were intermediate, and alder was least digestible. Three observations of Kenai moose lead the authors to suspect that the winter diet for moose on the Kenai is energy deficient: they weigh less than those in comparable areas; the percentage of pregnant moose is less than elsewhere; and the Kenai moose population is declining. The authors attribute these changes to a great change in plant species composition. The current winter range is dominated by paper birch, which overall was ranked poorest in winter nutritional quality. Previously there was a mixture of birch, willow, aspen and perhaps some alder. The results, therefore, show the importance of browse variety in moose diet.

Oldemeyer, J.L., and W.L. Regelin. 1980. Response of vegetation to tree crushing in Alaska. Proc. N. Amer. Moose Conf. and Workshop 16: 429-443.

This study evaluates the effects of using LeTourneau tree crushers on moose forage in the Kenai National Moose Range. Three areas were mechanically treated, and the pattern of crushing changed during the 4 years of the study. The results were different at each site. At Willow Lake study area, browse densities were higher in 8 of 10 sample stands, and subdominant browse species made up a larger proportion of the browse population than before crushing. At South Moose Research Center (SMRC) an improvement in the browse population has been slower than at Willow Lake, but the 4 year densities are higher than the 2 year, indicating that the area is beginning to respond favorably. The authors hesitate to make conclusions regarding the third area, the Mystery Creek site. In all areas, except part of the Mystery Cr. area, spruce density was decreased by at least 70%. Density in the Mystery Cr. area was reduced 53% in 8 stands of spruce which averaged less than 1 m in height. The proper interspersion of food and cover provided optimum moose habitat. Areas too thoroughly disturbed resulted in less moose use probably because of the lack of cover.

Peek, J.M. 1972. Adaptations to the burn: moose and deer studies. Naturaliste 23: 8-14.

This paper appears to be for a general audience. Research was initiated in NE Minnesota following a fire in an area known as Little Sioux Burn. Research objectives included: obtaining data on moose and deer distributions; conducting a moose census; determining group sizes; and estimating the percentages of calves, yearlings, cows, and bulls in the moose population. Population census data revealed a high percentage of yearling moose on the burn, which implied that the fire had created habitat which resulted in a shift in distribution of yearlings in the general area of the Burn. Factors which contibuted to a shift include intolerance of yearlings by bulls during the breeding season, and by cows with newborn calves. It is also suggested that adult moose tend to remain resident in a given territory rather than move around as yearlings do. Burned areas provide a place for yearlings to move into, without being as harassed as in established habitats. The abundance of forage would tend to keep them there as they matured into adults.

Peek, J.M. 1974. A review of moose food habits studies in North America. Naturaliste can. 101: 195-215.

This article reviews 41 studies of moose food habits, including 13 from the intermountain west, 22 from Canada, Minnesota, Isle Royal and Maine and 6 from Alaska. Spencer and Chatelain (1953) found that 95% of Alaskan moose winter forage consisted of willow, birch, aspen and cottonwood. Murie (1944) considered willows the major summer and winter food of moose in Mt. McKinley Park, while conifers were unimportant because the predominant species (white and black spruce) are unpalatable. Spencer and Hakala (1964) and Hosley (1949) recorded willows to be important to Kenai moose. LeResche and Davis (1973) observed that winter forages varied according to range conditions on the Kenai. Milke (1969) reported moose preference for various willow species, and noted a correlation between plant density and intensity of browsing. The role of aquatic vegetation in the diet of moose is addressed in several studies. Although general conclusions reveal willow important to Alaskan moose, local variations in forage preferences are important. The author concludes that the majority of these studies do not depict food habitats well enough to adequately compare annual, seasonal and habitat-type forage use patterns.

Peek, J.M. 1974. Initial response of moose to a forest fire in northeastern Minnesota. Amer. Midl. Nat. 91: 435-438.

Previous studies have noted that moose populations often increase following fires because of the proliferation of palatable forage. This study was designed to determine if the observed increase in moose populations is due to improved productivity and survival, or to immigration. These factors were evaluated over a 2 year period on a 14,600 acre burn in northeastern Minnesota. Substantial immigration to the burn occurred within 6 months after the fire. Apparently immigration of yearlings and perhaps other moose to this burn contributed substantially to the population buildup. This capability serves as an important function in the adaptation to survival in boreal forest, where mature spruce-fir and jackpine communities produce very little forage for moose and fires may create an abudance of woody browse quite rapidly.

Peek, J.M., R.E. LeResche and D.R. Stevens. 1974. Dynamics of moose aggregations in Alaska, Minnesota and Montana. J. Mammal. 55: 126-137.

Distributions of annual aggregation patterns in three populations of moose occupying different habitats in Kenai, Alaska, southeastern Montana and northeastern Montana were evaluated. Aggregation sizes were related to different activities, relationships and characterstics; including habitat characteristics such as forage sources, topography and cover distribution. Group sizes were the highest and most variable in the Kenai population which was the most dense of the three populations studied. The largest group sizes in the Kenai occurred when moose were occupying the alpine tundra. The authors concluded that aggregrations from mid-winter to spring are primarily related to forage location and cover. In addition, the solitary, aggressive nature of the cow with calf may be an attempt to minimize intraspecific competition and facilitate access to the best forage. Aggregations during the prerut, rutting and postrutting periods can be attributed in part to environmental factors including access to high quality forage supplies in early winter.

Peek, J.M., M.D. Scott, L.J. Nelson, D.J. Pierce, and L.L. Irwin. 1982. Role of cover in habitat management for big game in northwestern USA. Trans. N. Amer. Wildl. Conf. 47: 363-373.

The objectives of this paper are to review and evaluate studies of cover use patterns of big game, and to discuss the relationship between cover preference and requirement. In mountainous regions of the northwestern U.S., moose are usually restricted to areas where snows are less than 90 cm. Where snow depths approach this depth, cover is critical; cover is less critical where snow depths average less than 90 cm. Shiras moose use of cover types varies during the year, and between years, reflecting differences in winter severity. Use of more open communities, including clearcuts and burns, is associated with selection of cooler micro-climates, cooler times of the day, and year.

Peek, J.M., D.L. Urich and R.J. Mackie. 1976. Moose habitat selection and relationships to forest managment in northeastern Minnesota. Wildl. Monogr. No. 48. 65pp

Objectives of this study were to determine numbers, age and sex composition, and aggregation patterns of the moose population, its year long habitat use and forage use patterns for comprehensive forest resource management purposes. The study area in the Superior National Forest in Central Lake County, Minnesota encompassed 1,958 Km^2 of high intensity moose range. This study includes detailed discussion of food habits (including monthly and seasonal trends, browse preferences, browse utilization and forage trends and relationships); habitat use (including seasonal use of terrestrial habitats and use of aquatic habitats, and nutrient content of common understory species); and characteristics of conifer plantations related to use by moose (including shrub composition, density, production, shrub nutrient levels and soil nutrient levels). Aquatic communities and sparsely stocked stands were most frequently used by moose in early summer. Upland habitats dominated by aspen and white birch, moderately to sparsely stocked, and relatively mature received the major share of the use during summer. Shifts in habitat use as summer progressed may be correlated with decreased palatability of open grown species. The winter period encompassed the most pronounced changes in habitat use. Moose aggregations were highest in late fall and early winter. In conclusion, habitat selection by moose in the area could be correlated primarily with forage and cover requirements and breeding behavoir.

Ream, C.H. 1981. The effects of fire and other disturbances on small mammals and their predators: An annotated bibiliography. USDA For. Serv. General Tech. Report INT-106. Intermountain Forest and Range Exp. Stn., Ogden, Utah. 55pp.

This annotated bibliography contains 237 references related to the effects of fire, logging, grazing and herbicides on small mammals and their predators. Because the major effects of disturbances on small mamals is the modification of vegetation, references describing specific habitat requirements are included. Publications dealing with predator-prey relationships where small mammals are the prey species have been included. Emphasis is on western coniferous forests, with other geographical areas cited. Although contradictions exist, general responses to the effects of fire can be predicted by most species. Publications are listed alphabetically by author with a keywork index.

Regelin, W.L., A.W. Franzmann, and C.C. Schwartz. 1980. Short-term effects of nitrogen fertilization upon production of moose forage in Alaska. Proc. N. Amer. Moose Conf. Workshop 16: 392-397.

This study reports on the effects of fertilizing plots of black spruce and white spruce-paper birch mixed forest types, at the Moose Research Center on Kenai Peninsula. The plots had been burned in the 1947 fire and were disturbed by Le Tourneau tree crushers in 1976, one year before treatment with nitrogen applied as ammonium sulfate or urea. Results showed that nitrogen fertilization would not be an effective treatment for short-term improvement of forage production. Growth of forb and shrub species were not changed. Only grass species (mostly Calamagrostis canadensis) increased due to fertilization. This may have a detrimental effect on moose because grasses are seldom eaten and they compete with preferred forbs and shrubs. Thus, nitrogen fertilization is not recommended as a short-term method for increasing forage production for moose in this area.

Rowe, J.S., and G.W. Scotter. 1973. Fire in the boreal forest. Quaternary Res. 3: 444-464.

This paper discusses the ecological interrelationships between fire and the flora and fauna of the boreal forest. Since fire initiates and terminates succession, it exerts both short-term and long-term effects. The often stated relationship of fire to "more browse, more moose" is simplistic. However, there is evidence that browse species available to deer and moose on recently burned-over areas are generally superior in quality as well as in quantity. This may be due in part to the increase in available nitrates and other minerals. There is ample evidence that productivity can be higher in early stages of ecosystem development than in later stages. It is concluded that fire should be viewed as a normal ecological process in the boreal forest.

Scotter, G.W. 1964. Effects of forest fires on the winter range of barren ground caribou in northern Saskatchewan. Can. Wildl. Serv., Wildl. Manage. Bull., Series 1(18):1-111.

This paper attempts to provide a quantitative and qualitative appraisal of the effects of fire on the winter range of barren-ground caribou. This includes the extent and history of forest fires, the effect of fire on terrestrial forage and arboreal lichen production, plant succession following forest fires, and the effect of fire on soil properties and wildlife. One of the most obvious effects of fire on the winter range of barren-ground caribou is reduction of forage in both quantity and quality, with forage production determined in six age classes in black spruce and white birch forests. There was a temporary reduction in range productivity, with the exception of high value "reindeer lichens". Pellet-group counts and aerial survey indicate that barren-ground caribou prefer climax forests while moose preferred the early successional stages of forest growth, particularly the post-fire stage 10 to 30 years after a fire. Neither moose nor caribou limited itself to any one age class.

Scotter, G.W. 1971. Fire vegetation, soil, and barren-ground caribou relations in northern Canada. Pages 209-230 in C.W. Slaughter, R.J. Barney and G.M. Hansen, eds. Fire in the northern environment - a symposium. April 1971, Fairbanks, Alaska. USDA For. Serv., Pacific N.W. For. and Range Exp. Stn., Portland, Oregon.

The purpose of this paper was to review results of the Canadian Wildlife Services's caribou research program and to report on new research which determined: the portion of burned winter range in upland lichen forests and any increase in recent years; the effects of fire on the usable standing crops of terrestrial forage and arboreal lichens; the effects of fire on soil properties; and the effects of fire on range use by barren-ground caribou and moose. The study found that moose preferred habitats in early stages of succession, but barren-ground caribou favored habitats in later stages of succession. Fire appears to reduce the winter range for barren-ground caribou and increase it for moose on upland forests. Fires adversely affect the standing crop of terrestrial and arboreal forage; lichens are apparently affected more than other forage plants because their reestablishment is delayed and their growth rates slow. Because forest fires affect the standing crop of forage, plant succession, and animal use, they may have been among the principal causes of caribou decline in N. Canada.

Scotter, G. W. 1972. Fire as an ecological factor in boreal forest ecosystems of Canada. Pages 15-22 in C.W. Slaughter, R.J. Barney and G.M. Hansen, eds. Fire in the northern environment-a symposium. April 1971. Fairbanks, Alaska. USDA For. Serv., Pacific N.W. For. and Range Exp. Stn. Portland, Oregon.

This paper reviews the effects of fire on vegetation, soil, animals, and hydrology in boreal ecosystems. Faunal succession occurs just as does plant succession. The optimum habitat for each animal is restricted to a particular stage in plant succession. Reports are cited which indicate that fire improves some ranges for moose. It is also noted that in both Alaska and Canada there are areas which have been repeatedly burned-over, but support few moose. In many areas, particularly on upland sites in the Precambrian Shield region, favored moose browse is seldom abundant following forest fires. The pattern of burned and unburned patches may be critical in determining the suitability of the burned areas as habitat for many species.

Scotter, G.W. 1980. Management of wild ungulate habitat in the western United States and Canada; a review. J. Range Manage. 33: 16-27.

This review discusses rehabilitation of wild ungulate habitat, modification of range and forest practices, better use of existing habitat, and manipulation of numbers and distributions of wild ungulates. Rehabilitation practices discussed include seeding and planting, herbicides, mechanical treatment, and prescribed burning. More range improvement and timber management practices should be implemented under a multiple-use concept. Conservation, use, and development of adequate habitat are probably the most important factors in wild ungulate management. The amounts and kinds of habitat needed to maintain wild ungulate populations require more long-term research and better application of existing knowledge. The concept of "two deer in every pot" as a universal objective of game management should be questioned. Habitat enhancement techniques for moose are not specifically discussed.

Sigman, M. 1979. Response of wintering moose to mechanical habitat rehabilitation in Alaska. Can. Field-Nat. 93: 191-193

In order to rehabilitate a portion of an area burned in 1947, vegetation was mechnically crushed in a 460-ha area located in the Willow Lakes Rehabilitation Area (WLRA) within the Kenai National Moose Range in 1975. Moose use of a 230-ha area which included the rehabilitated area was then compared with a similarly sized control area to document differential moose use. Aerial observations (Dec. '74 - May '75) documented 1374 days of moose use in the WLRA compared to 466 days in the control area. Observed densities ranged from 2.5 to 9.8 moose/km^2 in the WLRA compared to 1.3 to 3.1 moose/km^2 in the control area. Cow-calf ratios were fairly consistent in the WLRA and declined steadily in the control area from December 1974 through April 1975. The rapid build up of moose following crushing and prolonged use of this area by moose in the WLRA is attributable to a highly nutritious, concentrated, and available food supply. Large aggregations of moose were observed in crushed mature hardwood stands. The animals consumed branches and twigs of birch and aspen trees as well as aspen bark. In addition, movement of the large crushers compacted the snow into trails, and the removal of vegetation led to wind compaction of new fallen snow which resulted in less severe snow conditions. This in combination with a plentiful food supply seemed to have benefited calves in particular.

Spencer, D.L., and E.F. Chatelain. 1953. Progress in the management of the moose of southcentral Alaska. Trans. N. Amer. Wildl. Conf. 18: 539-552.

This paper reviews the state of moose management in Alaska, and emphasizes that although considerable research has been done on moose, insufficient data are available to define management measures for an indefinately sustained hunting season. The results of various moose studies indicate that the Kenai Peninsula and the Susitna Valley are two of the most important moose population centers in southcentral Alaska. About 850 square miles (7%) can be classified as good moose winter range of the 11,500 square miles in the Susitna Valley. Because of inherent adaptations, moose are more resistant to winter kill than some other ungulates. Stomach analysis of 96 moose in winter showed that willows constituted 53%, birch 32%, cottonwood 8%, aspen 4%, and seven other species 3% of the stomach contents. The under-use of a browse stand is more serious than over-use. Some Susitna Valley moose winter ranges are growing out of reach and others are being overutilized. Although moose are increasing here, they will decline; controlled burning cannot completely remedy it.

Spencer D.L. and J.B. Hakala. 1964. Moose and fire on the Kenai. Proc. Annu. Tall Timbers Fire Ecol. Conf. 3: 11-33.

The purpose of this paper was to examine the data obtained following the 1947 Burn on the Kenai Natioal Moose Range, and to present various moose and fire relationships. Browse growth through aspen root sucker growth immediately followed the fire. Browse growth providing winter forage progressively developed, and appeared significant in attracting moose for 5 years after the burn. Heavy browse growth was reached in about 7 years, with maximum growth obtained about 15 years after the burn. Moose forage conditions are favorable for about 5 to 20 years after burning in the boreal forest; occasionally 60-70 years. As winter forage in the Burn increased, the moose wintering population increased both through accelerated production in the herd and through animals drawn from other less favored wintering areas. Frequent severe winters appear to distribute moose utilization and may actually be favorable in the long-term by retaining browse species at an available height. The duration of browse growth and volume of growth are highly variable in location throughout the forest; some areas do not produce growth following fire. There is evidence that a single reburn at a proper interval will extend the browse production period by reducing the development of spruce growth. However, repeated burns may favor grasses and forbs with elimination of browse and spruce growth.

Stelfox, J.G. 1974. Browse production and utilization during 17 years of regeneration in a white spruce forest. Proc. N. Amer. Moose Conf. Workshop 10: 135-144.

This study compares habitat utilization and browse production in logged areas of a white spruce forest with unlogged areas along the Athabasca Valley, Alberta. Big game range data was examined from six sample areas; two in the mature white spruce forest, two in a logged-over strip and two in an adjacent scarified logged strip. Initially, logging led to a decrease in the numbers of woody plants; six years later logged areas contained 30 % more woody plants than unlogged areas; 17 years after logging woody plants were three times greater in the logged areas. Six years after logging, there were 147 and 422 spruce seedings per acre in the scarified and unscarified strips respectively, compared to 113 seedings per acre in the mature forest. Seventeen years after logging, there were three times more white spruce plants per acre in the scarified versus unscarified strips, and the unscarified area produced almost four times more browse than the unlogged areas. Big game (moose, elk, deer) use was 18.6 and 64.8 times greater in the 17-year old scarified and unscarified strips respectively than in the mature forest, with only moose observed in the mature forest. After logging, there were initial population declines in big game species due to decreased browse availability, but as regeneration occurs excellent range conditions will exist for 15-20 years.

Telfer, E.S. 1972. The effect of logging on wildlife in the boreal forest. Can. Society of Wildl. and Fish Ecol. Annu. Meeting. 9pp.

This paper discusses the effects of logging (in the area of boreal forest from Newfoundland to Alaska) on large game animals; moose, white-tailed deer and caribou, and to a lesser extent on snow-shoe hare and beaver. The effects of logging on wildlife is similar to that of fire, i.e. it creates subclimax successional habitat that is favored by moose and deer, while it decreases dense conifer stands that caribou require. Logging operations may increase the number of small game and spur increases in fur-bearing carnivores. Large clear cuts will be harmful to deer, while both deer and moose require diversity of forest cover within their home ranges at all times of the year. It is suggested that logging will become the principal ecological influence on the boreal forest.

Telfer, E. S., and T. C. Dauphine. 1981. Problems facing wildlife habitat management on Canadian forest lands. Tran. N. Amer. Wildl. Conf. 46: 358-368.

This paper reviews the problems of forest land management in Canada, with an emphasis on provincial rather than federal or private forests. There is no specific data presented relevant to moose habitat enhancement techniques.

Trigg, W.M. 1971. Fire season climatic zones of mainland Alaska. USDA For. Serv., Pacific N. W. For. and Range Exp. Stn., Portland, Oregon. Res. Pap. PNW-126. 13pp.

The purpose of this paper was to outline the fire-season climatic zones of the Alaska mainland. The Alaska mainland was defined as that part of the State lying between the Canadian border on the east and the Bering Sea on the west, and between the Brooks Range on the north and the Gulf of Alaska on the south. Data consisted of observations of temperature and precipitation from 48 weather stations. Calculated values of precipitation effectiveness index (PEI) and temperature efficiency index (TEI) were used to delineate areas that have different climatic subclassifications during the wildfire season of April through September. The climatic zones delineated show the maximum and minimum fire danger areas on a 6 month fire season basis. These zones have value as a wildfire management planning tool. No ecological or wildlife data are presented.

U.S. Department of Agriculture, Forest Service. 1977. Environmental statement for the Chugach moose-fire management program, USDA For. Serv., Chugach Natl. For. Rep. USDA-FS-R10-FES (ADM) 77-07. 146pp.

This Environmental Statement describes the purpose, the beneficial and adverse environmental impacts, and the alternatives considered, of establishing a controlled burning program on the Kenai Peninsula. For 10 years beginning in 1977, about 22,000 ac of land at 139 sites will be treated by prescribed burning. The purpose of this action is to improve vegetation for use as moose forage. The basis for carrying out this action rather than vegetation crushing or herbicide treatment, was the recognition that actions other than burning were not feasible in the Kenai Mts. The EA utilizes data derived from numerous scientific studies (e.g. Spencer and Hakala, 1964) that show the relationship between fire and moose ecology. These data show that the impacts of fire are extremely favorable for moose.

Viereck, L.A. 1970. Forest succession and soil development adjacent to the Chena river in interior Alaska. Arctic and Alp. Res. 2: 1-26.

This study attempts to show changes in soil and vegetation with time on the floodplain of the Chena River near Fairbanks. Four stands on different aged river deposits (a 15-yr old willow stand on a newly formed gravel bar, a 50-yr old balsam popular stand, a 120-yr old white spruce stand, and a 220-yr old white spruce/black spruce stand), were studied and compared with a fifth stand on a higher and older terrace (a climax black spruce/sphagnum stand). In early successional stands of willow and balsam popular, soil froze quicker and deeper and reached lower temperatures than in later successional stages. In the willow stand thawing was complete by the end of May. In the white spruce/black spruce stand thawing didn't begin until the end of May and was never completed; a frozen layer was continually present at a 40-80 cm depth. The thick moss layer accounts for delayed thawing and colder soil temperatures. Soil moisture changes varied from xeric on gravel bar, to mesic in popular and white spruce stands; to hydric in the climax stand.

Viereck, L.A. 1973. Wildfire in the taiga of Alaska. Quarternary Res. 3: 465-495.

Fire continually alters and initiates renewal of successional ecosystems in the taiga of Alaska, burning an average of 400,000 ha annually. This paper reviews the ecological effects of fire in the Alaskan taiga on vegetation (dry and wet sites and autecological relationships), soil, hydrology and siltation, wildlife, insects and recreation; and in less detail discusses climate, the fire season, and history of past fires. One of the most important effects of fire and the resultant burning of the organic layer in the taiga is the increase in the depth of the annual thaw (active layer) of permafrost soils and the following changes in the soil nutrient cycle. Construction of firelines in permafrost areas may be more damaging to soil erosion and siltation than the actual fire. Moose depend upon fire to create preferred habitat while fire might have negative effects on carribou winter range. Recently, the number of fires has increased, although effective fire control has caused a downward trend in acreage burned. Fire suppression alternatives include the safe burning of lightening-caused fires or surpressing these fires and duplicating the natural fire regime with prescribed - controlled fires.

Vierick, L.A. 1975. Forest ecology of the Alaska taiga. Proc. Circumpolar Conf. on Northern Ecology, September 1975, Ottawa. U.S. Dept. Agriculture. 22pp.

This paper presents a classification system for the common Alaska taiga vegetation types, and discusses the successional relationships of many of the vegetation types. A discussion is presented of the various attempts made to classify the taiga forests into subzones. Because of a current lack of information, the author believes it is best not to set any definite subzonal boundaries at the present time. The taiga zone in Alaska is usually delineated by the distribution of white spruce. The main disturbance factors of vegetation in the taiga are fire, and river erosion and deposition. Between 1940 and 1969 the average annual burned-over area in the Alaska taiga was approximately 400,000 acres; 78 percent was burned by lighting caused fires. The vast majority of the Alaska taiga has burned at least once in the last 200-250 years. Succession patterns on newly deposited river alluvium in the taiga follows the example of "classical textbook" primary succession.

Viereck, L.A. 1982. Effects of fire and firelines on active layer thickness and soil temperatures in interior Alaska. Proc. Can. Permafrost Conf. 4:123-135.

Changes in thaw depths and soil temperatures were monitored in a burned black spruce stand and an adjacent fireline to gather information on the process of permafrost thawing which follows fire and fireline construction. The study was conducted at the Washington Creek Fire Ecology Research Area, 50 km NW of Fairbanks. Erosion, siltation, subsidence, and gulleying may continue for ten years or more following fireline construction as a result of the use of heavy construction equipment. This study found that in a burned stand, the depth of thaw increased each year for 10 yr following the fire, and reached a maximum thaw depth of 187 cm. Thaw depth was greatest in the fireline and reached a maximum depth of 227 cm in 1979, but was 200 cm deep in 1980. This decrease was related to the reestablishment of a nearly continuous mat of moss vegetation. At all depths, the yearly average temperatures are warmest in the fireline, intermediate in the burned stand, and coldest in the unburned stand. The moss layer and its build-up of a deep organic layer is the most important control of active layer depth by vegetation.

Viereck, L.A. and C.T. Dryness. 1979. Ecological effects of the Wickersham Dome Fire near Fairbanks, Alaska. USDA For. Serv. Pacific N.W. For. and Range Exp. Stn., Portland, Oregon. Gen. Tech. Rep. PNW-90. 71 pp.

The Wickersham Dome Fire, located approximately 50 km northwest of Fairbanks, Alaska, burned over approximately 6,300 ha of predominantly black spruce forest land in June 1971. Shortly after the fire was controlled, eight plots were established in black spruce areas for intensive study of the ecological effects of the fire. Although certain portions of this study are continuing, results reported here are mainly for the first three years following the fire (1972-1974). Abiotic factors studied include soil, climatic factors and stream water quality; biotic factors such as vegetation analysis, biomass, litter fall, seedling establishment and autecology of first year post fire tree regeneration were looked at in detail. The moist, lower forest floor layers had minimized the impact of the fire on the soil. The reduction of forest floor thickness and blackening of the surface resulted in higher soil temperatures, which caused a retreat of the permafrost layer in burned areas. Development of vegetation was closely tied to fire severity. Limited biomass studies lead the authors to conclude that the high production of available browse illustrates the possible value of fire in the production of wildlife habitat. Studies of animals focused on arthropods, microtine rodents and snowshoe hares.

Viereck, L.A., J. Foote, C.T. Dyrness, K. Van Cleve, D. Kane, and R. Seifert. 1979. Preliminary results of experimental fires in the black spruce type of interior Alaska. USDA For. Serv., Pacific NW For. and Range Exp. Stn. Portland, Oregon. Research Note, PNW-132. 28pp.

This study was conducted in the Washington Creek experimental fire site 40 km N of Fairbanks, Alaska, to gather information useful to land managers for understanding the effects of fires of varying intensities on the major taiga ecosystems. Four units were burned and a fifth was the control. Measurements were taken during the fires and showed a difference of fire intensity among the four plots. The effects of fires on the vegetation, thickness of the organic layer, soil temperatures, phosphorus content of the forest floor, and the amounts of fuel were determined. Soil temperatures indicated that the heat generated by the fires had little long-lasting effect on soil temperatures. However, fire had a dramatic effect on the chemistry of the forest floor, showing an increase of up to 50 times the amount of available phosphorus in the burned areas as in the unburned control.

Viereck, L.A., and L.A. Schandelmeier. 1980. Effects of fire in Alaska and adjacent Canada - a literature review. USDI Bureau of Land Management Alaska Tech. Rep. 6. 124pp.

This review covers all available literature of fire effects in both the northern forest (taiga) and tundra. Information sources, fire history, fire regimes, effects of fire on soils, watersheds, vegetation, and animal life are discusseed and interpreted. Moose population changes in relation to fire are reviewed. (Most of the papers cited in this review have been covered in this series of annotations). Four subjects were noted as information gaps in the knowledge of problems related to fire and moose: 1) the quantity and quality of browse following fire, including identification of the original vegetation type, interval between fires, and differences in fire severity; 2) the whole problem (sic) of "traditional use of areas," the dynamics of burn invasion by moose, the optimum size of burns, and the optimum number of unburned islands left within burns; 3) the effects of moose on the developing vegetation; and 4) the possible competition between moose and snowshoe hares, and how hare cycles interact with fire frequencies and moose populations.

Walker, R. 1980. 1979 progress report on the Chugach moose-fire program. Pages 66-122 in M. Hoefs and D. Russell, eds. Wildlife and wild fire; proc. of a workshop. Nov. 27-28, 1980. Yukon Wildlife Branch, Whitehorse, Yukon, Canada.

This paper consists of a review of moose-fire relationships and habitat improvement data, descriptions of the prescribed burning program, and the overall moose management project conducted on the Chugach National Forest. This program began in 1977 in response to deteriorating moose winter forage conditions. Deciduous browse is becoming less available to wintering moose as a result of chronic overbrowsing, and natural forest succession. In 1966 mechanical crushing and herbicide sprays were used to achieve site conversion from the existing spruce-hardwood canopy, but each method proved not feasible. Prescribed burns proved successful and reasonably duplicated natural wildfires. A plan was developed to treat 22,000 acres of historical moose winter range at 139 sites over a 10 year period. Guidelines are presented on various aspects of how the prescribed burning program is implimented: decisions to be made, description and preparation of the site, determination of fuel moisture, etc.

Wolff, J.O. 1976. Utilization of hardwood browse by moose on the Tanana flood plain of interior Alaska. USDA For. Serv. Pacific N.W. For. and Range Exp. Stn., Portland Oregon. Research Note PNW-267. 7pp.

The purpose of this study was to estimate the amount of available browse in two areas of early seral plant communities along the Tanana River flood plain SW of Fairbanks, and to determine the importance of these two areas as winter foraging habitat for moose. The total amounts of available hardwood browse produced were 38 kg/ha in the 8 year old stand, and 113 kg/ha in the 15 year old stand. Approximately 55% of available browse was consumed by moose in 1 year. It appears that when the available browse is reduced below a critical density, moose move on to a different area. It was noted that some Salicaceae are preferred over others. The early successional stage plant communities on the Tanana flood plain provide an important winter habitat for moose.

Wolff, J.O. 1978. Burning and browsing effects on willow growth in interior Alaska. J. Wildl. Manage. 42(1): 135-140

Productivity and utilization of browsed and unbrowsed Scouler willow was measured in a 1971 burn and in an adjacent 70 year old mature black spruce forest during 1973 and 1974. The study area was located in the Wickersham study site of the U.S. Forest Service, 50 Km northwest of Fairbanks, Alaska. Production of available browse in the burn increased from 8 kg/ha in 1973 to 22.6 kg/ha in 1974, as compared to 9.9 kg/ha in the control in 1974. The greatest browse production came from branches which had been browsed the previous winter. In the burn in 1974, an average browsed branch produed 4.0 g of new growth, while an unbrowsed branch produced 2.4 g. In the control a browsed branch produced 2.8 g and an unbrowsed branch produced 0.8 g. Browse utilization in the burn was 44 and 45 percent in 1973 and 1974, whereas in the control utilization was 34 and 8 percent respectively. Browse consumption in the burn increased from 3.5 kg/ha during the 1973-74 winter to 10.2 kg/ha during the 1974-75 winter, while consumption in the control area was 0.8 kg/ha in 1974. Although browsed brancnes produced more than unbrowsed branches from 1973 to 1975, continuous browsing over several years might lead to an eventual decline in productivity. It has been suggested that 50 percent browse utilization may give maximum sustained production of hardwood browse.

Wolff, J. O. and J. C. Zasada. 1979. Moose habitat and forest succession on the Tanana river floodplain and Yukon-Tanana upland. Proc. N. Amer. Moose Conf. Workshop 15: 213-244.

This study compared browse production in different aged seral communities after disturbance to determine moose winter range capacity. Using data in this study and unpublished observations, the browse species preferences of moose were given. Sandbar willow is the most preferred, followed by other willow species, birch, aspen, cottonwood, poplar, highbush cranberry, and alder. The dominant trees and shrubs in seral communities important to moose winter range production are several species of willow, birch, aspen, balsam poplar, and alder. All of these, but particularly aspen, are capable of producing some browse within one growing season after disturbance through vegetative regeneration. For seed regeneration, a minimum of 3-5 years is required to produce useable browse. The carrying capacity of a stand may only be 75% of total browse available; the remaining 25% is less nutritious, less palatable, more scattered, and more energetically costly for moose to consume.

Yoakum, J., W. P. Dasmann, H. R. Sanderson, C. M. Nixon, and H. S. Crawford. 1980. Habitat Improvement Techniques, Ch. 20. Pages 329-403 in S.D. Schemnitz, ed. Wildlife Management Techniques Manual, 4th Edition. Wildl. Society Inc. Wash., D.C.

This paper is included as Chapter 20 from Wildlife Management Techniques Manual, 4th Edition (1980). It discusses methods and techniques of habitat manipulation specifically designed to increase food, water, or cover for wildlife, such as propogation regeneration, rejuvenation, or release; creating cover by use of hedge rows, and brush piles; creating water developments, etc. Information specific to moose habitat enhancement is not presented.

Zasada, J.C. 1981. Natural regeneration of interior Alaska forests - seed, seedbed, and vegetative reproduction considerations. Pages 231-246 in C.W. Slaughter, R.J. Barney and G.N. Hansen, eds. Fire in the northern environment - Proceedings of a symposium. April 1971. Fairbanks, Alaska. USDA For. Serv., Pacific N.W. For. and Range Exp. Stn., Portland, Oregon.

Various aspects of seed regeneration are evaluated relative to burn reforestation. The data provide a quantitative bases for evaluating reforestation potential of burned areas. The information presented is only indirectly relevant to the issue of moose habitat ennancement.

Zasada, J.C., R.A. Norum, R.M Veldhuizen and C.E. Teutsch. 1983. Artificial regeneration of trees and tall shrubs in experimentally burned upland black spruce/feathermoss stands in Alaska. Can. J. For. Res. 13:903-913.

The purpose of this study was to examine the possibility of artificially establishing hardwood trees and shrubs on burned sites dominated by black spruce. As land ownership changes, and the intensity of use and management in the Alaska taiga increases, measures to revegetate burned sites may be needed; e.g. it may be desirable to improve moose habitat. Artificial seeding and planting are two means of altering species composition. This study showed that germination of fall seed-dispersing species (birch, alder, and black spruce) occurred on moderately and severely burned seedbeds but not on scorcned or lightly burned surfaces; seedling survival of these species occurred almost exclusively on severely burned surfaces. After 3 years, 82% of plots with some severely burned surfaces sown with fall seed-dispersing species were stocked, whereas 32% of similar plots sown with summer-seeding species (aspen, balsam poplar, feltleaf willow, Scouler willow, and Bebb willow) were stocked.

Appendix B. Common and Scientific Names of Plants and Animals Cited in the Moose Habitat Enhancement Report and Annotated Bibliography.

1. PLANTS

Common Name	Scientific Name
alder	Alnus spp.
aspen	Populus tremuloides
trembling/quaking aspen	" "
Barclay willow	S. barclayi
birch	Betula spp.
dwarf birch	B. nana
paper birch	B. papyrifera
black spruce	Picea mariana
blueberry	Vaccinium spp.
bluejoint	Calamagrostis canadensis
buffaloberry	Shepherdia canadensis
cloudberry	Rubus chamaemorus
corydalis	Corydalis spp.
cottonwoods	Populus spp.
diamondleaf willow	Salix planifolia
feather moss	Hylocomnium spp.
fir	Abies spp.
fireweed	Epilobium spp.
flowering dogwood	Cornus florida
geranium	Geranium spp.
halberd willow	Salix hastata
highbush cranberry	Viburnum pauciflorum /edule
horsetail	Equisetum spp.
jack pine	Pinus divaricota /banksiana
labrador-tea	Ledum groenlandicum
lichens	Peltigera spp.

Common Name	Scientific Name
lowbush cranberry	Vaccinium vitis-idaea
mountain ash	Sorbus americana
mountain maple	Acer glabrum /spicatum
mushrooms	Boletus spp.
oldman's beard	Usnea spp.
pin cherry	Prunus pennsylvanica
poplars	Populus spp.
balsam poplar	P. balsamifera
black poplar	P. trichocarpa
raspberry	Rubus spp.
red maple	Acer rubrum
red pine	Pinus resinosa
redstem ceanothus	Ceanothus sanguineus
rose	Rosa spp.
roundleaf greenbriers	Smilax rotundifolia
sandbar willow	Salix interior
serviceberry	Amelanchier alnifolia
stink currant	Ribes bracteosum
twin-flower	Linnaea borealis
white oak	Quercus alba
white pine	Pinus strobus
white spruce	Picea glauca
willow	Salix spp.
bebb willow	S. bebbiana
feltleaf willow	S. alaxensis
scouler willow	S. scouleriana

2. MAMMALS

Common Name	Scientific Name
beaver	*Castor canadensis*
bighorn sheep	*Ovis canadensis*
black bear	*Ursus americanus*
caribou	*Rangifer tarandus*
elk	*Cervus canadensis*
flying squirrel	*Glaucomys sabrinus*
hare	*Lepus* spp.
least weasel	*Mustela rixosa*
lynx	*Lynx canadensis*
meadow vole	*Microtus pennsylvanicus*
moose	*Alces alces*
mule deer	*Odocoileus hemonius*
muskrat	*Ondatra zibethica*
red-back vole	*Clethrionomys rutilus*
red fox	*Vulpes fulva*
red squirrel	*Tamiasciurus hudsonicus*
short-tail weasel	*Mustela erminea*
snowshoe hare	*Lepus americanus*
stone sheep	*Ovis dalli*
white-tail deer	*Odocoileus virginianus*
wolf	*Canis lupus*

3. BIRDS

Common Name	Scientific Name
alder flycatcher	*Empidonax alnorum*
black-capped chickadee	*Parus atricapillus*
bohemina waxwing	*Bombycilla garrulus*
boreal chickadee	*Parus hudsonicus*

Common Name	Scientific Name
brown creeper	*Certhia familiaris*
dark-eyed junco	*Junco hyemalis*
flicker	*Colaptes auratus*
golden-crowned kinglet	*Regulus satrapa*
gray jay	*Perisoreus canadensis*
olive-sided flycatcher	*Nuttallornis borealis*
orange-crowned warbler	*Vermivora celata*
pine siskin	*Carduelis pinus*
ptarmigan	*Lagopus* spp.
ruby-crowned kinglet	*Regulus calendula*
ruffed grouse	*Bonasa umbellus*
savannah sparrow	*Passerculus sandwichensis*
sharp-shinned hawk	*Accipiter straitus*
sharp-tailed grouse	*Pedioecetes phasianellus*
spruce grouse	*Canachites canadensis*
Swainson's thrush	*Catharus ustulatus*
swans	*Olor* spp.
Townsend's warbler	*Dendroica townsendi*
tree swallows	*Iridoprocne bicolor*
varied thrush	*Ixoreus naevius*
western wood peewee	*Contopus sordidulus*
white-winged crossbill	*Loxia leucoptera*
woodpecker	*Picoides* spp.
yellow-rumped warbler	*Dendroica coronata*

Appendix C. Update of Status of Planned Prescribed Burns

Chugach Moose Fire Management Program

The program is proceeding on schedule in spite of a well-publicized incident in which a 1984 spring burn escaped the planned boundaries and required fire suppression efforts.

Kenai National Wildlife Refuge

The area crushed in the 1983-1984 winter was successfully burned. The forest floor was heavily burned, creating suitable microsites for browse plant seedling establishment. Due to the success of this burn, more prescribed burns are scheduled.

Alphabet Hills

Weather and fuel moisture conditions were not suitable for burning in 1984.

Tok

Weather and fuel moisture conditions were not suitable for burning in 1984.

Matanuska Valley

Weather and fuel moisture conditions were not suitable for burning the chained areas.