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ECOLOGICAL EFFECTS OF FIRE
AND ITS MANAGEMENT
IN CANADA'S NATIONAL PARKS:
A SYNTHESIS OF THE LITERATURE
VOLUME TWO, ANNOTATED BIBLIOGRAPHY

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A research report prepared for
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by A.D. Revill Associates,
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Parks Canada, 1978

This literature review has been compiled for Parks Canada purposes and is subject to further revision. It represents opinions and observations of the authors cited and does not reflect Parks Canada policy, although certain opinions and observations may affect our future policy on forest fire management and fire ecology.

ANNOTATED BIBLIOGRAPHY

Introduction

List of Abbreviations

Annotated References

ANNOTATED BIBLIOGRAPHY

This volume contains 446 items dealing with various aspects of forest fire as it relates to the ecology of our national parks. They are intended to be representative of the various aspects about which information has been published but are by no means exhaustive.

References are arranged alphabetically by author and where more than one paper of a particular authorship is abstracted, chronologically. In those cases where a paper was presented at a gathering in one calendar year and published in the proceedings the following year the date of publication is used.

Readers having a specialized interest are referred to the literature review which is topically arranged. At the end of each chapter all the papers cited are referenced and those which appear in this annotated bibliographic section are marked.

The search procedures used in preparing this section and the libraries consulted were described in the Preface. There and under Acknowledgements we mention the invaluable contribution made by the use of bibliographies prepared by others.

The names of the publications in which the various referenced papers appeared are in many cases, abbreviated. The abbreviations used are listed below.

LIST OF ABBREVIATIONS

Adv Ecol Res	Advances in Ecological Research
Amer For	American Forests
Amer Midland Naturalist	American Midland Naturalist
Amer Zoologist	The American Zoologist
Arctic & Alpine Res	Arctic and Alpine Research
ALUR	Arctic Land Use Research Program (Canada, Department of Indian Affairs and Northern Development)
Bi-monthly Res Notes	Bi-monthly Research Notes (Canadian Forestry Service)
Bot Rev	Botanical Review
BC For Ser	British Columbia Forest Service
Brit Ecol Soc Symp	British Ecological Society Symposium
Calif Div For Dept Nat Res	California Division of Forestry, Department of Natural Resources
Calif Fish & Game	California Department of Fish and Game
Calif State Bd of For	The California State Board of Forestry
*Canada, Dept Env	Canada, Department of the Environment
*Canada, Dept Fish & For	Canada, Department of Fisheries and Forestry

* The numerous name changes of the Canadian Forestry Service and the Department in which it has been located present a problem to bibliographers.

*Canada, Dept For, For Br	Canada, Department of Forestry, Forestry Branch
*Canada, Dept For, For Res Branch	Canada, Department of Forestry Forest Research Branch
*Canada, Dept For & Rural Dev	Canada, Department of Forestry and Rural Development
Canada, Dept Ind Aff & North Dev	Canada, Department of Indian Affairs and Northern Development
*Canada, Dept Int	Canada, Department of the Interior
*Can For Ser	Canadian Forestry Service
Can Inst For Rocky Mtn Sect	Canadian Institute of Forestry, Rocky Mountain Section
Can J Bot	Canadian Journal of Botany
Can J For Res	Canadian Journal of Forest Research
Can J Soil Sci	Canadian Journal of Soil Science
Can Wildlife Ser	Canadian Wildlife Service
Col State U Dept For Wood Sci	Colorado State University. Department of Forestry and Wood Science
Ecol Monogr	Ecological Monographs
*Env Can	Environment Canada. (Department of the Environment)
*Env Can N For Res Centre	Environment Canada, Northern Forest Research Centre, Edmonton. (Department of the Environment)
*Env Can Pacific For	Environment Canada, Pacific Forest Research Centre, Victoria. (Department of the Environment)

Fire Control Notes	Fire Control Notes (USDA, Forest Service)
Fire Ecol in Res Manage Workshop	Fire Ecology in Resources Management, Workshop. (Edmonton)
Fire Manag	Fire Management (USDA, Forest Service)
For Chron	Forest Chronicle
For Farmer	Forest Farmer
For Res Lab	Forestry Research Laboratory (Canadian Forestry Service)
For Sci	Forest Science
Intermt Fire Res Counc, Missoula, Mont.	Intermountain Fire Research Council Missoula, Montana.
Int Symp Air Qual & Smoke from Urban & For Fires (Ft. Collins, Col, 1973) Proc. Nat Acad Sci	International Symposium on Air Quality and Smoke from Urban and Forest Fires (Fort Collins, Colorado, 1973) Proceedings. National Academy of Sciences.
IUFRO	International Union of Forest Research Organizations
J Appl Ecol	Journal of Applied Ecology
J Appl Meteorol	Journal of Applied Meteorology
J Ecol	Journal of Ecology
J Env Manag	Journal of Environment Management
J For	Journal of Forestry
J For Hist	Journal of Forest History
J Geophys Res	Journal of Geophysical Research
J Range Manag	Journal of Range Management
J Soil Water Conserv	Journal of Soil and Water Conservation
J Ariz Acad Sci	Journal of the Arizona Academy of Science
J Wildl Manag	Journal of Wildlife Management

Minn Acad Sci Proc	Minnesota Academy of Science, Proceedings
Mont For Conserv Exp Sta, U Mont.	Montana Forest Conservation Experimental Station, University of Montana
Nat Parks Conserv Mag	National Parks Conservation Magazine
Nat Res Newsletter	National Resources Newsletter
Natur Land (Vienna)	Natur und Land (Vienna)
Nev Dept Fish & Game	Nevada Department of Fish and Game
Nfld J Commerce	Newfoundland Journal of Commerce
Nfld Res Comm Symp Presc Burn. Mem U Nfld	Newfoundland Research Committee Symposium on Prescribed Burning. Memorial University, Newfoundland.
NM Dept Game & Fish	New Mexico, Department of Game and Fisheries
N A Wildlife & Nat Res Conf Trans	North American Wildlife and Natural Resources Conference, Transactions
N A Wildlife Conf Trans	North American Wildlife Conference, Transactions
North For Res Centre	Northern Forest Research Centre, Edmonton. (Canadian Forestry Service)
North For Fire Laboratory, Missoula Mont	Northern Forest Fire Laboratory, Missoula, Mont. (USDA, Forest Service)
Ont Dept Lands & Forests Res Paper	Ontario Department of Lands and Forests, Research Paper
Ontario Min Nat Res	Ontario Ministry of Natural Resources
Outdoor Amer	Outdoor America
Park News	Park News (Toronto)
Proc West For Fire Comm Ann Meet (San Jose, Calif), 1973	Proceedings of the Western Forestry Fire Committee Annual Meeting, San Jose, California, 1973.

Pulp & Pap Mag of Can

Pulp and Paper Magazine of Canada

Quat Res

Quaternary Research

Québec Dept Lands
& Forests

Québec Department of Lands and Forests

Report for the Arctic Land
Use Research Program,
Dept Ind Affairs &
North Dev, Ottawa

Report for the Arctic Land Use Research
Program, Department of Indian Affairs and
Northern Development, Ottawa (See ALUR)

Sat Rev Sci

Saturday Review of Science

Sci Amer

Scientific American

Soc Am For Proc

Society of American Foresters, Proceedings

Symp Fire & Land
Manage (Missoula, Mont,
1974) Proc

Symposium on Fire and Land Management
(Missoula, Montana, 1974), Proceedings

Symp on Fire Ecol &
Control & Use of Fire
in Wildland Manage-
ment Proc

Symposium on Fire Ecology, and Control and
Use of Fire in Wildland Management,
Proceedings

Symp on Fire in the
Env (Denver, Col, 1972)
Proc

Symposium on Fire in the Environment
(Denver, Colorado, 1972), Proceedings

Symp on Fire in the North
Env (Fairbanks, AK, 1971)
Proc

Symposium on Fire in the Northern
Environment (Fairbanks, Alaska, 1971),
Proceedings. (Edited by Slaughter et al.)

Symp on For Harvesting
Mechanization and
Automation (Ottawa
1975), Proc.

Symposium on Forest Harvesting,
Mechanization, and Automation (Ottawa,
1975), Proceedings

Symp on Prescribed
Burning (Asheville,
NC, 1971) Proc

Symposium on Prescribed Burning (Asheville,
NC, 1971) Proceedings. Sponsored by USDA
Forest Service Southeastern Forest
Experiment Station, Asheville,
North Carolina.

Symp on Prescribed Fire
(Ottawa, Ont, 1967)
Proc

Symp North Envir Proc

Symp on the Role of Fire
in the Intermt West
(Missoula, Mont, 1970)
Proc

Symp 7th Ann Arizona
Watershed (Phoenix, AZ,
1963) Proc

Tall Timbers Conf on
Ecol Animal Control by
Habitat Manag Proc

Tall Timbers Fire Ecol
Conf Proc

Trans Am Soc Agr Eng

USDA

USDA For Ser

USDA For Serv Int
For Range Exp Sta

USDA For Serv Pac NW
For Range Exp Sta

USDA For Serv Rocky
Mtn For Range Exp Sta

Symposium on Prescribed Fire (Ottawa,
Canada, 1967), Proceedings

Symposium on the Northern Environment,
Proceedings

Symposium on the Role of Fire in the
Intermountain West (Missoula, Montana,
1970), Proceedings

Symposium, 7th Annual, on Arizona
Watershed (Phoenix, Arizona, 1963)
Proceedings

Tall Timbers Conference on Ecological
Animal Control by Habitat Management,
Proceedings

Tall Timbers Fire Ecology Conference,
Proceedings

Transactions of the American Society of
Agricultural Engineers

United States Department of Agriculture

USDA, Forest Service

USDA, Forest Service, Intermountain Forest
and Range Experiment Station, Ogden,
Utah. (INT)

USDA, Forest Service, Pacific Northwest
Forest and Range Experiment Station,
Portland, Oregon

USDA, Forest Service, Rocky Mountain Forest
and Range Experiment Station

USDA For Serv Nor Cen
For Exp Sta

USDA, Forest Service, North Central
Forest Experiment Station, St. Paul
Minnesota

USDA For Serv NE
For Exp Sta

USDA, Forest Service, Northeastern
Forest Experiment Station

USDA For Serv Prod
Res Rep

USDA, Forest Service, Production Research
Report

USDA For Serv Pac SW
For Range Exp Sta

USDA, Forest Service, Pacific Southwest
Forest and Range Experiment Station,
Berkeley, California

USDA For Serv SE For
Exp Sta

USDA, Forest Service, Southeast Forest
Experiment Station, Asheville, North
Carolina

US Nat Park Serv

United States, National Parks Service

U Minn Ag Exp Sta

University of Minnesota, Agricultural
Experimental Station

West Can J
Anthropology

Western Canada Journal of Anthropology

West For Con Assoc

Western Forest Conservation Association

West Wildlands

Western Wildlands

Wildland Manag

Wildland Management

Wildlife Manag Bull

Wildlife Management Bulletin

Woodlands Rev

Woodlands Review, (Canadian Pulp and
Paper Association)

World For Conf,
6th, Proc

World Forest Conference, 6th
Proceedings

Yellowstone Nat Park
Inf Paper

Yellowstone National Park, Information
Paper

ADVISORY BOARD ON WILDLIFE MANAGEMENT (A.S. Leopold, Chairman) 1963
 'Wildlife management in the [U.S.] national parks. A report to
 Sec. Interior.' N A Wildlife & Nat Res Conf Trans 28: 1-18.

Of the various methods of manipulating vegetation the controlled use of fire is the most natural and much the cheapest and easiest to apply. Unfortunately, forest and chaparral areas protected for long periods may require advance treatment to reduce fuel before a creeping ground fire can be risked. Some situations as the Isle Royale moose range, require a hot burn to open the forest canopy. Controlled burning sometimes is the only method that may have extensive application.

AGEE, J.K. 1974 Environmental impacts from fire management alternatives.
 U S Nat Park Serv West Reg Off. 92 p.

Four fire management alternatives are critically studied and their impacts identified. The four alternatives studied are (1) suppress all man-caused and natural fires at all times, (2) use prescribed burning in certain zones at certain times, (3) allow natural fires in certain zones under certain conditions, and (4) allow all man-caused and natural fires to burn at all times. There will be few if any cases where alternative 4 can be adopted. In most cases some combination of the first three alternatives will be appropriate. The optimum mix must be based upon the conditions prevailing at the park or wilderness in question.

Fire suppression has a detrimental effect on herbaceous vegetation in forest or shrub lands due to increasing competition in the lower story. The effects of fire suppression on vegetation can be mitigated only by using fire. Suppression of the understory forage has a detrimental effect on many species of wildlife. Without fire, vegetation trends toward uniformity, resulting in fewer wildlife species.

AGEE, J.K. 1974 'Fire management in the national parks.' West Wildlands
 1(3): 27-33.

Until recently National Park Service philosophy was that all fires were bad. The NPS followed a policy of fire exclusion which resulted in shifts in flora and fauna and in understory fuel buildup. This fuel buildup was noted in the 1963 Leopold report. A later report supported a shift in policy allowing a reintroduction of fire with a view of preserving and maintaining vegetative pattern in parks and wilderness. Current NPS policy recognizes fire as a part of the ecosystem. It allows fires resulting from natural causes to run their course, provided they can be contained in predetermined fire-management units and will accomplish the stated management objectives. Policy requires that fire not meeting these guides be extinguished. Prescribed fire may be used instead of lightning fires. Some parks (Yosemite and Sequoia-Kings Canyon) are using all three fire management alternatives while others will use only prescribed fire and suppression, or suppression alone. The implementation of current fire policies is expected to guarantee the perpetuation of America's national park resources.

AHLGREN, C.E. 1970 'Some effects of prescribed burning on jackpine reproduction in Northeastern Minnesota.' U of Minn Ag Exp Sta Misc Rep 94: 13.

This article contains a good literature review on the effects of prescribed burning on jackpine reproduction. The prescribed burning of the three tracts reported here resulted in good slash removal, humus reductions, shrub retardation, and an establishment of a new jackpine stand.

The merits of different firing techniques are also discussed. In this study the backfire technique used retarded shrub competition for several years following fire, allowing trees to become established and rise above the shrub layer.

AHLGREN, C.E. 1973 'Use of fire - comments from the north central states.' J For 71: 635-6.

This article compares prescribed burning methods in the north central states with those in the southeast.

The discussion includes fire effects on vegetation, especially on jackpine, black spruce, lands, effects on wildlife, deer, moose, grouse, and the Kirtland warbler; different firing techniques; the effects of topography on prescribed burning; and some effects in terms of smoke pollution.

AHLGREN, C.E. 1974 'Effects of fires on temperate forests: North Central U.S.' Fire and Ecosystems: 195-223 p. Kozlowski, T.T. and Ahlgren, C.E. (eds), Academic, New York.

This chapter of the Kozlowski - Ahlgren review discusses the effects of fire on vegetation in the north central states, including spruce, balsam-fir, tamarack, paperbirch, trembling aspen, shrubs, herbs, mosses and lichens.

Also discussed are site characteristics, such as post-fire soil temperature extremes, post-fire soil temperature duration, and relative humidity. Some general fire - vegetation interrelationships that are discussed are changes in height of plants in different strata of recovering vegetation in burned jackpine forests, changes in post-fire percent cover of trees, and changes in the number of plant species for the first fifteen years after fire in this area.

AHLGREN, I.F. 1974 'The effect of fire on soil organisms.'
Fire and Ecosystems: 47-72 p., Kozlowski, T.T. and Ahlgren, C.E.,
 (eds), Academic, New York.

A general review of the effects of fire intensity, temperature changes, changes in soil moisture, and changes in soil chemistry on algae, bacteria, actinomycetes, earthworms, snails, grasshoppers, leafhoppers, ants, termites, beetles, spiders, mites, collembolans, centipedes, and millipedes.

The effects of fire on soil fauna varied, and only two generalizations emerge. A) The effect of fire is greater in the forest than in grassland, perhaps because the species in grassland are better adapted to xeric conditions than the species found in the cooler, moist forest floor; or perhaps because fire intensity is greater in more abundant fuel in forest areas. B) With the exception of the mesofaunal species and spiders, the population reductions do not seem to be directly caused by heat of fire. More important in these decreases are post-fire changes in the environment.

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

This is an extensive review of literature and concepts of the ecology of forest fires. Topics include: Effects of fire on soil (soil-moisture relations, texture, temperature during burning, post-fire temperature, fertility, chemical and minor elements); Effects of fire on living organisms (lower plants, plant diseases, bacteria, invertebrates, vertebrates, plant succession, grasses and other herbs, shrubs, and trees.

AHLGREN, I.F., and C.E. Ahlgren 1965 'Effects of prescribed burning on soil microorganisms in a Minnesota jack-pine forest.' Ecology
 46: 304-10.

The effects of two prescribed burns on ten acre jack pine tracts are compared with similar tracts cut and unburned and uncut and unburned. Three-year results are given. The number and activity of most microorganisms decreased immediately after fire but rose abruptly to a very high level after the first rainfall following burning. This increase is believed caused by the leaching of ash minerals. Depth and extent of the effects were influenced by intensity of fire and moisture conditions. Number and activity of organisms were generally lower in burned soil the second growing season after fire. Some effects were still noticeable and third growing season. Rainfall also caused a fluctuation of microbial populations on the unburned tracts.

ALBINI, F.A. 1976 Estimating wildfire behaviour and effects. USDA For Serv Gen Tech Rep INT-30. 92 p.

This paper presents a brief survey of the research literature on wildfire behaviour and effects and assembles formulae and graphical computation aids based on selected theoretical and empirical models. The uses of mathematical fire behaviour models are discussed, and the general capabilities and limitations of currently available models are outlined.

Rothermel's fire spread model is used to develop nomographs for estimating rate of spread, reaction intensity, and flame length for a variety of typical fuel complexes under widely variable conditions. Factors affecting spread rate, and overall shape of a fire, are quantified as well as some fire effects, such as crown scorching, and duff removal.

Appendices give more details of formulations presented graphically in the text.

ALDRICH, D.F. 1973 Wilderness fire management planning guidelines and inventory procedures. USDA: 35 p. plus appendices.

Most guidelines and procedures outlined pertain to the northern Rocky Mountain Parks.

Considerable detail is offered on the topic of wilderness fire management planning, contents of wilderness fire management plans, chronology of wilderness fire management planning, data presentation and interpretation, fire management prescriptions, and inventories and procedures.

Fire management puts fire in perspective relating to overall forest service land management objectives meeting the needs of society, sustaining of environmental quality, and optimizing the lands productivity.

The objectives of wilderness management could be summarized as perpetuating natural and unmodified ecosystems.

ALDRICH, D.F. 1975 Fire management prescription: a model plan for wilderness ecosystems. USDA For Serv Res Pap INT: 103 p.

In 1970 the Forest Service Northern Region established a management direction which allows fire to play a more natural role in wilderness. The White Cap Wilderness Fire Management Study was begun in 1970 to investigate fire's role in wilderness and to describe procedures needed by fire managers to aid in the preparation of meaningful fire prescriptions. The study provides a defensible planning basis for preparing these prescriptions. The plan presented in this report does not represent a "let-burn" policy nor a slackening in fire prevention efforts. It is tailored to a specific area with specific management objectives. Subsequent reports will deal with inventory methods and fire prescription determinations.

ALDRICH, D.F., and R.W. Mutch 1972 'Wilderness fires allowed to burn more naturally.' Fire Control Notes 33(1): 3-6.

In 1970 a wilderness workshop was sponsored in Missoula by the Forest Service Northern Region. One of the outcomes of the workshop was a recognition by the participants that fire control was practiced in wilderness areas was unnatural. Subsequently, a new regional policy was adopted. This policy states that "fire will be allowed to more nearly play (sic) its natural role" in wilderness. This amounts to an administrative recognition of the influence of fire on vegetation diversity. Another product of the wilderness workshop was the Wilderness Fire Management Study established in the Selway-Bitterroot Wilderness. Others are also returning natural fire to wilderness areas and national parks. The 1970 Ringer Fire in the Gila Wilderness was allowed to burn with limited suppression action for 32 days. The Sequoia and Kings Canyon National Parks have instituted a program which allows lightning fires above 8,500 feet elevation to burn themselves out. At lower elevations prescribed burning is being used to return fire to the Sequoia groves.

ALEXANDER, M.E. 1976 A summary of book reviews on fire and ecosystems. Can For Ser, 12 p.

A bibliography of reviews with copies of reviews themselves, relating to fires in ecosystems edited by T.T. Kozlowski, and C.E. Ahlgren.

This informal report documents twelve completed reviews in professional and scientific journals as of the end of 1976.

ALEXANDER, M.E. n.d. The historical, ecological and managerial role of fire in Pukaskwa National Park. Unpublished proposal, submitted to Parks Canada. 19 p.

This is a detailed proposal documenting information needed and research methods for developing a fire management plan in Pukaskwa National Park.

ALEXANDER, M.E. n.d. Prescribed fire planning in Point Pelee National Park. Unpublished report. 14 p.

The purpose of the report was to provide a brief outline of a prescribed fire plan; to provide a list of selected references on prescribed fire management planning and associated matters in regard to the planning process; to provide an example of the current state of the art in evaluating potential fire behavior in a grass fuel complex; and to provide miscellaneous details for the proper execution of a prescribed fire.

ALEXANDER, M.E. and F.G. Hawksworth 1975 Wildland fires and dwarf mistletoes: A literature review of ecology and prescribed burning. USDA For Ser Tech Rep, Rocky Mount For & Range Exp St. 12 p.

Wildfires have been a primary factor in determining the distribution and intensity of dwarf mistletoes in unmanaged stands. In general, wildfires have tended to keep these widespread parasites in check. With the introduction of fire exclusion policies in most areas of the west in the last half century or so, dwarf mistletoes have increased, both in area affected and intensity. Encouraging wildfires in forests managed primarily for wood production in hopes that they will significantly reduce dwarf mistletoe losses cannot now be generally recommended. However, the possible encouragement of naturally occurring wildfires to reduce dwarf mistletoes in wilderness and park areas should be investigated.

Prescribed burning can also eliminate infected residual trees in logged-over areas, or destroy stands that are so heavily infested that the site is unproductive.

ALLEN, D.L. 1974 'Of fire, moose, and wolves.' Audubon 76: 39-49.

On Isle Royale in Lake Superior, one-quarter of the timberlands burned in 1936. The new growth of aspen, birch, willow, and other favored moose browse plants proliferated on thousands of acres. The moose responded with increasing numbers into the 1940s. This period was followed by overutilization of browse and increasing moose mortality.

ALUR, (various dates) 'North of 60.' Canada Dep Indian Aff North Dev Arctic Land Use Res Prog.

A series of papers under this title has been published dealing with fire and the vegetation in the western subarctic mostly in the MacKenzie River valley. The authors include a number of well-known ecologists: J.S. Rowe, K.A. Kershaw, and R.W. Wein.

AMMANN, G.A. 1963 'Status and management of sharp-tailed grouse in Michigan.' J Wildlife Manage 27: 802-9.

In Michigan, prescribed spring burning is practiced to improve sharp-tail grouse habitat. Spraying provides more control but is less selective. Spray followed by fire may be desirable, especially where conifers are present, for controlling brush.

ANDERSON, R.C. 1972 'The use of fire as a management tool on the Curtis Prairie.' Tall Timbers Fire Ecol Conf Proc 12: 23-35.

Studies on a Wisconsin prairie, of invertebrate response to fire, have shown that burning reduces the diversity and limits the number of soil arthropod individuals. Soil arthropod diversity is related to the quantity of litter and rate of decomposition. Fire reduces the amount of litter and also increases the rate of nutrient turnover; to this extent it limits soil arthropod diversity (from Lussenhop, Univ. Wisc. thesis, 1971). Organisms that occur below the soil surface are well shielded from fire because of the soil's insulating properties. During prairie fire, surface temperatures of up to 200°C were recorded for 70 to 140 seconds. However, at depths of 0.5 and 1.0 cm in the soil, temperatures were unchanged (from Reichert and Reeder, J. Animal Ecol., 1971). Immediately following fire, predatory spiders and soil arthropods that are resistant to dessication were found to increase. However, arthropods which were unable to escape the fire by getting under the soil or other protective objects such as stones, frequently are killed by fire.

ANDERSON, H.W. 1975 'Fire effects on water supply, floods, and sedimentation.' Tall Timbers Fire Ecol Conf Proc 15: 249-60.

The effects of fire on water in the forest are variable. Light or spot burning, away from channels, have little impact. Wildfires that kill the trees or consume the forest floor and other vegetation over a large area have a major impact on storms, erosion, sedimentation, and quantity of streamflow. The duration of effects is strongly influenced by the rate of revegetation. In the Pacific northwest, severe widespread wildfire continues to be a serious threat to water supply and to water and erosion control.

ARNOLD, J.F., D.A. Jameson, and E.H. Reid 1964 The pinyon-juniper type of Arizona: Effects of grazing, fire, and tree control. USDA For Ser Prod Res Rep 84.

In Arizona, pinyon and juniper have invaded both grazed and ungrazed grasslands. Small-scale broadcast burning of live stands of pinyon-juniper under controlled conditions was tried. Most of the type was too open for fire to carry between trees. Removal of overstory trees resulted in release of small trees, shrubs, and grasses. A light layer of slash increased production of grasses and forbs nearly 100 pounds per acre in one year. An August burn removed the most slash and killed most trees that had been missed on cabled areas. Burning increased grass production. If protected from fire, both shrub and grassland will be reinvaded by pinyon-juniper. Burning grasslands killed trees up to 3 feet in height. Grazing must be withheld prior to burning so fuel will be present. There is a high demand for forage and a low demand for trees in the area. Suppression of palatable understory browse and herbaceous species by overstory evergreens has reduced the forage supply for both game and livestock.

BADCOCK, A.C. 1958 'Prescribed burning and the growing of blueberries.'
Nfld Res Comm Symp Presc Burn, Mem U of Nfld 1958: 53-6.

It has long been observed that following the burning of an area of forest land, one of the first and most prolific plants to appear is the blueberry.

The summer following the burn new shoots generally refer to the sprouts grown to maturity and the following year their the most prolific crop of good quality fruit; except as and when new blueberry areas are required, prescribed burning is a cultural practice and will not pose any threat to Newfoundland forests. The full utilization of blueberry lands already in existence would take many years.

BAILEY, A. 1977 Alberta Range Improvement. U of Alta: 358 p.

This publication has a chapter on range improvement by prescribed burning. Bailey presents tables and findings gleaned from experience in burning on grassland, shrub land, and aspen forest habitat.

BAKER, J.O. 1975 The selected and annotated bibliography of wilderness fire managers. USDA For Serv: 36 p.

This bibliography is limited to works specifically relating to wilderness fire management. Many titles concerning fire control, prescribed burning, fire and smoke effects, and fire ecology have been omitted, though a representative few are included. It includes both the pro and con as well as planning methods, scientific studies, and editorials. Both technical and non-technical materials have been included. Eighty references are cited.

BAKER, W.W. 1973 'Longevity of lightning-struck trees and notes on wildlife use.'
Tall Timbers Fire Ecol Conf Proc 13: 497-504.

Of 66 pine trees that died following lightning strikes, all showed use by woodpeckers feeding; 80 percent had holes suitable for nesting or roosting. Hawks and vultures use snags for perching. Smaller birds such as chickadee and nuthatch, nest in snag cavities. Bats roosted under loose bark. Small mammals, such as rodents, utilize burned out root systems. Bears den in large holes. Burned out bases and root systems may be used by various reptiles. Numerous arthropods utilize dead trees under the basal bark. A number of forms of wildlife are associated with dead snags. Some species may be more or less dependent on dead trees.

BALDWIN, J.J. 1968 'Chaparral conversion on the Tonto national forest.'
Tall Timbers Fire Ecol Conf Proc 8: 203-8.

Grazing capacity in chaparral is low for both wildlife and live-stock because of the impenetrable cover and limited herbaceous growth. It appears that burning and spray treatment have improved the habitat for white-tailed and mule deer. Increases in the quail population were noted, and a notable increase in songbird populations was noted in the spring.

BANFIELD, A.W.F. 1949 'The present status of North American caribou.'
N A Wildlife Conf Trans 14: 477-91.

In parts of northeastern Canada, large forest fires during the latter part of the last century have been blamed for the caribou population decrease. On winter range in excellent condition bordering the barren grounds, there were no signs of fires.

BARROWS, J.S. 1966 Intelligence systems for forest fire control.
World For Conf, 6th, Proc, Madrid, Spain: 1934-1940.

Studies of fire control operations show a need for data on some 80 factors of weather, fuels, topography, risk, hazard, suppression force capabilities and characteristics of individual fires. The fire intelligence system which supplies these data involves gathering and processing information prior to the fire, during the fire, and after the fire. This system processes fire environment and control data over four main time periods: static information (very infrequent changes by time); gradually changing information (long term or seasonal changes); rapidly changing information (daily changes); and individual fire information (current data by hours and minutes). The system is designed to utilize constantly updated information in making two major types of calculations - one on fire behaviour and one on fire control actions. These calculations provide the primary guide for decision making.

BARROWS, J.S. 1973 'Forest fire management and Smokey Bear.' Nat Res Newsletter, 1(1): 2-4.

The recent emphasis on fire use by land managers has caused a controversy. Smokey the Bear, long a stalwart of fire prevention, is being challenged by those who claim that more fires are needed rather than fewer. Professional fire managers realize that although fire does have beneficial uses, it can be a killer and a destroyer as well.

BARROWS, J.S. 1974 'Forest fire management - for ecology and people.'
In Let the forests burn: Technical session proceedings. Colo State
 Univ, Coll For Nat Res, Dep For Wood Sci: 1-9.

Forest fire management is based upon the concept that forest fires may be good or bad. A fire which is bad for forest industry may be good for some aspects of the forest ecosystem. "Forest fire management is designed to resolve these conflicts." Management policies and technologies are applied to both prescribed fire and wildfire. Forest fire management must include a fire intelligence system, management of prescribed fire, management of wildfires, and a strong fire prevention program.

BARROWS, J.S. 1974 'The challenges of forest fire management.' West Wildlands 1(3): 3-5.

Revised concepts and new approaches are emerging for fire control and fire use. The overall concept of fire management recognizes that, among other things, some fires may be wanted while others are unwanted. The wanted fires require constant surveillance, suppression of portions that may violate planned standards, and full suppression if changed conditions cause the fire to be unwanted. New approaches to fire management are especially appropriate for large wildernesses. Fuels management, smoke management, fire prevention, and other problems provide constant challenges to the professional fire manager; however, some forestry colleges have expanded their curricula to help meet these needs. "There is one overriding challenge to fire management: that of maintaining full respect for the power of fire and its effects on both the wildland environments and the people who live and work in these environments."

B.C. FOREST SERVICE 1966 The stored moisture index/a guide to slash burning. B C For Ser. 2 p.

A brief discussion on how to use estimates of moisture stored in the upper layers of the soil as a guide to fire behaviour.

BEAUFAIT, W.R. 1970 Forest fire and the environment. North For Fire Laboratory, Missoula, MT. 10 p, 21 slides.

This is a pictorial presentation of fire in the Northern Rocky Mountains. Topics presented include: energy conversion, nature of fuels, causes and types of fires.

There is also a brief discussion and presentation of prescribed burns in the area.

BEAUFAIT, W.R. 1971 'Fire and smoke in Montana forests.' Forest land use and the environment, R.M. Weddle (ed), Mont For Conserv Exp Sta, Missoula, Mont.

Fire is an important ingredient in many wilderness ecosystems. Wildfires and prescribed fires will be used to accomplish management objectives such as maintaining vegetative diversity, reducing fuel accumulations, etc. One problem, however, is that of smoke emissions. Forest fire smoke, which is classified as a pollutant, contains primarily carbon dioxide, water, and particulates. Nothing is contained in it that doesn't occur naturally without fire. Fire only speeds up the oxidation processes. Fire exclusion only postpones the inevitable. Fuels build up to unnatural levels. When a fire does start, the unnatural fuel loadings make control very difficult. These fires also produce smoke, but in much greater quantities and under conditions that make it impossible to manage. One of the best ways to combat forest fire smoke pollution is to use fire - natural and prescribed - under conditions favorable to smoke dispersion.

BENDELL, J.F. 1974 'Effects of fire on birds and mammals.' Fire and Ecosystems: 73-138. Kozlowski, T.T. and C.E. Ahlgren (eds), New Academic Press, NY.

An extensive review of the immediate and long term effects of fire on birds and mammals. General principles are outlined and illustrated with species examples. In particular the effects of fire on climate and microclimate and the structure of vegetation are outlined.

The function of vegetation as both cover and food for wildlife is discussed in depth and effects of fire on these functions is related to a large number of bird and mammal species. Comprehensive tables on species change in terms of numbers and distribution before and after fire are compiled.

Case histories on moose and grouse are given and a discussion of the evolution of birds and mammals in a burnable habitat includes some considerations on how wildlife may affect fire.

BERNDT, H.W. 1971 Early effects of forest fire on streamflow characteristics. USDA For Serv Res Note.

A comparison of streamflow records from three small mountain streams in north-central Washington before, during, and after a severe forest fire showed three immediate effects of destructive burning.

- (1) Flow rate was greatly reduced while the fire was actively burning.
- (2) Destruction of vegetation in the riparian zone reduced diurnal oscillation of flow rates.
- (3) Flow rates quickly increased to points above protracted normal depletion rates but to varying degrees.

No drastic immediate change in stream temperatures was noted.

BERNIER, G.H. 1965 and 1966 Reports of the sub-committee on slash disposal and prescribed burns of the associate committee on forest fire protection of the National Research Council for the years 1964 and 1965. Quebec Dept Lands & Forests.

An outline of prescribed burns proposed and carried out in Canada in the preceding years. Results, objectives, and techniques are discussed for each burn. This publication was discontinued in 1966.

BISWELL, H.H. 1961 'Manipulation of chamise brush for deer range improvement.' Calif Fish & Game 47: 125-144.

Some mortality occurs when sprouts of deerbrush are heavily browsed during the first growing season after burning. Burning of brushfields in the fall appeared to produce more seedlings than spring burning. Burning after April 1 delayed seed germination until the following spring.

BISWELL, H.H. 1963 'Research in wildland fire ecology in California.' Tall Timbers Fire Ecol Conf Proc 2: 53-97.

Light controlled burning in ponderosa pine constituted no hazard in the development of tree-killing insects. Rodent trapping resulted in not a single mouse caught in areas of pine cleaned by prescribed burning. Fire may create conditions unfavorable to rodents.

BISWELL, H.H. 1969 'Prescribed burning for wildlife in California brushlands.' N A Wildlife & Nat Res Conf Trans 34: 438-44.

Prescribed burning can be a useful tool in the manipulation of brushlands for wildlife. Some shrubs put out crown sprouts after fire; others reproduce only from seed. A prescription must be prepared for each area to be burned. An associated benefit to burning is the improved access for hunting. Controlled burning under permit was authorized in California in 1945. Some prescribed burning, mainly in chamise chaparral, has been done exclusively for wildlife. Studies here showed that where dense brush had been opened by scattered, small burned patches, deer density was approximately three times greater than in untreated brush even after 5 and 6 years. On an intense wildfire burn, deer density rose 400 percent by the next summer, but rapidly declined. The wildfire burn was expected to reach the same status as the heavy untreated brush in 12 to 15 years. The forage in the opened-brush burns was of higher quality and deer maintained winter weights better than on untreated areas. The management objective apparently should be to reduce the brush cover in spots and introduce palatable, herbaceous species for use in winter and early spring. This results in desirable interspersions of food and cover. Management should maintain productivity over a long period.

BISWELL, H.H. 1972 'Fire ecology in ponderosa pine-grassland.' Tall Timbers Fire Ecol Conf Proc 12: 69-96.

Following burning in ponderosa pine-grass type, resprouting shrubs were more tender and available for browse. More sunshine reaching the understory improves palatability and nutrients. Fire is an effective tool in controlling shrubs in the pine understory. It might remove non-sprouting shrubs and reduce sprouters. If more shrubs is the objective, they should be established in openings. It may take several fires to deplete the supply of seeds in the ground. For highly desirable shrubs, such as bitterbrush, any fire should be used in the fall after the seeds have been cached where they will be protected.

BLACK, H.C. and E.H. Hooven 1974 'Response of small-mammal communities to habitat changes in Western Oregon.' Wildlife and Forest Management in the Pacific Northwest. Proceedings of a Symposium held in 1973 at Oregon State University, Corvallis, Or. Hugh C. Black (ed), p. 177-186.

In the Pacific Northwest, more than twice as many plant species occurred on a clearcut and slash burned Douglas-fir site as were found in a mature forest. After the 43,000 acre Oxbow Burn of 1966 in western Oregon, a study was initiated to determine the impact of the fire on small mammal communities. Plant succession progressed rapidly with forbs and bracken fern giving way to shrub dominance by 1973, seven years after the fire. Small mammal populations were decimated by the fire. Within one year, deer mice were much more numerous on burned areas than on unburned areas, but other species were absent or scarce. Shrews and voles which were abundant on unburned areas apparently were destroyed by the fire or were unable to survive after habitat destruction. Within two years large increases occurred in abundance of Oregon and long-tailed voles, and a few shrews were first recorded. Trowbridge's and vagrant shrews and Oregon voles continued to increase each year. Long-tailed voles had disappeared completely on burned areas by 1971; they were never trapped on unburned, control areas. In 1973, western red-backed voles were first taken on the unburned area in Douglas-fir regeneration. Populations of deer mice declined sharply and a decline in total numbers of small mammals occurred on burned areas in 1970. Thereafter, size and relative species composition of small mammal communities was nearly comparable on burned and unburned areas. However, seven years after the fire, chipmunks seldom were found on the burn.

BLAKEY, H.L. 1947 'The role of brush control in habitat improvement on the Arkansas National Wildlife Refuge.' N A Wildlife Conf Trans 12: 179-85.

Exclusion of natural and planned burning in some forests (Texas) has resulted in a jungle of mixed hardwoods that definitely limits the carrying capacity for wildlife. In the absence of burning on the Arkansas Refuge, the succession goes directly to brush dominated by live oak. The brush is becoming so dense it will exclude or limit use by most wildlife species. A combination of cutting and burning has been used for opening the cover initially. Thereafter, burning at frequent intervals maintains the desired conditions. Grass is the medium necessary for carrying a controlled fire. Proper burning does not kill the stand of perennials. Some of the most valuable forage and wildlife food plants are stimulated by the burning process. Some of the most valuable grasses appear most abundantly immediately after burning. It is doubtful that a rich leguminous flora can be retained for long without some amount of burning. Brush will overtop the grasses within five years if burning is not repeated. Live oak cannot survive properly planned and executed burning. Wildlife species benefited include: deer, turkeys, quail, dove, jacksnipe and sandhill cranes. Some wintering song and insectivorous birds must readjust to unburned tracts. Predators find less protection.

BOARDMAN, W.S. 1967 'Wildlife and natural area preservation.' Tall Timbers Fire Ecol Conf 6: 135-42.

The discussion of wildland preservation policies particularly by the Conservancy in Wisconsin. It is concluded that allowing fire is not only compatible with wilderness preservation, but where fire is excluded over a period of years the land ceases to be a living museum of the past.

BOUGHTON, V.H. 1970 A survey of the literature concerning the effects of fire on the forests of Australia. Harvard Press Pty Ltd, Pymble, Australia. 40 p.

This bibliography was prepared for the Council of the Municipality of Ku-ring-gai, an area within the metropolis of Sydney. This municipality is vulnerable to wildland fires. The bibliography includes material published about Australia or relevant to Australia organized under these topics: hazard reduction, fire on soil, fire on seed shedding, germination and regeneration, fire on animals, fire on runoff and erosion, fire on plant communities, and fire on the human community. There are about 175 citations. The information is presented in a 32-page report.

BRACKENBUSCH, A.P. 1973 'Smokey Bear - compatible with let burn?' Proc West For Fire Comm Annu Meet (San Jose, CA) 1973: 27-30. West For Conserv Assoc, Portland, OR.

Should Smokey Bear retire? Smokey's job is preventing forest fires, but the Forest Service and other agencies are using prescribed fire for management purposes. Scientists have established that fires play a natural role in wildland ecosystems. Some fires are needed; however, the "let burn" attitude is not compatible with Smokey Bear. This choice of words implies a "hands off" or "no management" stance. This should not be. According to the author there are no reasons for scientific disagreement between fire prevention and programs which permit fire by prescription management. Both are needed. Smokey, therefore, should not retire. His fire prevention message is as important as ever.

BROTAK, E.A. and W.E. Reifanyder 1977 'An investigation of the synoptic situations associated with major wildland fires.' J Appl Meteorol 16: 867-70.

A report on the analysis of the synoptic weather conditions at the time of occurrence of 52 wildland fires in the eastern U.S. in the period 1963-73. There were frontal situations associated with seventy-five percent of the fires, half occurred following the passage of a dry cold front. Analysis of the pressure patterns of the 500 mb level showed that the vast majority of fires occurred in the southern portion of a short wave trough of small amplitude having a radius of curvature of less than 640 km normally centred in Canada. This lack of latitudinal spread mitigated against large scale advancement of moisture from the south and therefore hindered the occurrence of precipitation in the frontal passage.

BROWN, A.A. and K.P. Davis 1973 Forest fire control and use. 2nd ed. MacGraw-Hill, New York. 686 p.

This is the second edition of the well-known textbook on forest fire; see Davis (1959). Several chapters deal with certain ecological aspects of fire such as the shaping of forest types, fire injuries, and effects of fire on microclimate, soil, and vegetation. There is a full chapter on use of fire in wildland management, and another chapter on prescribed burning.

BUCKLEY, J.L. 1958 'Effects of fire on Alaskan wildlife.' Soc Amer Foresters Proc (1957): 123-6.

The effects of fire on wildlife are direct and indirect. The direct destruction of animals would be principally in the spring on nests and young of birds and mammals. These losses are temporary provided there is a source of reinvasion and provided the habitats have not changed significantly. The indirect effects on habitat are far more important and may last for decades, or may be irreversible. Fire may be responsible for decreased water levels due to denuded surface effect on lowering permafrost table - this may be the most significant and far-reaching effect of fire on wildlife. The present patchwork of vegetation types provides much desirable edge. Relatively few wildlife species depend upon climax vegetation. The caribou is the best example - they can survive without lichens, however, they regularly prefer them. Lichens do not recover from fire for 30-40 years or more. Immediately following fire there is little to attract any wildlife species. By the third or fourth year sub-climax communities provide browse from sprouts, etc. The effect of lowered water levels reduces the area available to waterfowl. But removal of woody vegetation as by fire increases the attractiveness of areas to waterfowl. Also, new vegetation appears earlier and provides early nesting sites. Early nests are most successful where growing seasons are short.

BURTON, D.H. 1949 The Gogama Fire of 1941. Ont Dept Lands & Forests Res Paper. 10 p.

The fire occurred in the spring in a time of unusual hazard. The fire was of incendiary origin for the two main fires and probably for the third. A greater proportion of cut-over land lay in the fire track than in the case of most other large fires. This fire killed practically all the trees present excepting an occasional white and red pine. There were also some isolated patches of black spruce and black ash along with some jack pine that survived the fire. The presence of hardwoods and underbrush may have been a factor that helped protect these patches.

A map accompanies the study showing the fire area with areas that warrant a high degree of protection from fire.

BURTON, D.H., and N. H. Sloane 1958 Progress report on prescribed burning in the hard maple-yellow birch cover type in Ontario. Ont Dept Lands & Forests, Sect Rep No 24.

The experiment described in this report is directed towards the improvement of low quality hardwood stands by the use of prescribed burning. The preparation of the seed bed for spruce, pine and yellow birch seed and the partial elimination of brush competition are the desired results.

The author contends that the prescribed burning described in this report merits consideration as a silvicultural method in improving low quality hard wood stands. The fire is burned satisfactorily with relative humidities up to 60% and with low velocity winds. It is improbable that one fire will create a suitable seed bed as the lower layer of leaves are generally too wet to burn. However this layer dries out after the initial fire removes the upper layer of dried leaves and in some years it may be possible to burn the litter twice during the same fall. Some portion of the undesirable competition will also be eliminated.

BURTON, D.H., W.H. Anderson, and L.F. Reilly 1969 'Natural regeneration of yellow birch in Canada.' Birch Symposium Proc, N E For Exp Stat USDA: 55-63.

An ecological framework and background research is outlined for regeneration of yellow birch. Experimental regeneration systems are outlined and brief attention is given to prescribed burning.

BUTTS, D.B. 1973 'Fire management planning in Rocky Mountain National Park.' In Let the forests burn: Colo State U Dept For Wood Sci Coll For Nat Res Nat Sess Proc: 10-18.

The intent of the fire-management program for the Rocky Mountain National Park is to perpetuate the various ecosystems that were present before "modern man". The past policy of strict fire suppression has created unnatural balances within these ecosystems. The National Park Service has now implemented a plan which calls for lightning-caused fires to be allowed to burn under certain predetermined conditions. Lightning fires, occurring when these conditions are not met, and all man-caused fires are extinguished as quickly as possible.

BUTTS, D.B. 1974 'Fire management in Rocky Mountain National Park.' Tall Timbers Fire Ecol Conf 14: 59-73.

The terminology that is used by professionals in fire management is discussed and related to public perception of fire management policies.

CABLE, D.R. 1972 'Fire effects in southwestern semidesert grass-shrub communities.' Tall Timbers Fire Ecol Conf Proc 12: 109-27.

Shrubs are most susceptible to burning in June. Mature mesquite and creosotebush can be controlled by burning if sufficient ground fuel is present. False mesquite and some other species sprout. Fire can be used to control spread of shrubs. Prescribed burning seldom increases perennial grasses in the southwest semi-desert.

CALIFORNIA DIVISION OF FORESTRY 1959 'Suggested safety guides for controlled burning.' Dept Nat Res, 12 p.

A government publication that outlines inspection of the area before a prescribed burn, suggestions for precautions for burning, location of fire lines, construction of fire lines, safety measures for controlled burns, pre-firing plans, and patrol and mop-up action.

CANADA FORESTRY SERVICE 1976 Fire in the forest, fact sheet. Env Can Ottawa, 4 p.

A brief brochure intended for the layman which describes forest fire losses in Canada, the function of protection, and beneficial uses of fire. Steps to fire safety in the woods are emphasized.

CAYFORD, H.H. 1963 Some factors influencing jackpine regeneration after fire in southeastern Manitoba. Canada Dep For Publ 1016, 16 p.

A study of a burn which occurred on the Sandilands Forest Reserve in 1955. Information was obtained on the number of jackpine seedlings and the factors that affected germination and survival. Practically all of the seedlings germinated in the spring following the fire. Mortality due to drought was heavy in the second and sixth seasons especially on dry sites.

CAYFORD, J.H. 1970 'The role of fire in the ecology and silviculture of jackpine.' Tall Timbers Fire Ecol Conf Proc 10: 221-44.

A review of the effects of both wildfire and prescribed burning on the regeneration of this species. Topics discussed include: cone production, cone opening and seed dissemination, and proper seedbed conditions for regeneration of jack pine.

The role of prescribed burning in disposal of slash is also discussed.

This review relates fire to the silvical characteristics of jack pine and many examples of prescribed burns and wildfires are cited from Canada, particularly Ontario and Manitoba.

CHAMRAD, A.D. and J.D. Dodd 1972 'Prescribed burning and grazing for prairie chicken habitat manipulation in the Texas Coastal Prairie.' Tall Timbers Fire Ecol Conf Proc 12: 257-75.

Prescribed burning offers strong possibilities for prairie chicken habitat manipulation in the Coastal Prairie. It appears to be a useful management tool for maintaining high quality habitat where grazing is greatly restricted or eliminated. Nesting and brooding is the most critical period. In ungrazed areas, all dates of prescribed burning improved the quality of nesting and brood habitat. Fall burning is most favorable for food production.

CHANCEY, H.W.R. 1958 'Changes in the soil following burning.' Nfld Res Comm Symp on Prescribed Burning. Mem U of Nfld.

Characteristics of Newfoundland mineral soils are outlined, and peculiar conditions which often develop after burning are described.

Generally soils are invariably acid, shallow, and stony and possessing in most cases low plant fertility, and low organic matter content.

The greatest constituent loss in soils after a severe fire is organic matter.

The author concludes that burning has a negative effect on soils under specific circumstances, but with prescribed burning for definite purposes there should be no significant soil change.

CHANDLER, C.C. and C.F. Roberts 1973 'Problems and priorities for forest fire research.' J For 71(10): 626-8.

An outline of needs in the forest fire research area, with special emphasis on better understanding fire behaviour and its effects, and more effective risk reduction in the area of prescribed burning.

CHAPMAN, H.H. 1960 'The use of prescribed and controlled fire in the silviculture of North American conifers.' Proc Fifth World For Congr, Seattle. SP/232/I-USA. 4 p.

Professor Chapman of Yale University gives a history of his observations about fire and silviculture with USA beginning in 1908. He argues for the absolute necessity of prescribed fire to attain healthy reproduction of long-leaf pine in southern USA. He recounts his long arguments with other members of the forestry profession in his efforts to get fire accepted as a silvicultural tool.

CHRISTENSEN, G.C. 1970 The chukar partridge. Nev Dept Fish & Game Biol Bull 4.

When cheatgrass fires occur after chukars are capable of strong flight, it is doubtful that any serious loss is sustained. Chukars have been observed to return to a burned area almost immediately following a fire.

CHROSCIEWICZ, Z. 1970 Regeneration of jackpine by burning and seeding treatments on clear-cut sites in central Ontario, Can For Ser Dept Fish & For, Info Report 0-X-138, 11p.

Eleven summer-burning and spring-seeding treatments were experimentally tested in central Ontario for the purpose of regenerating jack pine on clearcut sites. Burning was done under different drought conditions and the resulting seedbeds were then broadcast seeded at a rate of 16 ounces of seed per acre. In terms of pine establishment, the treatments were highly successful. The third-year stocking by 0.001 acre quadrats was 60 percent on one plot and 80 to 99 percent on 10 plots. The number of trees ranged from 2,564 to 27,638 per acre, and practical means for controlling regeneration density in future burning and seeding treatments were suggested.

CLAR, C.R. and L.R. Chatten 1966 Principles of forest fire management. Calif State Bd of For, 26 p.

A general text on the principles of forest fire management oriented primarily towards suppression. Of particular interest for this study were chapters on the principles of combustion, the effects of weather on fire, and the effects of topography on fire.

CLAYTON, J.L. 1976 'Nutrient gains to adjacent ecosystems during a forest fire: an evaluation.' For Sci 22: 162-6.

Concentration of Na, K, Ca, Mg, and N in precipitation falling through smoke during a forest fire in central Idaho was 20 to 70 times greater than in normal precipitation. Hypothetically calculated nutrient inputs by dry deposition and wet deposition summed together provided 1 to 4 percent of the annual nutrient gain to standing timber in an adjacent watershed. In spite of the naturally high return frequency of wildfires in the mountains of central Idaho, it is unlikely that nutrient redistribution by smoke is of ecological significance away from the burned site.

COCHRANE, G.R. and J.S. Rowe 1969 'Fire in the tundra at Rankin Inlet N.W.T.' Tall Timbers Fire Ecol Conf Proc 9: 61-74.

Fires do occur in the Canadian tundra and their traces were observed on a variety of topographic sites. They burn readily downwind but are easily halted by physical obstacles in an upwind direction.

Burning is selective, reflecting fuel differences in the vegetation and habitat moistness. *Alectoria* lichen communities burn readily and evenly. *Cetraria* lichen communities burn less easily, while mixed lichen-and-heath communities burn irregularly according to type and quantity of fuel. Apparently Labrador tea and ground birch are particularly flammable and burn fiercely.

Growths and regeneration of lichens and heaths following fire seems to be slow. Arctic holy grass is an important early colonizer of dry, sandy and stoney burned areas. Its dominance in a locality, especially if banded alternately with sparsely vegetated moss-peat areas, strongly suggests earlier fire influences.

COMMITTEE ON NORTH AMERICAN WILDLIFE POLICY 1973 N A Wildlife & Nat Res Conf Trans Report 38: 152-78.

Wild fires in forests and grassland can be hugely wasteful. But planned burning is essential to the maintenance of certain habitats and wildlife. Prescribed surface fires are needed to perpetuate many western conifer types.

Fires played an essential role in preserving most of our primitive grasslands. Burning usually is required to retard woody plant invasions and rejuvenate native grasses. It should be generally recognized that properly controlled burning is essential technology in managing many kinds of vegetation.

In successional communities it is necessary to manage the habitat to achieve or stabilize it at a desired stage. For example, fire is an essential management tool to maintain the American prairie.

COOK, S.F. 1959 'The effects of fire on a population of small rodents.'
Ecology 40: 102-8.

A 600 acre of grassland and brush near Berkeley burned by an October wildfire. Both the grass and brush covered areas burned completely leaving practically no cover. Annual grasses dominated the grassland during the second and third years following the fire. On the brush habitat which had been *Baccharis*, *Rhus*, and *Artemisia* species interspersed with grasses, no cover remained. Annual grasses and weeds came in along with some shrubs the second and third years. Small mammals were trapped on the two habitats, both on the burn and on adjacent control areas. After an initial extermination of mice on the burn, lack of cover apparently restricted size of rodent populations. Food was abundant by the spring following fire. *Microtus* apparently needed at least one year's accumulation of litter to afford cover. Conditions reached an optimum the second year for *Reithrodontomys* in the grassland. *Peromyscus*, also a seed eater, remained at low population levels - probably due to restricted home ranges. The many seed producing annuals occurring after the fire especially benefited *Reithrodontomys*, which irrupted on the burned grass area during the second recovery year. The change in habitat type from brush to grass was accompanied by a general species shift from brush dwelling mice to grass dwelling species.

COOPER, C.F. 1961 'The ecology of fire.' Sci Am 204(4): 150-60.

"Fire has played a major role in shaping the world's grasslands and forests. Attempts to eliminate it have introduced problems fully as serious as those created by accidental conflagrations. Over wide regions the patterns of plant life have changed. Large areas of grasslands, once maintained by fire, are being replaced by shrubs, while fire is being excluded. Douglas-fir stands are being replaced by cedar and hemlock. In some forested areas fire exclusion has also resulted in massive buildup of fuels which, when subsequently burned, add to the intensity of the fire and result in very destructive fires. Once park-like ponderosa pine savannahs are being clogged with dense thickets of young trees. Fuel is accumulating to the extent that future fires may destroy the ponderosa stands. It is time that the ingrained prejudices against fire be abandoned in favor of the judicious use of fire as a tool in wildland management."

COOPER, R.W. 1975 'Prescribed burning.' J For 73: 776-81.

Prescribed fire, once considered an art in itself, has achieved scientific status.

This general review of burning practices identifies fuel and weather conditions necessary for successful treatment; burning techniques and practices that produce required intensities and behaviour; and effects and responses that can be predicted from various burning operations. Smoke management is also discussed.

COOPER, R.W. 1975 'Trade-offs between smoke from wild and prescribed forest fires.' Int Symp Air Qual & Smoke from Urban & For Fires (Ft. Collins, CO, 1973), Proc Nat Acad Sci, Washington, D.C.

Wildfire smoke is often ten times greater than prescribed fire smoke, because wildfires consume considerably more fuel per acre. The particulate count per ton of fuel consumed is also much higher. Hazard-reducing prescribed fire reduces the acreage lost to wildfire. Therefore, a small amount of smoke in the right places and under the right conditions is a better alternative than the problems and consequences of wildfires and their big smokes. "Trading off potentially large quantities of objectionable smoke for small quantities of inoffensive smoke is just good business."

CONNAUGHTON, C.A. 1972 'The impact of fire on forest values and services other than wood.' Symp on Fire in the Env (Denver, 1972) Proc p. 51-54. Also published under title 'Forest fires damage more than trees.' Am For 78(8): 30-31, 60-63.

Fire affects other forest resources as well as timber. Its impact on watershed and recreation are generally adverse. The positive impact on recreation is in the maintenance of ecological succession. The direct effects of fire on wildlife are detrimental, while the secondary effects are beneficial. Beneficial effects of fire must outweigh the detrimental ones if fire is to be used by man. If there is uncertainty, fire should not be used!

CORBETT, E. and R. Rice 1966 Soil slippage increased by brush conversion. USDA For Serv Res Note PSW-128, Pac Southwest For & Range Exp Stn, Berkeley.

In the San Dimas area, six years after about 350 acres of a burned brushland was converted to grass, the area and number of soil slips were about five times greater on the grass area than on the naturally recovering brush cover.

COUNTRYMAN, C.M. 1969 'Fuel evaluation for fire control and fire use.'
J Ariz Acad of Sci Proc Symp on Fire Ecol and Control and Use of
Fire. Wildland Man, April 19, 1969: 30-37.

How a fire will burn and how much damage it will do depends on the characteristics of vegetation as a fuel. If we are to protect our wildlands from fire and use fire efficiently as a management tool, then we must regard vegetation in the same way fire would - as a fuel - and learn to evaluate it in terms that relate to fire behaviour.

This article establishes the meaning of some basic fuel descriptors, such as the ratio of the surface area to the volume of the fuel, fuel bed porosity, moisture content, thermal pulse, and fuel loading. Techniques are suggested for altering the nature of fuel to obtain desired results through prescribed burning.

COWLES, R.B. 1967 'Fire suppression, faunal changes and condor diets.'
Tall Timbers Fire Ecol Conf Proc 7: 217-24.

Extensive suppression of fire in much of southern California chaparral areas might have caused serious stresses in the lives of its native fauna possibly including a food deficiency for the condor. Extensive fire suppression with extreme changes in vegetation and the associated faunistic consequences may have adversely affected condors. There may be a calcium deficiency due to changing diet to larger animals. Condor are hampered or excluded from tall, dense vegetation as chaparral; small mammals are not plentiful and are difficult to get. Lack of large openings results in difficulties of gaining flight.

CRAIG, J.B. 1972 'Scientific incendiarism.' Am For 78(8): 11.

The opposite extremes of the fire-use issues are represented by those who say "keep fire out" and those that refer to "fire as a resource". The "let-burners" want to change the image of Smokey the Bear. They want his thrust to be that fire can be used as a tool. The American Forestry Association is being accused of being too conservative about fire. AFA feels the emphasis should be placed on bringing more forested land under organized protection rather than on more prescribed fire. AFA also feels that the air pollution questions raised by the "management fire" issue must be answered. The author believes that it may be unwise to change the image of Smokey now. He raised the question as to whether long-term research on "let burn" is adequately considering the effects on watershed.

CRAIG, J.B. 1974 'Herding fires.' Am For 81(1): 39, 50-1.

With changing attitudes toward fire use as a part of fire management, some believe that the new concepts are widely and generally accepted by both the professional and lay public. This, however, is not the case. In fact many people are getting angry at the thought of letting fires burn. Many more are concerned with the smoke that is being generated. The fire manager is suggesting that some fires be "herded" rather than "suppressed". He says that without fire, wilderness ecosystems will be damaged. At the Fire and Land Management Symposium that was held in Missoula in 1974 most of the speakers were in favour of herding fires. Some of the participants may have been over enthusiastic. The American Forestry Association cautions that practitioners should not be too enthusiastic. They should show prudent restraint. They should not hide the dangers of herding fire in obscurity. Fire herding is not "over the hump" yet. Fire managers should expect some "powerful people" to challenge the principles of this program.

CRAIG, J.B. 1974 'Lightning strikes.' Am For 80(7): 38-9.

Today, in some areas, fires caused by lightning and other ignition sources are allowed to burn on a prescription basis. When fires threaten to cause unacceptable losses, they are extinguished. Fire is a scientific tool under proper scientific controls. The American Forestry Association accepts "prescribed" fire when such fires serve useful purposes and are controllable. The Association does not accept nature's fires as good or bad but believes that all fires must be subject to control.

CRAIG, J.B. and I. McManus 1972 'Fire in the environment.' Am For 78(8): 24-9, 52-5.

In May 1972 a "Fire in the Environment Conference" was held in Denver, Colorado. The meeting became a confrontation between "let-burners" and "keep-fire-outers". Views represented at the conference ranged from a very liberal one calling for increased use of fire to one calling for care and moderation. This article presents a summary of the meeting and the papers presented.

CRINGAN, A.T. 1958 'Influence of forest fires and fire protection on wildlife.' For Chron 34(1): 25-30.

In Ontario, when all other succession-inducing factors such as wind, flood, or insects, remain constant, effective fire protection will reduce the moose-carrying capacity of the area quite rapidly. Moose need large areas of plant communities that are in relatively early stages of plant succession. On the other hand, woodland caribou need mature forest stands; therefore, fire protection will result in a slow increase in the caribou-carrying capacity.

CUSHWA, C.T. 1968 Fire: a summary of literature in the United States from the mid-1920's to 1966, Asheville, N.C. USDA, For Ser, SE For Exp St Z5991 C87, 117 p. Ref.

A bibliography containing 823 items broken down by author and subject categories.

CUSHWA, C.T. and R.E. Martin 1969 'The status of prescribed burning for wildlife management in the southeast.' N A Wildlife & Nat Res Conf Trans 34: 419-28.

The southeastern Coastal Plain is a fire-disturbed ecosystem. The flora and fauna have evolved in the presence of frequent burning. The characteristics of a fire that determine the effects on the biotic community are: (a) fire temperatures, (b) duration of temperature, and (c) transfer of heat. These factors are governed primarily by (1) fuel size, moisture content, and density; (2) fuel arrangement and (3) wind. Also, note heat transfer within a body and the lethal temperature-time relationships of living tissue.

CWYNAR, L.C. 1976 'The recent fire history of Barron Township, Algonquin Park.' Can J Bot 55: 1525-38.

The recent fire history of Barron Township was studied by examining historical documents and dating past forest fires using fire scar techniques. Lightning is still a major ignition source. Meteorological data showed that drought prevailed across southern Ontario during 1875, when major fires burned in Barron Township. The recent fire rotation, i.e., the average time required to burn an area equivalent to the size of the study area, is about 70 years. Field evidence and increment borings suggest that the present vegetation mostly originated as a consequence of the fire of 1875.

DANIELS, O.L. 1974 'Test of a new land management concept: Fritz Creek 1973.' West Wildlands 1(3): 23-6.

The first real test of the White Cap Fire Management Plan came in 1973 with the Fritz Creek and Snake Creek fires. The fire-management prescriptions for the five ecological land units were based on many years of study and experience. The Fritz Creek Fire was lightning caused. It was within the planned area and burned according to predictions. A minimal suppression effort kept this fire within the planned area. The Snake Creek Fire was outside the planned area and was caused by either a spot fire or, more probably, a slop-over from the Fritz Creek Fire. This fire was extinguished only after a sizable expenditure of funds. It too burned according to predictions and gave much valuable information. One thing learned was how to make better use of fire-behaviour specialists. These events proved that fire could be permitted in wilderness ecosystems. The payoffs are a more ecologically stable wilderness, knowledge of fire ecology, and development of alternative methods of fire suppression.

DANIELS, O.L. 1974 'The practice of fire management requires commitment.' Tall Timbers Fire Ecol Conf Proc 14. (Fire and Land Manage Symp co-sponsored by Intermt Fire Res Counc, Missoula, MT, Oct. 1974).

The land manager faces many obstacles once the decision is made to implement a fire management program such as the one in effect in the Selway-Bitterroot Wilderness. These obstacles are caused by: tradition of the fire suppression and prevention profession; feared losses by users of forest products; and a lack of understanding by the lay public. The land manager must anticipate these problems and, before they occur, develop plans for avoiding and/or dealing with them. Personal and organizational commitments are a must.

DASMANN, W., R. Hubbard, W.G. Macgregor, and A.E. Smith 1967 'Evaluation of the wildlife results from fuel breaks, browseways, and type conversions.' Tall Timbers Fire Ecol Conf Proc 7: 179-93.

Bulldozed lanes on ridgetops, parallel contours, etc. for fuel breaks, access for fire fighters, etc. also provide access for deer and improve nutritive value of forage. Deer use increased ten times. Some 14-year-old jobs are still functioning. Prescribed burning, preferably after crushing the brush with bulldozers, is also done to open stands. When burned for deer habitat improvement, areas should be small or at least discontinuous. Cover patches of 40 acres or more are necessary. No point should be more than 100 yards to cover. Burning with crushing has cost approximately \$30 per acre. Wildfire rehab usually consists of aerial seeding to grass and spraying with herbicide to control brush sprouts. Rehab provides opportunities for considering wildlife. Studies on Cow Mountain showed that fawn production and the total population of deer increased markedly on treated areas.

DAUBENMIRE, R. 1959 Plants and environment: a textbook of autecology.
2nd ed, Wiley, New York. 422 p.

In its first edition (1947) this was one of the first textbooks to recognize fire as a factor of the plant environment. This book deals with ecology in terms of the environmental factors and their effects on organisms. A chapter is devoted to each of soil, water, temperature, light, atmospheric factor, biotic factor, fire, the environmental complex, and ecological adaptations. The chapter on fire deals with kinds of fire, the various ways in which plant species have adapted to fire, injury and stimulation, removal of competing species, alterations of the environmental factors, and the use of fire to favour certain plant species, to improve the quality of forage, and to remove organic debris.

DAUBENMIRE, R. 1968 'Ecology of fire in grasslands.' Adv Ecol Res
5: 209-66.

This is a comprehensive review of the literature leading to generalizations regarding environmental alterations, effects on plant species, effects on vegetation, and effects on animals. The following topics are covered: temperature during fires, the character of grass fires, environmental effects (temperature, organic matter, erosion, soil moisture, soil chemistry, and microclimate), effects on soil biota and above-ground animals, effects on individual plants and plant communities, and burning versus mowing. The central theme of the review is the ubiquity and importance of burning in determining the distribution and form of many plants and the composition of vegetation.

DAVIS, K.P. 1959 Forest fire control and use. McGraw-Hill, New York. 584 p.

This is the basic text on control and use of forest fire in the United States and it has been used extensively in Canada as well.

Although the emphasis is on suppression, chapters on different kinds of fire and fire weather were particularly useful for this study. See Brown and Dans (1973)

DAY, R.J. and G.T. Woods 1977 The role of wildfire in the ecology of jack and red pine forest in Quetico Provincial Park. Ontario Min Nat Res, Fire Ecol Study, Rep 5. 79 p.

A study of virgin stands of a range of successional stages were studied. All jack pine - poplar and red pine - white pine stands were initiated by fire. In the absence of fire, jack pine and red pine fail to reproduce. Jack pine trees are killed by fire but seeds are available immediately from the serotinous cones. Large red pine survive fire because of their thick bark, so that after fire seeds are provided by living trees over a period of time. It is suggested that jack pine stands be regenerated by fire at age 80 to 120 years, red pine at age 175 to 200 years.

DESPAIN, D.G. 1972 Fire as an ecological force in Yellowstone ecosystems.
Yellowstone Nat Park Inf Paper 16, U S Nat Park Ser, 3 p.

Fire has been a natural ecological force that has been operating in Yellowstone National Park since those ecosystems originated. Many plants in the Yellowstone ecosystems are fire dependent or fire adapted. Fire serves both to check the spread of tree diseases in the forests and to reduce encroachment of trees into the grasslands. Fire also has a strong influence on nutrient cycling. The extent to which fires are controlled determines the degree of departure from natural conditions. Suppression activity also produces unnatural results. Nature is amoral. Changes in a natural area are neither good nor bad, beneficial nor detrimental. Only when human values are interjected do things become good or bad.

DEVET, D.D. 1974 'DESCON: Utilizing benign wildfires to achieve land management objectives.' Tall Timbers Fire Ecol Conf Proc 14.
 (Fire and Land Management Symp, cosponsored by Intermt Fire Res Counc Missoula, MT, Oct 1974).

DESCON (DESigned CONTROL) is a plan to utilize wildfires (man-caused and lightning-caused) to accomplish land management objectives. Wildfires are allowed to burn with a minimum of control effort when they occur in areas and under conditions called for in approved prescribed burning plans.

DeWITT, J.B. and J.V. Derby, Jr. 1955 'Changes in nutritive value of browse plants following forest fires.' J Wildlife Manage 19:
 65-70.

A plot study in Maryland to determine nutritive value of several deer browse-forage species showed that four species were unaffected by fire. Protein content was significantly higher in greenbrier (smilax), red maple and dogwood foliage in the season following low-intensity fire, but no effects were found the second year. The high intensity fire produced significant increases in protein contents of all four species (as above, plus white oak), and effects were still apparent at the end of two years.

DIETERICH, J.H. 1976 Prescribed burning in ponderosa pine - State of the Art, presented at Region 6 Eastside Prescribed Fire Workshop, Bend, Oregon, May 3-7, 1976. 13 p.

A discussion of a range and distribution and predicting of effects of fire in ponderosa pine stands. The author concludes that it is easier to list what we don't know about fire in ponderosa pine than what we do know. He expresses the personal opinion that ponderosa pine is not a fire dependent species, and also identifies a laundry list of the most urgent needs in getting prescribed fire used more effectively as a land management tool.

DINGWALL, D. 1972 Weather forecasting plays a vital role. Fire Season Special. 2 p.

An article done in newspaper style which relates the importance of weather forecasting to prescribed burning in slash in British Columbia.

DOAN, G. 1967 Weather in prescribed burning. Ontario Dept Lands and For Prescribed Fire Symp. 13p

The various weather elements affecting fire behaviour are outlined and described in detail.

Tailoring weather prescriptions to fire prescriptions is discussed and utilizing weather factors in the final decision, whether or not to burn is considered.

DOBBS, R.C. 1967 The use of prescribed burning in jack pine management in the boreal forest region of Saskatchewan. Project MS-250. Internal Report MS-43, For Res Lab, Winnipeg, Manitoba. 13 p.

A review of prescribed burning as a silvicultural tool in Ontario, Manitoba, and Saskatchewan. In the burn described the fire consumed all fine to moderate slash. However, a larger amount of heavier debris, stems and chunks remained. Post-burn humus depths range from 0.1 - 2.5 inches with an average depth of 0.65 inches.

Calculations were made of the viable seed per acre which fell on the burned area, and it was estimated that 64.5 percent of this germinated.

DOERR, P.D., L.B. Keith, and D.H. Rusch 1970 'Effects of fire on a ruffed grouse population.' Tall Timbers Fire Ecol Conf Proc 10: 25-46.

In Alberta it is reported that fire, a recurrent natural phenomenon, significantly influences animal populations. A spring wildfire on a four-square-mile study area resulted in a spectacular increase in aspen from sprouts. Grouse were little affected in distribution or in their use of drumming logs. About half the birds moved out of the burn for about one year. There was nearly complete nesting failure due to destruction of nests by fire. Nesting returned to normal the next year. The number of drumming males was reduced for two years following the fire.

DOMAN, E.R. 1967 'Prescribed burning and brush type conversion in California national forests.' Tall Timbers Fire Ecol Conf Proc 7: 225-33.

The concept of "worthless brush" applied to this chaparral cover is fallacious and dangerous, particular in relation to wildlife habitat, watershed protection, and environmental control.

DOUGLAS, G.W. 1974 Ecological impact of chemical fire retardants: A review. Env Can N For Res Centre, Edmonton, Alberta. 33 p.

Ecological impact appears to be greatest in aquatic ecosystems, and this area should receive primary consideration. In addition, research directed towards the ecological impact of fire retardants on terrestrial systems is urgently needed. In particular the author identifies needs in the area of soil nutrient capital and soil microbial systems and the ability of these organisms to recycle nitrogen in a normal manner. He is also concerned about plant community compositions, structure, and dynamics in both the drop areas and the boundary between treated and non-treated areas. The direct or indirect effects of fire retardants on different types of animals such as insects, mice, birds, elk, etc. also require investigation.

DUBE, D.E. 1976 Early plant succession following a 1968 wildfire in the subalpine zone of the Vermilion Pass, Kootenay Nat Park. M.Sc. thesis, Dept Bot, U of Alberta. 213 p.

In 1971 and 1972 a tenfold increase in fallen stems was observed. Lodgepole pine seedlings were most abundant. Species richness increased in the Pass as a result of fire. Major constituents of the post-burn community were represented in the unburned forest.

DUBE, D.E. 1976 Guidelines and operational plan for a prescribed fire on Henry House Prairie, Jasper National Park. Env Can N For Res Centre, Unpub Rep, Edmonton, Alberta. 10 p.

This report provides an introduction reviewing recent research, proposed objectives, a description of a study area, a proposed burning prescription, pre-burn preparations, ignition and burning techniques, public awareness program, and agency responsibilities for a prescribed burn in Jasper National Park.

DUBE, D.E. 1977 Study proposal for development of an operational fire management plan for Nahanni National Park. Env Can N For Res Centre, Unpub Rep, Edmonton, Alberta. 5 p.

The proposal includes background statements, study objectives, scope, approach, and proposed schedule for a study proposal for development of a fire management plan for Nahanni National Park.

DWIGHT, T.W. 1913 Forest conditions in the Rocky Mountains Forest Reserve. Canada, Dept Int For Br Bull 33. 62p

This bulletin is interesting because it describes the forests on the East Slope of the Rocky Mountains as they were in the early 1900's. Two National Parks, Banff and Jasper, are located on the East Slope. A chapter is devoted to fires in the region which were notable for their intensity and the destruction of the vegetation and the surface organic matter. Such fires changed spruce forests to grassland. Repeated fires also changed lodgepole pine forests to grassland. Fires spaced 25 years or more, favoured lodgepole pine. The silvical characters of the commercial tree species were described: lodgepole pine, Douglas-fir, alpine fir, white spruce, timber pine, white-bark pine, alpine larch, balsam poplar, and aspen. Burning was recommended for disposing of the slash left after logging.

EASTMAN, J. 1972 'In wildness is fire.' Living Wilderness 36(117): 10-7.

Long before man appeared on this continent, fire was a naturally occurring ecological force. The continental fire mosaic consisted of many different plant communities in various stages of fire adjustment. Since fire is a natural force, its exclusion is unnatural and will result in a loss of the wild environment. To this extent the advocates of Smokey the Bear may be doing a disservice by preaching that forest fires are bad. Recently, however, foresters have begun to realize that fire does have a role in the natural scheme of things. If fire is a legitimate wildness in nature, a wildness that may, on occasion be utilized for man's benefit, integration of this knowledge would appear not only useful, but wise.

EDWARDS, R.Y. 1954 'Fire and the decline of a mountain caribou herd.' J Wildlife Manage 18: 521-6.

The mountain caribou has decreased alarmingly throughout most of British Columbia. Fire has drastically changed the vegetation of the valleys. Fire destroyed the forest, and made new and extensive range for a number of species. It totally removed the marten for decades; it restricted the wolverine and grizzly bear. Mule deer increased abundantly. Cougars became common. Coyotes flourished where deer mice and Columbia ground squirrels were abundant. Beaver increased; also black bears. Moose expanded ranges into burned areas followed by wolves. Caribou moved seasonally from high meadows and open forests to lowland mature forests interspersed with bogs and ponds where lichens and browse are the chief forage. Fires reduced mature lowland forests by 60-70 percent. Caribou decline occurred following destruction of forests used as winter range (1930s). Small areas of climax vegetation are necessary for survival of the caribou (from 3 to 10 percent of its total annual range). Protection of existing remnants of lowland forests from fire is necessary for survival of the caribou.

ENVIRONMENT CANADA 1971 Forest fire behavior system - Supplement BC-1, guides to initiate a prescribed burning program. Env Can Pacific For Res Centre, Victoria, BC. 2 p.

A discussion of how to use the Drought Code which is found in the Fire Weather Index, for more effective prescribed burning in British Columbia.

EVERGLADES NATIONAL PARK 1976 Revised Fire Management Plan. U S Nat Park
Serv Everglades Nat Park. 100 p.

This management plan is based on the premise that the presence or absence of natural fires within a given ecosystem is recognized as a potential factor stimulating, retarding or eliminating various components of that ecosystem.

Defines management fires and the limits within which natural fires will be allowed to burn. The plan discusses prescribed burning and outlines those conditions which should be itemized in developing fire prescription. As well a discussion of smoke management is included.

FAHNESTOCK, G.R. 1972 'Use of fire in managing forest vegetation.'
Trans Am Soc Agr Eng 16: 410-3.

A general review which identifies the history of attitudes towards fire in North America, different uses to which prescribed burning can be put, changes that enter into a prescribed burning prescription, environmental impacts of burning, and some future uses for fire.

FAHNESTOCK, G.R. 1975 'Fires, fuels, and flora as factors in wilderness management: the Pasayteu case.' Tall Timbers Fire Ecol Conf Proc 15: 33-64.

Pasayteu wilderness is over one-half million acres in northern Washington, bordering on the Canadian border. The author presents an in depth description of fuel and vegetation in this area. The article includes a discussion of fire regime, forest succession, fuel succession, and implications for management.

FAHNESTOCK, G.R. n.d. An opportunity for fire ecology research in Jasper National Park. Env Can N For Res Centre, Unpub Rep. 8 p.

The author offers observations on the vegetation and fuel complex found in Jasper National Park, and suggests that prescribed burning could be used to restore and maintain something approaching pristine conditions.

FAHNESTOCK, G.R., and D. Dube n.d. Prospectus for an exploratory study of the natural and historic role of fire in Wood Buffalo National Park. Env Can N For Res Centre Unpub Rep. 4 p.

A proposal outlining the problem, background, objectives, scope, approach, reporting procedures, responsibilities, and costs of a study of the natural and historical role of fire in Wood Buffalo National Park.

FALKNER, A.C. and J.A. Carruthers 1974 'National Parks of Canada.' Conservation in Canada J.A. Maini and A. Carlisle (eds), Canada Dep Envir, Can For Serv Publ 1340, p. 143-67.

This paper describes the National Parks system in terms of history, present conditions, and future prospects. The location of each Park is given with respect to the natural regions recognized for park planning. Parks are located in 21 of the 39 natural regions. The natural role of fire in ecosystems is noted, and it is suggested that prescribed burning will be employed in certain areas.

FILLMORE, W.J. 1974 'Is prescribed burning compatible with environmental quality?' Tall Timbers Fire Ecol Conf Proc 14. (Fire and Land Manage Symp Cosponsored by Intermt Fire Res Counc, Missoula, MT, Oct 1974)

Panelists I.D. Aldrich, J.S. Barrows, R.R. Perry, and B.F. Wake debated the question: "Is prescribed burning compatible with environmental quality?" Aldrich pointed out the benefits of prescribed fires. Fire is not only environmentally acceptable, it is ecologically irreplaceable. Barrows agreed that prescribed fire is beneficial and does not adversely affect environmental quality, but only when it is properly planned and managed. Improper planning or execution can make a prescribed burn detrimental to the environment. Perry said that wood smoke is an air pollutant, but since day to day activities are not being monitored closely enough for definitive answers, no one can say for sure that prescribed burning is or is not compatible with a quality environment. Wake stated that air pollution occurs from the use of fire. Deliberate fire starting violates the Clean Air Act of Montana and the Federal Clean Air Act. The smoke from prescribed burning deteriorates air quality and causes physical and psychological problems for many people. The intentional use of prescribed burning is protested by Wake. He predicts that in the not too distant future prescribed burning may be completely banned.

FLEIGER, B.W. 1970 'Forest fire and insects: the relation of fire to insect outbreak.' Tall Timbers Fire Ecol Conf Proc 10: 107-14.

An outline of forest history and the history of fire in eastern Canada with suggestions as to what role the spruce budworm has played. The author focuses in particular on the 10 or more years during which it takes the killed trees to pass out of the fire fuel category after an insect infestation. This is the critical time during which an occurrence of fire can have most effect on the forest landscape. Stresses the view that more fires than ever will perhaps occur now, not as a result of the spruce budworm, but because of the fuel for fire that has been left behind as logging slash. There is no doubt in the author's mind that more effective insect control and complete fire suppression would radically change the forest face in New Brunswick. But he does seem to doubt whether these changes would necessarily be desirable.

FLINN, M.A. and R.W. Wein 1977 'Depth of underground plant organs and theoretical survival during fire.' Can J of Bot 60: 2550-4.

Studies of Acadia Forest Experiment Station in New Brunswick determine the depth of underground plant organs capable of growing shoots.

Depth of these plant parts tended to be species specific. These depth data together with a knowledge of the sprouting ability of the underground organs were used to postulate which species would survive fires of varying intensities. Most species found in a litter layer or in the F and H layer of the forested study sites would be susceptible to fires of low intensity.

FOWELLS, H.A. (compiler) 1965 'Silvics of forest trees of the United States.' USDA For Serv Agr Handbook 271. 762 p.

This is a comprehensive review of the literature. Each species is described with regard to range, climate, soils, topography, associated trees and shrubs, reproduction, growth to maturity, races and hybrids, reaction to competition and principal enemies. Under the last topic there is usually a paragraph on how the species is affected by fire.

FRISSELL, S.S. 1973 'The importance of fire as a natural ecological factor in Itasca State Park, Minnesota.' Quaternary Res 3:397-407

The author discusses the history of fire in this area. He concludes that such wilderness has always been dependent on disturbance and that wildfire played a dominant role in forming and maintaining the character and pattern of the primeval biotic communities. Expresses the view that as a result of fire suppression, sub-climax types such as red, white, and jack pine are slowly but surely passing out of the picture, and that there is a general reduction of vegetational variety. That the forest in the park is evolving to stands of aspen, birch, northern hardwoods, or balsam fir. He also detects a trend towards all age types spread over extensive areas. This reduced diversity is having a negative effect on the area as a wildlife habitat.

FUQUAY, D.M., A.R. Taylor, R.G. Hawe, and C.W. Schmid, Jr. 1972
'Lightning discharges that caused forest fires.' J Geophys Res
77: 2156-8.

Sixteen lightning discharges were documented. Eleven caused forest fires in western Montana. Each of the eleven discharges had a long-continuing current (LCC) phase of at least 40 msec. Of the 5 discharges that did not cause fires, 2 had LCC phases and 3 did not. Although results to date strongly support the hypothesis that forest fires are caused by discharges with long-continuing currents, data suggest that cloud-to-ground discharges without LCC portions cannot be entirely ruled out as a source of forest fuel ignition.

FUQUAY, D.M. 1974 'Lightning damage and lightning modification by cloud seeding.' In W.N. Hess (ed) Weather and climate modification. Wiley: 604-12.

According to experts some 2,000 thunderstorms are in progress someplace on the earth's surface at any given time. Lightning has many effects, but probably the most dramatic is that of kindling forest fires. Annually lightning ignites approximately 10,000 reported forest fires in the U.S. Several hundred fires may occur in any one day. In one case over 1,500 lightning fires were started in a two state area within a 10-day period. Scientists have studied ways to reduce lightning and therefore lightning fires. The BLM in Alaska has experimented with cloud seeding in order to cause rain in dry areas and thus reduce fire danger. In 1960 and 1961 the Forest Service conducted the first systematic program of lightning modification. Fewer cloud-to-ground discharges were recorded from seeded clouds than from non-seeded ones. From 1965 through 1967 scientists conducted additional experiments with cloud seeding. Results showed 66% fewer cloud-to-ground discharges from seeded clouds. Cloud-to-ground flash rates, lightning duration, and the duration of continuing current in hybrid discharges were all less from clouds that had been seeded. These data strongly suggest that, in some instances, lightning can be modified in a way that is beneficial to man.

GABRIELSON, I.N. 1928 'Forest fire and wildlife.' Four L Lumber News 10(13): 32.

Rapid running forest fires, particularly crown fires, may be very destructive to wildlife. If they occur in the nesting season of birds, the broods of the year and often the breeding stock are destroyed.

GAGNON, J.D. 1965 'Nitrogen deficiency in the York River burn, Gaspé, Quebec.' Canada, Dep For, Québec District

Visual symptoms of malnutrition associated with the unsatisfactory development of natural and planted black spruce seedlings in a 20-year-old burn suggested low supply and uptake of nitrogen, phosphorus, and possibly other nutrients as the primarily adverse factors.

Of the elements studied, only nitrogen was found to be related to needle colour and poor leader growth.

A lichen crust *Lecidea granulosa* rich in nutrients, especially nitrogen, dominates the sites. The crust decomposes very slowly and retains large proportions of available nutrients in its tissues. Incorporation of the crust in the mineral soil is suggested as a means of accelerating nutrient cycling and promoting development of future plantations.

GAGNON, J.D. 1973 Le grande brulé de 1938-41 de la Rivière York; son histoire, son evolution naturelle, et sa restauration forestière, Centre des Recherches Forestières Des Laurentides, Service Canadien Des Forêts, Rapport d'information LAU-X-7.

This study showed that on about 2 percent of the burned area, the problem of natural forest restoration, considered as unsolvable in 1951, remains as such in 1971. On about 15 percent of the burned areas, without man's intervention, 100 years may elapse before natural forest restoration with softwood can attain the stage of harvest. On close to 80 percent of the burned areas there is in 1971, no problem as far as natural forest restoration is concerned.

GARTNER, F.R. and W.W. Thompson 1972 'Fire in the Black Hills forest-grass ecotone.' Tall Timbers Ecol Conf Proc 12: 37-68.

In the Black Hills of South Dakota under exclusion of natural fires, woody plants increase and often become dominant. Controlled burning results in more productive grasslands with maximum diversity, more productive forests with a more diverse understory, better wildlife habitat, increased water production, decreased cost of wildfire protection and aesthetic enhancement. Controlled burning is manageable in the spring and should be usable in fall and winter depending on weather, and soil and fuel moisture. Controlled spring burning in bluestem grasslands for reducing invading pine seedlings is practical and will not reduce forage production. Controlled fires are being used in the Black Hills to improve big game range.

GLASCOCK, H.R. 1972 'Forces shaping public opinion toward fire and the environment.' Symp on Fire in the Env (Denver, CO, 1972) Proc 65-8. USDA For Serv Publ FS-276.

Personal opinions regarding fire in the environment are shaped by forces of emotion and reason. "Education is the most powerful single force deliberately used to shape public opinion towards fire." Most people believe that forest fires are bad. However, foresters have long realized the beneficial uses of fire. Recent development of "let-burn" zones in some national parks and wildernesses is apt to cause concern among a public that has been conditioned by Smokey the Bear. Another problem clouding the public message about fire is the lack of agreement among professionals as to the benefits of fire, if any. This disagreement must be overcome, and public attitudes and policies must be shaped if fire is to play its proper role in achieving and maintaining an acceptable environment.

GORDON, L.S. 1954 Effect of fire on game habitat and game species.
PR Proj W-61-R-3, Job Completion Rep Santa Fe. NM Dept Game & Fish.

In June and July 1951, two large forest fires in New Mexico apparently had extremely detrimental initial effects on young turkeys and deer fawns. Game animals moved back into the burned areas during the following spring when weeds and some browse made good new growth (aspen, locust, oak). The food and cover were favorable for turkeys and deer, and their populations increased during 1952 and 1953. Studies indicate that, in general, the habitat has been improved and that the fires have benefited wildlife after the initial detrimental effect by opening up dense stands of timber and thus allowing a dense ground cover and more abundant food supply. Grass seeding in the burns was recommended.

GRANGE, W.B. 1949 The way to game abundance. Scribner, New York.

Whether fire is beneficial or detrimental depends upon the land use objectives. Plant species differ in fire tolerance. The role of controlled fire as a method of increasing game is always that of partial denudation for the purpose of inducing an earlier succession, or to secure certain additional benefits which arise from exposing the soil to sunlight and air. Fire is a natural method of initiating succession. Fire on game ranges is best applied on a rotation system, burning each segment at least every 20 years. Rotation burning provides desired diversity. Forest production on many plants increases following burning. Fire may reduce parasites on game ranges. It provides some immediate fertilizer effect. Some hard seeds of woody species are stimulated to germinate. In Wisconsin woods, burn patches should be from 5 to 40 acres, preferably in irregular strips. Burned marshlands attract waterfowl. Some marshes can be burned over the ice. Burn in the north from mid-March to mid-April. In the southeast, burn in February. Avoid burning cover needed in winter.

Suggestions for controlled burning:

1. Determine the objectives.
2. Determine the area to be covered.
3. Choose the season carefully.
4. Have the tools and manpower for control available.
5. Choose the right weather condition by test burning.
6. Strip burn in advance around burn boundaries.
7. Watch the wind situation carefully.
8. Do not burn peat or muck when dry.

GRANGE, W.B. 1965 'Fire and tree growth relationships to snowshoe rabbits.' Tall Timbers Fire Ecol Conf Proc 4: 111-25.

The abundance of many northern forest animals is related to the length of time since the habitat burned. The snowshoe rabbit cycle, with high populations lasting two to five years, averages about once in ten years. This orderly progression of events springs from the habits and adaptations of animals and of vegetation under the environmental circumstances altered or set in motion by the initiating force - which generally is fire. Snowshoe rabbit population explosions are limited to very early succession forest stages not long after the occurrence of fire. A reservoir of breeding stock carries over in older forests, but rabbits become abundant only when there are large acreages of new forest reproduction. Other agencies of disturbance, often of small size, explain the survival of small populations. Virtually all plant species important to snowshoe rabbits show pronounced adjustment to fire: jackpine, lodgepole pine, black spruce, quaking aspen, white cedar, tamarack, birch, willow, etc. When an appropriate point of food and shelter deterioration arrives, the rabbit population crash occurs. Immediate causes may be disease, starvation, climatic factors, etc. The role of fire must be taken into account in order to understand the ecology of the snowshoe rabbit country.

GRIER, C.C. 1975 'Wildfire effects on nutrient distribution and leaching in a coniferous ecosystem.' Can J For Res 5: 499-607.

Distribution of nutrients after the Entiat fire in north central Washington was examined. This intense fire produced an average ash weight on the soil surface of 2900 kg/ha. Weights in kg/ha for N, Ca, Mg, K, and Na are calculated for the ash layer and for nutrient losses during the fire as a result of combined volatilization in ash convection. Nitrogen loss apparently was proportional to fuel dry weight loss. Weights in kg/ha of the major elements are given for leaching from the ash layer in the first year after burning. Cation leaching from ash layers was primarily related to water percolation through the ash.

GULLION, G. 1974 'A case for forest fires.' Outdoor Am 39(10): 12.
Arlington, VA: Izaak Walton League of Amer.

While occasional losses of wildlife do occur, most species benefit much more than they suffer when fire sweeps a forested area. Fire in the forest is the ecological agent most likely to maintain habitat qualities beneficial to bears. The habitat requirements of other forest wildlife species show similar associations between the disturbance created by fire in the forest and the abundance of many animals. There is good evidence that many grouse are dependent on fire. The prairie evidently thrives best on grasslands which are burned at nearly yearly intervals. There is increasing evidence that an important reason for the decline in sharp-tail grouse in the midwest is the elimination of fire in the meadows and bog areas adjacent to forest - although conversion of brush to cropland has been an important factor. Intensive research in the Lake States has indicated that fire provides the highest quality habitat for ruffed grouse. Windthrown or "cleared" forest following by fire provides quality habitat for a period of about 40 years. Fire also produces quality habitat for white-tailed deer. There is good reason to suspect that the success of fire prevention programs is the major factor responsible for the continent-wide decline in deer numbers. This affects a remnant wolf population. Fire also is related to habitat of moose, beaver, and snowshoe rabbit. Food of desert quail is more abundant on burned rangelands than on unburned chaparral or blackbrush. For ruffed grouse, fires at about 8 to 12 year intervals and 1 to 3 acres in size, are most desirable. A mosaic of mixed age classes is needed. Fire patches larger than 10 to 12 acres have adverse effects. Deer benefit from burns of 30 to 40 or up to 100 acres. For moose, fire must be 2 to 10 times that large for greatest benefit. While wildfire is generally unacceptable in wildlife management, prescribed fire is a useful tool. Once a hardwood forest has aged beyond 50-60 years, habitat restoration requires felling the timber before burning.

GUNN, A., G.W. Scotter, D. Sept, and L. Carbyn 1976 Prescribed burn study of fescue grasslands in Prince Albert National Park Can Wildlife Ser, Edmonton. 117 p.

In response to Parks Canada concern over the invasion of rough fescue grassland by aspen in Prince Alberta National Park a study of the potential use of prescribed burning for the management of the grasslands was initiated by Parks Canada and the Canadian Wildlife Service. The first years work was to inventory the flora and fauna of the grasslands and to plan for the prescribed burning. Experimental plots were established on three areas, one of fescue grassland, and the other two areas representing more advanced stages of aspen and dwarf birch invasion. Provision was made for the comparison of fall and spring burns. The grassland and ecotone plant communities were mapped from aerial photography and described from mean cover and frequency estimates at 600 meter square permanent plots. Insect and spider communities were described from pit-fall traps and sweep samples. Live trapping of small mammals, pellet group counts of ungulates, and bird counts based on sight and song were used to describe the mammal and bird communities. The animal communities showed some loss of grassland species, and on two of the study areas grassland plant species were also lost. The inventory of the plants and animals shows rich and diverse communities with some species near their northern limits of distribution. Such species in the overall diversity of the communities are likely to be favored by the prescribed burning program.

GUNZEL, L.L. 1974 'National policy change: Natural prescribed fire.' Fire Manage 35(3): 6-8.

In 1971 the Saguaro National Monument instituted a fire management plan which provided quite a change from past practices of total fire exclusion. Under prescribed conditions lightning-caused fires were allowed to burn unhampered by man. In the first three years a total of 24 fires were allowed to burn without significant damage to the overstory or to the watershed. These fires reduced fuels on more than 900 acres leaving more open park-like stands that are more resistant to disastrous high-intensity fire.

HABECK, J.R., and R.W. Mutch 1973 'Fire dependent forests of the northern Rocky Mountains.' Quat Res 3: 408-24.

One of the management objectives for national parks and wildernesses is the perpetuation of all naturally-occurring ecosystems within their boundaries. Many of these ecosystems in the northern Rocky Mountains are fire-dependent, but an effective fire exclusion effort by the land-management agencies has had detrimental effects. The fire-dependent ecosystems are not perpetuated. A fire management plan is necessary before fire can be restored to the ecosystem. This plan must be based on fuels data, fire-behaviour predictions, understanding of plant and fuel succession, landform types, fire history, and comprehensive pre-attack planning. Wilderness fire management is a preplanned program that will result in a more natural incidence of fire in wilderness. The fire manager must have a thorough understanding of fire as an ecological process. He must be able to integrate the knowledge with the land-management objectives while applying constraints to his work. A fire-management plan has been prepared for the White Cap area of the Selway-Bitterroot Wilderness to provide information about the development of relative inventory methods, relationships between fire and wilderness, ecosystems, and strategies for more natural occurrence of fire in wilderness.

HALL, A.D. 1972 'Public attitudes toward fire.' Symp on Fire in the Env (Denver, CO, 1972) Proc: 57-62.

The author discusses what is an attitude toward fire, and authors' explanations for groups of people feel that fire is bad, those who feel fire can be good, and those who have no feeling towards forest fire at all. He discusses variations in attitudes, and tries to pinpoint special attitudes of special sectors of the public. He concludes that the wide range of attitudes of fire must be considered in developing fire management program, the attitude of those experts who are presently involved in forest fire control, and the changing attitudes of society in the '70s will have particular influence on future management of wildfires and prescribed fires.

HALL, J.A. 1972 'Forest fuels, prescribed fire, and air quality.' USDA For Serv Pac NW For Range Exp Stn, Portland, OR. 44 p.

Smoke from forest wildfires and prescribed burns is thought by many to be on a par with industrial emissions which affect air quality. Research has shown that this is not the case. Its primary importance as a pollutant is that it obstructs visibility. Much of the organic matter in smoke is similar to that entering the atmosphere from vegetative life or its decomposition under normal conditions. Fire simply compresses these chemical processes into a much shorter time period.

HANDLEY, C.O. Jr. 1969 'Fire and mammals.' Tall Timbers Fire Ecol Conf Proc 9: 151-59.

Many of the animals that live in the grasslands create conditions by their own activities that either change the vegetation or cause the effect of fire to be different. If most natural grasslands developed with fire and are at least in part perpetuated by it, then a large proportion of the mammals must be at least indirectly adapted to fire. According to Allee et al. (1949), fire often is a disaster for mammals dwelling where fires are infrequent. Mammals living where fire is a frequent and regular occurring feature of the environment, as in grassland, survive fires because of their adaptation of them. Hot fires might overtake runners, suffocate or incinerate burrowers, burn up tree holes, and induce starvation; but the effect likely would be local. Many species depend on frequent fires for their existence.

HANES, T.L. 1971 'Succession after fire in the chaparral of southern California.' Ecol Monogr 41: 27-52.

The slowest succession in south-coastal chaparral is on lower south slopes. Climax vegetation develops within 30 years after fire. Chaparral succession is not a series of vegetational replacements, but a gradual ascendance of long-lived species present in the pre-fire stand. Maintenance of vigorous chamise-chaparral is dependent upon fire. The fire exclusion policy is least apt to perpetuate chamise-chaparral.

HARNISS, R.O. and R.B. Murray 1973 '30 years of vegetal change following burning of sagebrush-grass range.' J Range Manag 26: 322-5.

A sagebrush-grass range was burned according to plan in 1936. Long-term results show that sagebrush yields have decreased. Evaluation by subspecies of sagebrush was helpful in interpreting sagebrush behaviour. The return of sagebrush shows the need for planning sagebrush control on a continuing basis for maximum forage qualities.

HARVEY, A.E., M.F. Jurgensen, and M.J. Larsen 1976 Intensive fiber utilization and prescribed fire: effects on the microbial ecology of forests. USDA For Serv Gen Tech Rep INT-28 1976. Intermount For Range Exp Sta For Serv USDA Ogden, UT. 46 p.

From the many potential effects on microbial ecology that could result from the practices of intensive fiber utilization or prescribed burning in forested ecosystems, four major functional areas directly influence subsequent site quality. These include: (1) decay with its effects on carbon transformations, carbon, and mineral cycling, and the associated soil development; (2) the formation and function of mycorrhizal roots; (3) fixation of nitrogen and its transformations; and (4) the development and damage caused by plant disease fungi.

HATTER, J. 1949 'The status of moose in North America.' N A Wildlife Conf Trans 14: 492-501.

In British Columbia increases in moose population have occurred in regions burned over during the early days of land settlement and railway construction.

HEADY, H.F. 1972 'Burning and the grasslands in California.' Tall Timbers Fire Ecol Conf Proc 12: 97-107.

Changes in percentage species composition of plants and animals in the annual grassland for a year or more are the most striking effects of burning. There is an immediate reduction in rodent numbers following fire, but a few of all species survive.

HEINSELMAN, M.L. 1965 'Vegetation management in wilderness areas and primitive parks.' J For 63: 440-5.

Both the Wilderness Act of 1964 and the National Park Service Act of 1916 call for these areas to be managed in a way that will retain their primeval character and influence. Maintenance of the natural landscape is the center of all wilderness management goals. In this respect managed forests can not be equated with wilderness. The biotic communities found in wilderness areas and parks vary greatly. Management of these areas requires people with training and experience from many disciplines. A conscious effort is required to maintain and restore the natural scene. The fire-exclusion policies of the past may not be sound. Natural agents must be used in maintaining and restoring the natural landscape. Mechanical tree removal violates the wilderness concept; however, fire can be used to serve the same purpose. Every wilderness management program should consist of a biotic inventory, research into the crucial problems, and a sound action program. Prescribed fire will probably become the primary tool for implementing the action program; however, where lightning fires can be allowed to burn, they should be used in ecosystem management.

HEINSELMAN, M.L. 1970 'The natural role of fire in northern conifer forests.' Naturalist 21(4): 14-23.

Northern North American primeval conifer forest ecosystems were fire dependent. Relevant research is not lacking, because much has been accomplished. What is important is the simple recognition that fire is part of the natural environment. It is not unnatural. Fire plays many ecological roles from initiating new forests to removing old ones. Fire exclusion by man has greatly reduced the ecological effects of fire. Man's management options range from continued fire exclusion to some use of prescribed and natural fires. A need exists to retain some examples of primeval ecosystems where fire is allowed to fulfill its natural role. If wildfires can not be tolerated, prescribed fires may be an alternative.

HEINSELMAN, M.L. 1970 'Preserving nature in forested wilderness areas and national parks.' Nat Parks Conserv Mag 44(276): 8-14.

The value of wilderness depends upon "preserving nature". The absence of fire and other destructive forces will gradually result in unnaturally high proportions of plant communities composed of shade-tolerant species. Philosophically, the focus should be on restoring the primeval environment. To do this it is important to reintroduce missing members of the ecosystem, avoid introduction of exotics, allow native insects and diseases to reap their toll, not cleanup blowdowns or other dead material, and assure a natural fire regime by prescribed burning if necessary.

HEINSELMAN, M.L. 1970 'Restoring fire to the ecosystems of the Boundary Waters Canoe Area, Minnesota, and to similar wilderness areas.' Tall Timbers Fire Ecol Conf Proc 10: 9-23.

This article summarizes the fire history studies done in the Boundary Waters Canoe Area which are recorded more extensively in Quaternary Research. Heinselman reports on the present condition of the forests and suggests management implications and alternatives in terms of fire. He discusses problems involved in reintroducing fire into the area and also mentions a number of environmental impacts that should be minimized.

HEINSELMAN, M.L. 1973 'Fire in the Virgin Forests of the Boundary Waters Canoe Area, Minnesota.' Quat Res 3: 329-82.

Fire largely determined the composition and structure of the presettlement vegetation of the Boundary Waters Canoe Area as well as the vegetation mosaic on the landscape and the habitat patterns for wildlife. It also influenced nutrient cycles, and energy pathways, and helped maintain the diversity, productivity, and long-term stability of the ecosystem. Thus the whole ecosystem was fire-dependent.

At least some overstory elements in virtually all forest stands still date from regeneration that followed one or more fires since 1595 A.D. However, 83% of the area burned before the beginning of suppression programs resulted from just nine fire periods: 1894, 1875, 1863-4, 1801, 1755-9, 1727, 1692 and 1681. The average interval between these major fire years was 26 years. Most present virgin forests date from regeneration that followed fires in these years. Most major fire years occurred during prolonged summer droughts. Many fires were man-caused, but lightning ignitions were also common. Lightning alone is probably a sufficient source of ignitions to guarantee that older stands will burn before attaining climax. Dry matter accumulations, spruce budworm outbreaks, blowdowns, and other interactions related to time since fire increase the probability of old stands burning.

A natural fire rotation of about 100 years prevailed in pre-settlement times, but many red and white pine stands remained largely intact for 105-350 years, and some jack pine and aspen-birch forests probably burned at intervals of 50 years or less. Probably few areas ever attained the postulated fir-spruce-cedar-birch climax in post-glacial times. The search for stable communities that might develop without fire is futile and avoids the real challenge of understanding nature on her own terms.

To restore the natural ecosystem of the Canoe Area fire should soon be reintroduced through a program of prescribed fires and monitored lightning fires. Failing this, major unnatural, perhaps unpredictable, changes in the ecosystem will occur.

HELVEY, J.D., A.R. Tiedemann, and W.B. Fowler 1975 'Some climatic and hydrologic effects of wildfire in Washington State.' Tall Timbers Fire Ecol Conf Proc 15: 201-22.

Streamflow increased strikingly after the vegetation was destroyed by wildfire. Snowmelt runoff started earlier and runoff peaks were higher after the fire compared with the calibration period.

No effects of fire or fire followed by erosion control fertilization were detected on quality of water for municipal uses. Stream temperature increased after the channels were exposed to direct sunlight, but temperature remained within the range recommended for trout. Suspected air temperature changes could not be documented because prefire data are limited.

HENDRICKS, J.H. 1968 'Control burning for deer management in chaparral in California.' Tall Timbers Fire Ecol Conf Proc 8: 219-33.

In Lake County, ideal deer range could be made up of many 5-10 acre burns scattered through an entire area. This is not feasible due to excessive cost. Intermediate-size burns of 100-200 acres are practical. Most brush began sprouting within a few weeks after burning. Grass growth was much improved. Deer left croplands to return to burned hill-sides where food was abundant. Old brushfields produce about 50 pounds of available feed per acre with a protein content of about 1 percent. After burning, the same area may produce a ton of available forage at around 6 percent protein. Shrub sprouts should not be sprayed with herbicide for optimum deer populations. For deer range, burn every 10 to 12 years; for livestock (grass production) burn every 3 or 4 years for a while. Size of burns can be too small, resulting in over-use. Controlled burns also improve habitat for quail, doves, and rabbits.

HENDRICKSON, W.H. 1970 'Consideration of natural fire, variance of viewpoint.' Symp on the role of fire in the Intermt West (Missoula, MT, 1970) Proc Intermt Fire Res Counc, Missoula, MT: 76-80.

In relating the natural role of fire, the author reviews the papers of Wellner, Heinselman, and Vogl. The author suggests that Heinselman's option to "allow all wildfires to burn unchecked unless life or property are directly threatened" be given full consideration in national parks and wilderness areas.

HENDRICKSON, W.H. 1974 'Fire in the National Parks Symposium.' Tall Timbers Fire Ecol Conf Proc 12: 339-43.

The author reviews those parks in the U.S. system that have adopted new fire management approaches. What exists is a set of administrative policies that allow the tolerance of fire where it is appropriate. But that does not mean that the U.S. parks system is contemplating the use of fire everywhere in the national parks system. Fire management must be understood and endorsed by the general population including the Congress which really decides how the national parks are to be administered. In particular those who advocate the incorporation of fire must be aware of the extra degree of understanding that must be conveyed to the public to justify crown burning. Approaches to fire management in Africa and those in the United States are briefly compared.

HOFFMAN, J.E. 1971 'Fire in park management.' Symp on Fire in the North Env (Fairbanks, AK, 1971) Proc. USDA For Serv Pac NW For Range Exp Stn: 73-8.

Most of Alaska's state and national parks were established to provide human enjoyment of the natural features and to preserve the area in its natural condition. Fire was an important ecological factor operating to maintain this natural condition, but park policy generally dictates that fire be suppressed. Such action has resulted in the development of unnatural conditions. To counter this problem future park management should determine if fire was a factor in the environment. If so, policy should be changed to allow fire to be used as a tool. Once this policy is adopted, the next step is to develop an ecologically sound fire management plan. The last step is to carefully implement the plan on the ground.

HORNE, E.E. 1938 'Some wildlife forest relationships.' N A Wildlife Conf Trans 3: 376-80.

On a thousand acre burn, deer avoided the fire and returned the first year, rabbits were eliminated for several years. Chipmunks were reduced to a breeding nucleus. Mice survived the fire in good numbers.

HORTON, K.W. and E.J. Hopkins 1965 Influence of fire on aspen suckering. Canada Dep For Publ 1095. 19 p.

Experiments were conducted in aspen stands in southern Ontario. A light burn was silviculturally poor because only a few suckers resulted. A moderate burn resulted in a prolific crop of suckers, after killing all stems and removing most of the organic layer. Even a severe burn did not kill the aspen roots, and hence was not effective in eliminating aspen from the area.

HOUSTON, D.B. 1973 'Wildfire in northern Yellowstone National Park.' Ecology 54: 1111-7.

A recent study revealed that during the past 300-400 years fires have burned with a frequency of about 20-25 years on any given area. Data support the belief that 8 or 10 extensive fires burned during this period. Euro-American man has significantly reduced the natural fire frequency since about 1890-1895. This reduction has contributed to changes in plant succession.

HOWARD, E.W. 1969 'Prescribed burning: new tool in forest management.'
Nfld J Commerce.

A very brief review of silvicultural applications on prescribed burning in Newfoundland.

HOWARD, W.E., R. L. Fenner, and H.E. Childs 1959 'Wildlife survival
 in brush burns.' J Range Manag 12: 230-4.

A study was conducted in California to learn how destructive controlled brush burning is to small animals. The principal vegetation was annual grasses and forbs, ceanothus, live oaks and digger pine. Caged animals placed within the fire area were: rattlesnakes, ground squirrels, white-footed mice and laboratory rats. Cages placed beneath logs or dead brush reached lethal temperatures even when buried 6 inches deep. Animals in rock outcrops survived as long as shielded from radiant heat and as long as the crevice did not serve as a chimney to adjacent burning vegetation. The lethal temperature for the rodents seems to be between 138-145°F. The rattlesnakes, placed in rock crevices, survived. A second procedure was to count animals coming to a spring. Increased use occurred the day after the fire (valley quail, small cottontails, and gray squirrels). Few, if any, adult birds of any kind were killed by the fire. The authors reported numerous observations of birds and mammals in the fire area during the fire. None of the three observers saw animals that had been singed or burned by fire. Animals displayed amazing calmness and all managed to avoid hot spots. It was concluded that most range fires are not directly destructive to wildlife. Once an area has been burned, however, population densities may markedly change because of alteration in habitat conditions. In general, the opening up of dense stands of brush benefits most wildlife species. Birds, rodents and cottontail rabbits frequently make trails, removing forage from around woody vegetation, and these become natural fire-breaks protecting stands of woody vegetation.

HOWE, G.E. 1974 'The evolutionary role of wildfire in the northern Rockies and implications for resource managers.' Tall Timbers Fire Ecol Conf Proc 14. Symp Fire & Land Manage (Missoula, MT, 1974) Proc.

Fire has been an integral part of the northern Rocky Mountains for at least 10,000 years. During this time it has become second only to climate in influencing the evolution of indigenous plant species.

The author documents a number of possible evolutionary roles that fire can play. Fire may function as a mutagen, fire may function as an agent of migration, fire may function as a selection agent, or it may function as an agent of random genetic drift. Having considered the consequences of each of these possible functions, the author concludes that an understanding of these principles is helping to bring about new fire related policies. Fire management including fire use is replacing the objective of total fire exclusion.

HUMPHREY, R.R. 1963 'The role of fire in the desert and desert grassland areas of Arizona.' Tall Timbers Fire Ecol Conf Proc 2: 45-61.

Fires have not been much of a factor historically in the Sonoran or Chihuahuan deserts. In desert grassland, fires formerly occurred at frequent intervals; mesquite and other woody species have invaded with fire control. Where fuel supply is adequate, controlled burning could still be used on the grasslands.

ISAAC, L.A. 1963 'Fire - a tool not a blanket rule in Douglas-fir ecology.' Tall Timbers Fire Ecol Conf Proc 2: 1-17.

Young Douglas-fir stands which follow fire are singularly free from insects and disease. Bird and animal life thrives in openings in forests and use the dense forest only for cover and protection. A dense continuous forest of Douglas-fir is almost a biological desert. The great Tillamook (Oregon) forest fire wiped out the dry-land snail which is an intermediate host for certain liver fluke and lungworms in deer.

JAHN, E. 1955 'The effects of forest fires, with special reference to changes in the soil and faunal populations.' Natur U Land (Vienna) 41: 149-51.

The destruction of organic matter and soil cover and the increases in pH values and CO₂ contents are usually associated with a poverty of species of soil fauna. A drought following fire may entirely suppress faunal activity.

JAMES, T.D.W. and D.W. Smith 1977 'Short-term effects of surface fire on the biomass and nutrient standing crop of *Populus tremuloides* in southern Ontario.' Can J For Res 7: 666-79.

The standing crop of biomass and nutrients (N, P, K, Ca and Mg) were estimated for trembling aspen, lateral branch twig trunk, and foliage in an open stand, age 30, in Ontario.

Accumulation of tree biomass was unchanged by light surface burning. Evidently the environment changes were too slight to cause postfire changes in the established overstory.

The relative importance of various tree components as nutrient accumulation sites followed the order; leaves greater than twigs, greater than lateral branches, greater than trunk. Accumulation of nutrients in the trunk, lateral branches and twigs was not appreciably altered by fire. Major proportions of nutrients in these components would have accumulated prior to burning.

Amounts of nutrients contained in leaf biomass, however, were significantly changed after burning. Concentration in leaves from burned areas were 42-24% higher than control levels, whereas the preburn levels were similar. These substantial postburn increases in leaf nutrient levels, related to a flush of soil nutrients from ash, would have an important effect on those wildlife species utilizing the aspen as a food source.

JEMISON, G.M. 1971 'Sacred cows: Barriers to improving forest fire management.' In Western forest fire conditions. West For Fire Comm Annu Meet (Portland, OR, 1971), West For Conserv Assoc, Portland, OR: 24-8.

Many "sacred cows" stand in the way of improving forest fire management. These obstacles are divided into four topics for discussion. First, many people believe that existing fire management objectives are all sound, while others do not think so. The second obstacle is the belief that fire suppression cannot be over-emphasized. The author suggests that fire managers are "suppression-happy". Another obstacle in the way of improving fire management is the "sacred cow" that new technology is its salvation. New technology is important, but better judgement is needed in the use of all new techniques. The final obstacle is the belief that fire organizations are doing an all-out job of fire management.

JOHNSON, E.A., and J.S. Rowe 1975 'Fire in the subarctic wintering ground of the Beverley caribou herd.' Am Midland Naturalist 94(1): 1-14.

The study documents the timing, prevalence and importance of fires in a 105,000-sq-km area of the Northwest Territories. Lightning caused most of the fires and accounted for almost all of the area burned in a 7-year period. In this part of the subarctic, the fires appear to follow a seasonal pulse that progresses in June and July from the SW toward tree line in the NE, retreating in August. The normality of fire in this part of the northern boreal zone is beyond dispute. There is no conclusive proof that fire regime has changed substantially in recent times from what it was previously. The implication is that endemic animals, such as caribou, are adjusted to recurring fires.

JOHNSON, E.A., and J.S. Rowe 1977 Fire and vegetation change in the western subarctic. Report for the Arctic Land Use Research Program, Dept Ind Affairs & North Dev, Ottawa. 58 p.

The objectives of the report were to develop a method for determining the fire frequency for a region; specifically, to elucidate the fire frequencies for the Caribou Range and relate this to environmental parameters and vegetation change. The second objective was to study changes in the composition of vegetation on uplands following fire and to describe quantitatively these changes in plant populations along temporal and environmental gradients.

JOHNSON, V.J. 1970 A water curtain for controlling experimental forest fires. Exp Sta St Paul, Minn, USDA For Serv Res Paper NC-48, 7 p. N Cent Forest.

Describes the components, assembly, and performance of a high-capacity water pumping and distributing system developed for control of intensely burning experimental fires in northeastern forests.

JONES, L. (Moderator) 1974 'Are current fire management activities compatible with park and wilderness values?' Tall Timbers Fire Ecol Conf Proc 14. Symp Fire & Land Manage (Missoula, MT, 1974) Proc.

S. Barnett, J.B. Craig, R.C. Lucas, D. Milner, and R.I. Walker were panelists who debated whether or not current fire management activities are compatible with park and wilderness values. Barnett concluded that burning should be part of a larger well thought out resource management plan with specific objectives. These would include a desire to maintain natural ecosystems. With this in mind fire is definitely compatible with park and wilderness values. Craig spoke of the deep fear many people have of fire. Many affluent people have been voicing their concerns to the American Forestry Association. Property owners fear that prescribed burns will escape and cause damage to their property. Some people believe that sanitation cutting would be better and safer than fire. AFA urges fire managers to level with the public concerning the dangers of using fire as a management tool. According to Lucas the diversity of fire management activities and the differing views regarding park and wilderness values make it difficult to assess the question of compatibility. Each situation must be considered separately; however, one can consider that by definition, activities that move toward a more natural role for wildfire are compatible with wilderness values. Most wilderness visitors do not oppose a greater incidence of wildfire. Milner pointed out that using fire in its natural ecological role was compatible with the Wilderness Act and the National Park Act. The Montana Wilderness Society supports the philosophy that fire is a necessary tool in maintaining the natural ecosystems in national parks and in established wilderness areas. Walker concluded with the deduction that since much of the history of the Rocky Mountain area has been shaped by fire, the new fire management policies are helping to achieve a more natural and compatible role of fire in wilderness and park management.

KAUFERT, F.H. 1974 'Timber harvesters: Good guys or bad?' Am For 80(9): 16-9, 56-8.

For years the timber harvester has been classified as a "bad guy", but uncontrolled wildfire and land-clearing fires were primarily responsible for what happened to the forests of the Lake States. The real public enemy is fire. Prescribed fire is a tool for the professional forester. He uses it for slash disposal, site preparation, and brush control. It also probably has a place in some of our more remote wildernesses and other recreation areas. "However, the danger of using fire in uncut forests, such as cover most of our less remote parks, and wildernesses, is such that the safer and generally more effective tool of logging is recommended."

KAYLL, A.J. 1966 A technique for studying the fire tolerance of living tree trunks. Can Dept For Pub 1012. 22 p.

An apparatus consisting of a propane torch with fine controls, mounted on a frame and directed against the tree trunk, was used to measure the time required to reach lethal cambium temperature (60°C) in white pine, as a function of applied surface temperature and bark thickness. At highest temperature, 500°C, time required was such that gentle fires would not be expected to affect mature trees, say 10 in dbh and up.

KAYLL, A.J. 1968 'Heat tolerance of tree seedlings.' Tall Timbers Fire Ecol Conf Proc 8: 89-105.

Heat tolerance of physiologically-active and dormant seedlings (six species) was determined by applying controlled-temperature heat to restricted area on the stems, and also by heating whole seedlings in a hot air shroud. For a duration of 1 minute, lethal exposures for active seedlings ranged from 62°C to 78°C on the stems, and 52°C to 65°C for whole tops. Dormant lethal temperatures were 30 to 50 degrees higher.

KAYLL, A.J. 1968 The role of fire in the boreal forest of Canada. Can Dept For & Rural Dev Inf Rep PS-X-7. 15 p.

Review of literature on the boreal forest and fire as an agent of disturbance, regulation, and cycling. Discusses beneficial role of fire of right periodicity and intensity, harmful effects of repeated fire at short intervals or under wrong conditions. Treats individual tree species and ecological effects of fire, also effects on soils and wildlife. Foresees greater use of prescribed fire in northern forest management. Lists 93 references.

KAYLL, A.J. and C.H. Gimingham 1965 'Vegetative regeneration of *Calluna vulgaris* after fire.' J Ecol 53: 729-34.

The effects of age and fire on vegetative regeneration of *Calluna* were investigated by applying controlled high temperature (400°C) to the bases of plants of ages 12, 17, and 24 years, and then comparing the results with similar clipped but unheated plants. Fewer stem bases regenerated after burning than after clipping, and the younger plants produced a significantly higher number of sprouts. These results confirm the belief that after 15 years of age *Calluna* tends to lose its ability to regenerate vegetatively.

KAYLL, A.J. 1974 "Use of fire in land management." Fire and ecosystems. Kozlowski, T.T. and Ahlgren, C.E. (eds), Academic, New York: 483-511.

This article defines prescribed burning according to the Society of American Foresters, and outlines literature on the subject. The author reviews the history and purposes of prescribed burning in North America. He outlines techniques of prescribed burning in grasslands and savannas, shrub lands, and forest lands. Canadian examples are given from eastern Canada. There is also discussion of some parks related issues such as watershed air quality, and recreation applications of prescribed burning.

KEITH, L.B. and D.C. Surrendi 1971 'Effects of fire on a snowshoe hare population.' J Wildlife Manage 35: 16-26.

A spring wildfire on a square-mile study area in central Alberta caused snowshoe hares to abandon severely burned sites. Adult hares moved to less intensively burned areas. The proportion of juveniles on the burn was reduced markedly during the first summer. It was believed they moved to unburned habitat within one-half mile. There was no evidence of direct mortality. The abandonment and reoccupation of severely burned areas were clearly related to cover changes caused by the fire and subsequent revegetation. Food was also scarce on the burn during the first two months after the fire. Hares returned to the severe burn during the second summer following the fire, as brushy cover redeveloped through sprouting - principally aspen and poplar.

KELSALL, J.P., E.S. Telfer, and T.D. 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 Wildlife Serv, Ottawa, Occ Pap No 32. 58 p.

This review analyses literature relevant to fire on the Boreal Forest and on its related wildlife resources with particular reference to the Canadian North. A selected bibliography contains the more recent and historically important references, but is not all inclusive. The study concludes that fire is the most important factor influencing the ecology of the northern boreal forest, that fires in the resulting forest mosaic are natural features of long standing and that the boreal forest can be characterized as a fire dependent ecosystem. Trees, other plants, birds, mammals, and other animals of the forest have evolved in response and adaptation to the frequency extent and intensity of fire. With some possible exception, a mosaic of very successional stages of 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 fish, herbs, and mammals, particularly to important species of game and fur-bearers, and to such characteristics of the northern forests as the presence of permafrost, soils, and characteristics of unique vegetation. The basic characteristics of different types of fire are also described.

KERSHAW, K.A. and W.R. Rouse 1971 'Studies on lichen-dominated systems. 1. The water relations of *Cladonia alpestris* in spruce-lichen woodland in northern Ontario.' Can J Bot 49: 1389-99.

The water relations of *Cladonia alpestris* in spruce-lichen woodland in northern Ontario is described. The rate of drying of the lichen canopy was measured by resistance grids. The effects of dew were measured in a similar fashion. The lichen mat showed a very high stratified resistance to water loss. The physiological response of the lichen to conditions of varying levels of saturation is also discussed.

KERSHAW, K.R., and W.R. Rouse 1976 The impact of fire on forest and tundra ecosystems. Final Report 1975. A Report for the Arctic Land Use Research Program, Can Dept Ind Aff & North Dev. 54 p.

Objectives were to study the recovery of burnt surfaces characteristic of the region to the east of Great Slave Lake, in terms of vegetation development, soil properties, microclimate, and the interaction between these facets of the central problem of fire damage.

Following the two phases of succession dominated initially by the moss *Polytrichum piliferum* and then by the lichen *Cladonia stellaris* the 75 year old burns are dominated by the lichen *Stereocaulon paschale* constituting a phase which lasts up to 150 years when the lichen cover is replaced by a carpet of mosses and herbaceous plants typical of the final recovery phase. Concurrently with the development of the stereocaulon woodland there is a continued increase in tree density, tree size, and peat depth.

It is significant that caribou grazing is restricted to the stereocaulon phase, with fire essential to the maintenance of such prime grazing habitat in this area.

Burning of the lichen woodland leads to long term microclimatic changes which are of considerable magnitude for periods in excess of a half century in this environment. Burning is accompanied by a hotter soil and a hotter, drier atmosphere for a period exceeding 50 years.

If controlled burning is planned, fires of limited area extent are preferable and burning in the early summer is recommended. It is questionable if large-scale wildfires should be left uncontrolled to burn themselves out since they affect not only the immediate environment but will lead to an increased desiccation of areas downwind.

KICKERT, R.N., A.R. Taylor, D.H. Firmage, and M.J. Behan 1974 'Fire ecology research needs identified by research scientists and land managers.' Tall Timbers Fire Ecol Conf Proc 14: 217-56.

Reports on a questionnaire that was distributed in 13 western states and in 2 western Canadian provinces. From this question survey, 910 sets of questions emerged. The author suggests a way of organizing the questions into categories to more effectively identify research needs in the fire management field today.

KIIL, A.D. 1964 On describing and measuring locality, fuels and fire intensity of prescribed burns. Paper presented at the Can Inst For Rocky Mtn Sect, Edmonton. 10 p.

The author reviews the need for descriptive measurements of site and fuel, and fire behaviour to most effectively conduct prescribed burns. Most of the discussion centres on ways of describing fuels. The author also emphasizes the importance of documenting results and recording information that may be useful for prescribed burns in the future.

KIIL, A.D. 1965 A problem analysis of forest fire research in Alberta.
Can Dept of For, For Res Branch. 25 p.

The report describes in detail, the area and values affected by forest fires in Alberta, and describes fire problems in Alberta.

Topics outlined include: the forests of Alberta; history of forest fires and forest fire protection in Alberta; causes of fire in Alberta; forest fire weather; forest fuels; and a proposed research program for that province.

KIIL, A.D. 1966 Three prescribed burns in 1-year old white spruce slash. Can Dept of For, For Branch Calgary, Alta. Internal Report A-6. 19 p.

In 1965, three 2-acre prescribed burns were carried out in 1-year-old white spruce slash in west-central Alberta. The primary objectives were to compare fire hazard in lopped and unlopped slash; to reduce the fire hazard; and to study fire effects on fuel consumption. Observations and measurements were made of weather and fuel conditions, including fuel weight and size distribution. The proportion of slash, herbs, shrubs, litter, and humus consumed was determined for each burn. Ignition procedures are described and rate of spread estimated for each burn are recorded.

The author concludes that hazard reduction can be accomplished under relatively poor burning conditions, regardless of slash treatment or humus moisture conditions. Lopping increases the continuity of fuel beds and facilitates the drying of fuels after cutting. Rate of spread appears to be related primarily to fuel, size, continuity and moisture content. All three burns were effective in eliminating herbs and shrubs. Depth of burn varied greatly from spot to spot, but the variation was least where fuel continuity was greatest.

KIIL, A.D. 1967 Fuel weight tables for white spruce and lodgepole pine crowns in Alberta. Can Dept of For, For Branch Dept Pub No 1196.

Tables are presented to provide estimates of oven-dry weights for live branchwood and crowns of white spruce and lodgepole pine in west-central Alberta. Other tables give the proportion of fine material less than one-half inch in diameter and the weight of the unmerchantable portion of the stem. Basic data for the tables are from 60 white spruce and 101 lodgepole pine trees in a variety of sites and stands.

KIIL, A.D. 1967 Weight of the fuel complex in 70-year-old lodgepole pine stands of different densities. Special paper prepared for Internat Union of For Res Org, Munich, Germany, September 4-9, 1967. For Branch Dept Pub No 1228.

A study was made of the fuel complex in 70-year-old lodgepole pine stands in west-central Alberta to facilitate measurement and prediction of weight-and-size distribution of fuel components. Results showed that the weight of the entire fuel complex increased with increasing stand density in the range of 300 to 900 stems per acre but that the weight of some fuel components decreased in the same stand-density range. Correlations between basal area and expressions of fuel weight were used to construct prediction equations for minor vegetation, forest-floor litter (except humus), slash, the standing tree crop, and the entire fuel complex. The weight of aerial-fuel components can be estimated with greater precision than the weight of ground-fuel components. The weight of ground-fuel components may also be estimated from weight per acre-inch.

KIIL, A.D. 1969 'Fuel consumption by a prescribed burn in spruce-fir logging slash in Alberta.' For Chron 45(2), April 1969.

On 20-acre spruce-fir slash block was burned at moderate fire hazard. Weather, fuel-sampling, ignition pattern and fire effects are reported. The burn effectively reduced the slash-fuel-loading to a level where the spread of wildfire through the residual fuels is unlikely and cleared the site for planting by eliminating much of the physical barrier of fine-fuel concentrations. The burn did not, however, eliminate the possibility of a slow spread of wildfire through the remaining humus.

KIIL, A.D. 1969 Basic considerations in the planning and use of prescribed fire. Can For Ser North For Res Lab Info Rep Z-X-21. Edmonton, Alberta. 11p

The author restates the Society of American Foresters definition of prescribed burning and reviews the uses of prescribed burning in western Canada. These uses include removal of hazardous fuel, back-firing and burning out fuel ahead of an existing fire, silvicultural applications, improvement of wildlife habitat, grazing applications, land clearing, resource management in parks, and mistletoe control. The planning process for prescribed burning is reviewed including the definition of objectives, various area considerations, fuel considerations, and construction of fire guards. Some firing techniques are outlined, as are a range of effects of prescribed burning; including a reduction of fine fuel concentration; the reduction of the depth of the forest floor; the increase of surface temperatures; the removal of the organic mantle; and a possible decrease in total nitrogen but an increase in available phosphorus, potassium, calcium and magnesium; a decrease in soil acidity; reduction of vegetative competition for moisture, space and light; and the effect on public opinion about resources management.

KIIL, A.D. 1971 Prescribed fire effects in subalpine spruce-fir slash.
Can For Ser North For Res Lab Info Rep Nor-X-3, Edmonton, Alberta. 30p

The author concludes that fire spread is related to fuel loading, but equal loadings of different size class distributions will not necessarily result in the same rate of spread. Fuel fineness and compactness affect rate of fire spread. In this fire, duff consumption was achieved after several days of smouldering, and only spotty exposure of mineral soil around stumps and dead logs on the forest floor was achieved.

Prescribed burning is an effective method for reducing the slash fire hazard to an acceptable level. However, in the range of moisture regimes tested, prescribed burning cannot be expected to reduce more than 20 percent by weight of the entire duff layer of 6 inches or more common on such sites. Similarly the deep duff layers preclude any appreciable exposure of mineral soil even after moderately long periods of drought.

In light of this experience the author makes a number of specific recommendations for slash burning in this kind of vegetation.

KIIL, A.D. 1975 'Forest fire effects on environment in Canada.'
Proc IUFRO Symp on For Harvesting Mechanization and Automation
(Ottawa, 1975): 371-90.

This paper discusses the historical and current significance of wildfires and prescribed fires in Canada, with particular emphasis on northern coniferous forests. The role of fire is discussed in terms of a natural ecosystem process having significant direct and indirect effects on species succession and diversity, accumulation of organic matter, nutrient status and cycling, wildlife habitats, potential for natural disturbances - such as blowdown and insect epidemics, chemical soil properties, water quality and quantity, atmospheric pollution, and aesthetical considerations. The fire ecology principles governing these processes are briefly reviewed to provide a perspective for assessing effects of wildfires and prescribed burns following harvesting.

KIIL, A.D. 1975 Position paper on fire research in the Canadian Forestry Service. Dept Env, Can For Serv, Prog Coord & Eval Br Info Rep DPC-X-5.

The author reviews fire research being conducted in various research institutes right across Canada. He also briefly reviews research being conducted outside the Canadian Forestry Service. The major work categories identified are: prediction of fire occurrence and behaviour, optimization of fire control operations, fire ecology and environmental effects, and fire management concepts and planning aids. Needs in each of these areas are identified.

KILGORE, B.M. 1971 'The role of fire in managing red fir forests.'
N A Wildlife & Nat Res Conf Trans 36: 405-16.

A prescribed burn in the red fir type in King's Canyon National Park resulted in no noticeable change in deer or bird numbers. Fire suppression seems to be of questionable value in this type unless there is danger to human life or property. It would seem to be desirable to allow most lightning fires in red fir forests to burn without suppression.

KILGORE, B.M. 1973 'The ecological role of fire in Sierran conifer forests: its application to national park management.' Quat Res 3: 496-513.

The major effects of fire in the Sierran conifer forests include seedbed preparation, nutrient cycling, controlling patterns of succession, wildlife habitat modification, and reduction of fire hazards. Several species of trees, including the giant sequoia and some of the pines, probably owe their existence to periodic fires. For years National Park Service policy was to exclude fire. This resulted in unnatural ecological changes. Current NPS management policies are aimed at restoring fire, as nearly as possible, to its natural role in the Sierran conifer forests. To do this prescribed fire is being used to lower and middle elevations, and lightning-caused fires are allowed to burn at higher elevations.

KILGORE, B.M. 1974 'Fire management in the National Parks: An overview.'
Tall Timbers Fire Ecol Conf Proc 14: 45-57.

The author reviews and lists the various parks in the U.S. system where new fire management policies are emerging or being practiced.

KILGORE, B.M. 1975 'Restoring fire to national park wilderness.' Am For 81(3): 16-9, 57-9.

In 1968 the National Park Service changed its basic policy concerning fire from one of suppression of all fires to one which recognizes that some fires are beneficial. The new policy seeks to restore fire to the park environment in order to restore and maintain natural conditions. New fire management programs designed to implement this policy have been initiated in eleven national parks and monuments. Over 3,000,000 acres are being managed under these programs. Park personnel have allowed 274 natural fires to burn almost 30,000 acres since 1968. During the same period prescribed burns have been used to treat 37,000 acres. Smoke from these fires is causing concern among NPS officials and others. Researchers in universities and the Forest Service are trying to answer smoke-related questions, while NPS, FS, and university scientists are investigating other aspects of the new programs. The goal of these new efforts must not be to provide the "safest" management for the short run, but the best possible management for the long run.

KILGORE, B.M. and G.S. Briggs 1972 'Restoring fire to high elevation forests in California.' J For 70: 266-71.

Until 1968 National Park Service fire policy in the West called for all fire to be extinguished as rapidly as possible. This policy resulted in unnatural ecosystem changes. Species composition changes, interruptions in nutrient cycling, and build-ups in understory fuels resulted. The 1963 Leopold Report called for restoring park forests to pre-European man conditions. The report attacked over protection from fire as being unnatural. NPS policy was changed, so that in 1968 certain lightning-caused fires were allowed to burn in the Sequoia and Kings Canyon National Parks. This natural fire policy conforms to the NPS policy of restoring and maintaining natural environmental conditions in parks.

KIRSCH, L.M. and A.D. Kruse 1972 'Prairie fires and wildlife.' Tall Timbers Fire Ecol Conf Proc 12: 289-303.

Without fire most native grasslands are rapidly colonized by woody species. Historically, prairie chickens were abundant on Kansas prairies where fires were frequent. In Dakota, both prairie chickens and sharp-tails became abundant after big game herds were decimated and fires were not effectively controlled. Fire suppression and the absence of deliberate use of fire to control vegetational succession has done untold damage to prairie wildlife. Preliminary results of a study revealed a similar number of nests but a greater variety of species on burned vs unburned grassland. Burning eliminated brush and produced a greater variety of plant species. Burning occurred in May. Duck nests were more numerous, as were sharp-tail broods, on the burn. Fire can be an important tool for wildlife management on prairie areas.

KITTAMS, W.H. 1972 'Effect of fire on vegetation of the Chihuahuan Desert Region.' Tall Timbers Fire Ecol Conf Proc 12: 427-44.

In the evergreen shrub type, burning improves deer forage. Shrubby redberry juniper (*J. pinchoti*) and alligator juniper (*J. deppeana*), skunkbush (*Rhus trilobata*) and hairy mountain mahogany (*Ceanothus breviflorus*) all sprout following fire and are preferred deer food. Oaks, at higher elevations, are improved by burning. *Ceanothus greggii*, much used by deer and often decadent, rarely sprouts but fire results in seedling production. Among other plants sustaining more use following fire are: catclaw, sacahuista, goldeneye and dalea. Range recovery may take from 5 to 10 years for species like skunkbush, up to 50 years for juniper.

KLEBENOW, D.A. 1972 'The habitat requirements of sage grouse and the role of fire in management.' Tall Timbers Fire Ecol Conf Proc 12: 305-16.

In Idaho, an area unintentionally burned created a strutting ground that birds were quick to occupy. These openings are necessary for the birds, and small burned areas, 1 to 10 acres in size, at the elevations utilized for breeding would be beneficial in homogeneous sagebrush types. Where sage is dense, habitat improvements could be achieved by moderate burning coupled with grazing management to get the desired mosaic of shrub, grass and forbs. Repeated burning could be bad in this case, as could the use of large, hot fires where an excessive amount of cover is removed. Where cover is limiting, burning has been a problem. Fire can be an important part of management of meadows invaded by sagebrush. Small areas burned to produce a mosaic of food and cover should be desirable. There should be different stages of successional growth to produce the greatest variety of forbs. Rotational burning of different patches each year or every few years, possibly with as long as 20 years between burning treatments, was recommended. Fire appears to be an ideal tool to create openings and a diversity of habitat types. In wintering habitats, there seems to be little place for fire due to complete reliability on shrubs for food or cover. Burning should be a more desirable practice than the present reliance on herbicides.

KLOCK, G.O. and J.D. Helvey 1974 'Soil - water trends following wild-fire on the Entiat Exp. Forest.' Tall Timbers Fire Ecol Conf Proc 14: 193-200.

Fire which removes all foliar vegetation does have an important impact on the minimum autumnal soil-water content. Higher autumnal soil-water contents caused by wildfire which reduces the evapotranspiration demand appear to make watersheds more hydrologically sensitive. The watershed buffering capacity provided by the soil mantle for unusually large precipitation events during the winter and spring months has been reduced and streamflow becomes more responsive to precipitation input. Mass soil movement on fire-affected steep mountain slopes could also be accelerated.

KOMAREK, E.V. 1962 'Fire ecology.' Tall Timbers Fire Ecol Conf Proc 1: 95-107.

The author defines fire ecology as the study of fire as it affects the environment in the interrelationships of plants and animals therein.

The author outlines opportunities and problems in studying fire ecology, focusing on the difficulties in devising measurements of fire in nature.

KOMAREK, E.V. Sr. 1963 'The use of fire in wildland management.'
Symp 7th Ann on Arizona Watershed (Phoenix, AZ, 1963) Proc.

This article reviews the history of prescribed burning in the United States, and states some of the native impact of fire suppression. In particular the high initial costs of removing fuel accumulations when prescribed burning is undertaken under years of suppression is emphasized. The initial prescribed burn is more expensive and dangerous than a regular schedule of fires. Undesirable hardwood underbrush fuel accumulations in commercial pine stands particularly in the southeast United States is also reviewed. Wildlife applications of prescribed burning for management of prairie chickens, sharpshooters, ruffed grouse, wild turkey, Kirtland's warbler, bobwhite quail, water fowl, Virginia deer, mule deer, elk, white tailed deer, and moose are also reviewed.

KOMAREK, E.V. 1967 'Fire and the ecology of man.' Tall Timbers Fire Ecol Conf Proc 6: 142-70.

Fire effects are placed in the context of man's cultural history.

KOMAREK, E.V. Sr. 1969 'Fire and animal behavior.' Tall Timbers Fire Ecol Proc 9: 161-208.

This is an extensive review article concerning the reaction and behavior of animals to smoke, fire, and the resulting burnt ground along four general lines: 1. avoidance response to fire and smoke; 2. animals attracted to fire and smoke; 3. animals relationships to blackened areas caused by fire, and 4. animals attracted to the "greening" burns. It is evident that many animals are adapted to a fire environment and that natural selection has been a major factor in such adaptation. Animals have certain mechanisms, such as infra-red detection, olfactory detection, sight, and possibly other unknown receptors or sensing organs that allow them to live safely in a fire environment. The aspects of fire and animal behavior is a much neglected scientific endeavor. The article contains fairly lengthy tables summarizing the four criteria outlined above.

KOMAREK, E.V. 1970 'Insect control - fire for habitat management.'
Tall Timbers Conf on Ecol Animal Control by Habitat Manage Proc 2: 157-71.

The action of fire in regulating insect populations is manifold and complex, depending upon the kind of fire, time of day or year, climatic and moisture conditions, wind speed, amount of fuel, moisture content of the fuel, etc. It can also be influenced by the weather conditions after the fire. The effect of fire depends on the stage in the life cycle of the insect, the degree of activity, and its ability to fly or escape the fire. Insect control by fire has long been used in agriculture, e.g. on rangeland for grasshopper control.

KOMAREK, E.V. 1970 'Controlled burning and air pollution: An ecological review.' Tall Timbers Fire Ecol Conf Proc 10: 141-73.

Air quality on a global basis is much the same today as it was centuries ago. Most of today's air pollution is a city problem. Since lightning fires have been around much longer than man, so has forest fire smoke. In fact, according to existing evidence, smoke from controlled burning for forestry, wildlife, and agriculture is not hazardous to human health. The primary problem with smoke from these operations is that it is visible. Even then it is only a local matter and can be properly managed. Fire exclusion results in fuel accumulations which, when burned by wildfires occurring under adverse conditions, produce much more smoke than is produced by carefully managed controlled burns.

KOMAREK, E.V. 1971 'Effects of fire on wildlife and range habitats.' Symp on Prescribed Burning (Charleston, SC, 1971) Proc, sponsored by USDA For Serv Southeastern For & Range Exp Stn, Asheville, NC.

Fire is essential in the management of wildlife and range animals, and plants in the southeastern pine forest, grasslands, and adjacent wetlands. Ecologically, fire has been a natural force affecting these communities long before man arrived. All living things respond to certain biological laws, and the relationship of fire to these laws must be recognized and understood. Emphasis must be on the habitat rather than on the wildlife. In the southeast, under a pine-quail management program where controlled burning is regularly conducted, fine quail hunting has been developed to the point where 30 to 35 coveys per shooting day can be found with regularity throughout the season. In some regions, on good soils, the undesired successional change can occur so rapidly that the grassland and its inhabitants can be replaced in from 3 to 6 years of fire exclusion. Through burning, these grasslands under the pine are kept in a youthful stage of plant succession productive of wildlife. Fire, when properly applied, favors grasslands over bush or forest. When a burn greens up with new vegetation, it has a very strong attraction for many species of animals - including high populations of insects. The disappearance of the heath hen is a good example of species elimination through fire exclusion.

KOMAREK, E.V. 1972 'Ancient fires.' Tall Timbers Fire Ecol Conf Proc 12: 214-40.

Fire has been an integral part of the ecosystem from the Carboniferous period to the present. Fossil charcoal, called fusain, has been found in coal deposits dating to the Mesozoic. This charcoal confirms the presence of fire in the ecosystems of that time. Fire was a naturally occurring ecological factor long before the appearance of man.

KOMAREK, E.V. Sr. 1974 'Fire ecology review.' Tall Timbers Fire Ecol Conf Proc 14: 201-16.

This article reviews the purposes and development of Tall Timbers Research Incorporated. A brief section reviews the history of ancient fires. General attention is given to early fire vegetation in forests, grasslands, and savannas, brush or shrub lands, and wetlands, marshes and swamps. General attention is given to effects of fire on animal life and mankind's relationship to and use of fire from ancient times is generally outlined.

KOMAREK, R. 1963 'Fire and the changing wildlife habitat.' Tall Timbers Fire Ecol Conf Proc 2: 35-43.

Wild animal populations usually are mobile and may move when ecological succession destroys their habitat, but if it occurs over a wide enough area they perish. Land management for wildlife must provide measures to maintain and control vegetation patterns. Fire was at least one of the prime ecological factors responsible for the original varied mantle of vegetation.

KOURTZ, P. 1967 Lightning behavior and lightning fires in Canadian forests. For Branch, Dept Publ No 1179. 34 p.

The behavior and occurrence of lightning and lightning-caused forest fires in the years 1960-63 are studied on the basis of data on 3,615 lightning-caused forest fires. A review of literature indicated that the tree species most frequently struck were the most abundant species having the most favorable characteristics to attract lightning. The nature of the damage depends on the dielectric properties of the tree and on lightning-flash energy.

Approximately 80% of the trees ignited by lightning are softwoods. Hardwood snags seem to be more susceptible to lightning fires than softwood snags. All dry snags are very susceptible to lightning fires. Relative height and elevation are important factors determining where lightning will strike. However, the ability of the tree and the soil to conduct electricity is also an important factor. Lightning-fire zones do exist, but the reasons for their existence are not understood.

KOZLOWSKI, T.T. and C.E. Ahlgren (eds) 1974 Fire and ecosystems.
Academic Press, New York. 542 p.

This volume is a collection of papers by world authorities showing how fire relates to various broad classes of vegetation as well as soil and organisms. Some authors and their topic are as follows: P.J. Viro on soils, I.F. Ahlgren on soil organisms, J.F. Bendell on birds and animals, R.J. Vogl on grasslands, C.E. Ahlgren on temperate forests of north central United States, S. Little on temperate forests of northeastern United States, E.V. Komarek on temperate forests of southeastern United States, H. Weaver on temperate forests of western United States, H.E. Biswell on chaparral, R.R. Humphrey on desert grasslands of North America, Z. Naveh on the Mediterranean Region, J. Phillips on forests and savannas of Africa, A.J. Kayll on the use of fire in land management. Each chapter has an extensive bibliography.

LAWRENCE, G.E. 1966 'Ecology of vertebrate animals in relation to chaparral fire in the Sierra Nevada foothills.' Ecology 47: 278-91.

In California, no species is totally eliminated following a chaparral fire, nor is there any apparent diminution of total life on a burn after plant growth resumes. The woodrat, due to its tree nests, was perhaps the most vulnerable species present. In the bare ash following the fire many species were severely exposed to predation, and populations of most small mammals and some brush-dwelling birds decreased rapidly. Predatory birds and mammals increased, as did some seed-eating birds that found good foraging on the exposed earth. Birds and mammals that normally exhibit a strong preference for chaparral habitat were substantially reduced in numbers in the years following a burn. Conversely, some birds preferring grassland or oak-woodland increased in number. The fire resulted in an overall increase in densities of nesting birds. None of the small mammals increased in numbers but some of the larger predators, such as the coyote and badger, moved into the burn during the months following the fire. Temperature measurements indicate that animals probably experience no ill effects of the fire heat if they occupy a burrow system of at least 3 inches in depth. Suffocation is a greater danger. Another result of the fire was a large increase in numbers of hawks and owls.

LAWRENCE, G.E. and H. Biswell 1972 'Effect of forest manipulation on deer habitat in giant sequoia.' J Wildlife Manage 36: 595-605.

In California's Sierra Nevada sequoia forest, management has created open, park-like conditions. Studies on four 20-acre plots included cutting, piling and burning small trees, underbrush and debris. Cutting and burning increased rate of seedling growth and produced new sprouts. Utilization by deer seemed to increase. Shrubs were not abundant on untreated areas because of absence of fires. The number of shrubs increased on the lightly burned areas. Fire suppression for over 70 years resulted in accumulated forest debris and increased canopy density and simultaneously diminished the quality of wildlife habitat and increased the fire hazards. Treatment improved conditions for deer. Accessibility of forage plants improved.

LAWSON, D.B. 1973 Report on joint U.S. Forest Service - U.S. National Park Service Meeting on Fire Management in Forest Ecosystems.
North For Fire Lab Missoula, MT, May 1 to 3, 1973. 6 p.

The report on discussion at this meeting includes a list of the meeting participants. The principle objectives were the preliminary discussion of wildlife management policies and practices within the context of the United States Forest Service wilderness areas and National Park natural areas. Extending fire management concepts to multiple use non-wilderness areas was also discussed. Research background relevant to the topic was provided by those involved in various fire research projects. Park policies on fire management as presently practiced were presented by representatives from Yellowstone, Rocky Mountain, Grand Teton, and Glacier National Parks. Future plans with respect to restoring fire as a natural factor in a national park ecosystem were discussed and at policy and action levels. The need for service-wide coordination of fire management programs were stressed.

LEEGE, T.A. 1968 'Prescribed burning for elk in northern Idaho.'
Tall Timbers Fire Ecol Conf Proc 8: 235-54.

In northern Idaho mixed-conifer forest the most abundant food shrubs for deer and elk are: willow (*Salix scouleriana*), serviceberry (*Amelanchier alnifolia*), mountain maple (*Acer glabrum*) and redstem ceanothus (*Ceanothus sanguineus*). Prescribed burning trials indicated that both spring and fall burning were feasible and produced desirable results. Large wildfires early in the century created extensive browse ranges and big game animals have thrived. Important shrubs, like redstem ceanothus, are now being shaded and dying out. Prescribed burning trials have shown that fall burning more completely consumed the litter and exposed bare soil causing greater erosion potential. Willow, mountain maple, serviceberry and ocean spray (*Holodiscus discolor*) sprouted most prolificly producing as many as 120 sprouts per plant. Less active (about 15 to 50 sprouts per plant) were redstem ceanothus, bitter cherry (*Prunus emarginata*), cascara (*Rhamnus purshiana*) and syringa (*Philadelphus lewisii*). Willow made the best growth after one season, averaging 3-5 feet in height. Fall burned plants produced fewer sprouts but growth was greater. Number of sprouts is more important than length. After three growing seasons, most of the principal species had grown beyond reach (willow, serviceberry, maple). Big game preferred eating the new growth on the burned area rather than on unburned areas regardless of species or season burned. Spring burning produced sprouts for the following winter, fall burning one year later. Normally unpalatable shrubs like ocean spray, syringa and bitter cherry were much better utilized after burning. Elk also browsed larger twigs. These effects, on spring burns, continued through two winters. Protein content was consistently higher on burned-area shrubs; effects lasted at least through two winter seasons. Redstem ceanothus and bitter cherry seedlings were numerous on burns. Spring burning produced 60,000 redstem ceanothus seedlings per acre; fall burning gave 242,000. The average cost of burning 4,000 acres on three forests was 71 cents per acre.

LEEGE, T.A. 1969 'Burning seral brush ranges for big game in northern Idaho.' N A Wildlife & Nat Res Conf Trans 34: 429-38.

Controlled burning is feasible in early spring after snow melt at lower elevations, and in the fall soon after seasonal rains begin. Key game winter ranges are scheduled to be burned on a rotation to keep maximum production of browse.

LEHMANN, V.W. 1965 'Fire in the range of Attwater's prairie chicken.' Tall Timbers Fire Ecol Conf Proc 4: 127-43.

On the coastal prairie, fire exclusion has not been good for Attwater's prairie chicken. Fires caused little direct mortality of adults. Prescribed burning should be done in March-April to precede nesting. Fires during the laying and hatching seasons can be destructive.

LEOPOLD, A. 1933 Game management. Scribner, New York.

Fire is an influence operating on environmental factors rather than directly on wildlife. The effects of fire vary with kind of game, composition of habitat, etc. Game ordinarily evades fire but may at times be entrapped or stampeded. Species with restricted home ranges may not move freely to escape fire. Even slight body burns may be fatal to game. The loss of nests and young in forest or marsh fires is a leading source of direct losses. Fire in advance of the nesting season may remove nesting cover for the season. Nesting cover on dangerous ground (e.g. subject to flooding) can be removed by burning. Fires may concentrate nests on unburned cover. Birds may appear in new areas due to dispersal caused by eviction by fire. Prairie chicken range was extended northward in the Lake States due to fire and lumbering. Controlled fire has been used to get the desired density of grass for quail nesting. Nesting cover for red grouse in Britain is maintained by controlled spot burning.

LEOPOLD, A.S. 1950 'Deer in relation to plant succession.' N A Wildlife Conf Trans 15: 571-8.

Prior to settlement, deer seem to have occurred principally along "edges" where forest and grassland met or on recent burns in the forest. Neither dense timber nor extensive prairie supported many deer. Staple items of deer diet are characteristic of sub-climax ecological conditions. The dense forest which cloaked so much of North America has been almost universally cut over and burned. The resultant brush fields and young stands of forest reproduction are now well stocked with deer. Logging, fire and grazing are the three principal influences which in the past have created or improved most of our present deer range. In forest areas, controlled burning might be adopted as a tool to stimulate deer food production on critical sites not adapted to timber production. Controlled burning is the cheapest tool where applicable.

LEOPOLD, A.S. and F.F. Darling 1953 'Effects of land use on moose and caribou in Alaska.' N A Wildlife Conf Trans 18: 553-62.

Moose achieves highest density in forest areas where winter ranges have been opened by fire or any other form of timber removal, permitting regeneration of willow, birch or aspen - characteristic of secondary stages of forest succession. The moose is primarily an animal of a sub-climax biota. Conversely, the caribou seems to require a winter range supplied with lichens which are part of the climax flora of forest borders. The caribou is a member of a climax fauna. Accelerated burning has influenced moose favorably and caribou unfavorably over a large part of Alaska south of the Arctic Circle. The controlled use of fire to improve critical areas of winter range in central and southern Alaska would be advantageous and, in some localities, quite practicable. Moose range can be destroyed by a burn as readily as it can be created. Such intensive management is most desirable near population centres. Caribou numbers probably will continue to diminish - particularly in central and southern Alaska. The remaining lichen ranges must be protected from fire if caribou are to survive. The controlled use or exclusion of fire should be part of an integrated plan of game management.

LEOPOLD, A.S. and F.F. Darling 1953 Wildlife in Alaska: An ecological reconnaissance. Ronald Press, New York.

The mere passage of fire through timberland does not necessarily create optimum conditions for moose. Fire may produce grassland, spruce, etc. with little birch or willow. Aspen sprouts do not withstand heavy browsing. Years may pass before appreciable amounts of browse come in following fire.

LEOPOLD, E.B. 1969 'Ecological requirements of the Wilderness Act.'
In Quality of life, M.E. McCloskey and J.P. Gilligan (eds),
 Sierra Club: 267 p.

The Wilderness Act requires the maintenance of biological naturalness. Some scientists agree that this means restoration to the conditions that prevailed when the areas were first visited by the white man. Naturalness is characterized by extensive species and structural diversity of native plants with high productivity. In many areas, such as the Everglades National Park and the Gila Wilderness, fire is a necessary part of the ecosystem. Yet man has tried to exclude it as a "bad" force. It has taken 40 years to realize that total fire exclusion is unnatural. It is not in keeping with the requirements of the Wilderness Act. Research is progressing but, in the author's opinion, not fast enough. More research is needed, and the agencies should implement their findings so that the ecological requirements of the Wilderness Act can be met.

LEOPOLD, E.B. and N. L. Bradley 1973 'Fire and productivity' In
Let the forests burn: Technical session proceedings. Colo State
 Univ, Coll For Nat Resour, Dep For Wood Sci: 27-37.

Fire plays a role of rapid cycling of soil minerals that have become tied up in plant material. If the burning temperature is not too hot, fire increases usable calcium, nitrogen, and phosphorus. Where nutrient content of forage has been increased by burning, wildlife reproduction and health are generally improved. Fires also improve diversity of plant life and increase "edge effect". Both of these factors are important to wildlife. A fourfold approach to fire is needed. (1) Continue research on fire and nutrient cycling. (2) Expand "let-burn" policies in all land-managing agencies. (3) Control man-made accidental fires. (4) Expand prescribed burn programs.

LESKO, G.L. 1971 Early effects of a prescribed fire in spruce-fir slash on some soil properties. Internal report A-44, For Res Lab, Edmonton, Alberta. 12 p.

The study was done in spruce-fir stands after clear-cutting in Hinton, Alberta. The fire left ash residue from burning slash and oxidized part of the surface organic layer. The extent of these effects depended on fuel concentrations and fire intensity. There was an increased pH in the surface organic layer and the amounts of organic matter and total nitrogen decreased, though the carbon: nitrogen ratio was not changed because the same percent of each was lost. Exchange properties did not change significantly, with the exception of exchangeable K. Soil temperature increased significantly in the burned area. As far as spruce and fir are concerned, increases in Ca and K and higher soil temperatures are all site improvements.

LEWIS, H.T. 1977 'Muskuta: the ecology of Indian fires in northern Alberta.' West Can J Anthropology, III(1): 15-52.

Interviews with more than 50 older native people across Alberta's boreal forest region, from more than 30 communities, elicited information on the types of microenvironments once burned, the variety of reasons for burning, and the considerations in controlling man-made fires. The evidence presented demonstrates the fact that the Indians of northern Alberta employed very sophisticated approaches to and understandings of the dynamics of fire for the management of plant and animal resources in a boreal forest environment.

The Cree name for the creek, Muskuta, meant prairie or a creek along which the original forest has long since been burned and had been replaced by small poplars and willows and abundant grass.

LITTLE, S. 1974 'Effects of fire on temperate forests: Northwestern U.S.' Fire and ecosystems, Kozlowski, T.T. and C.E. Ahlgren (eds), Academic, New York: 225-50.

This article contains a review of the effects of fire on spruce-fir species, northern hardwoods, and eastern white pine. Considerable Canadian work is cited in the article.

LONGHURST, W.M. 1969 The effects of brush burning on deer. Prog Rep 1968 and Summary Rep 1963-1968. Univ Calif Hopland Field Stn.

Brush burning trials were carried out in northern California (Cow Mountain) chaparral to determine effects on deer. Widely distributed burned spots averaged about 50 acres in size. The amount of burning should be kept in balance with utilization. Good distribution of unburned escape cover is essential to achieve good distribution of use in burns. Brush was crushed several months before burning. Burning occurred in May and June. North slopes supporting heavy live oak brush could be burned only during high risk conditions. South facing slopes of chamise could be burned at any dry season. Crushing before burning prevented thickets of blackened stubs which limit deer movement. The fires were not a direct hazard to deer on the small areas burned. Mature, unburned brush provides good cover but poor quality of forage. The shrub regrowth from seedlings and crown sprouts produces higher protein content over about a three-year period. Burning does not favor acorn production. By leaving unburned patches, deer use them for cover and acorns (may amount to one-half the late summer diet). A major benefit of burning for deer management results from increased accessibility of deer to hunters.

LOOPE, L.L. and G.E. Gruell 1973 'The ecological role of fire in the Jackson Hole, area Northwestern Wyoming.' Quat Res 3: 425-43.

Fire-history investigations in the Jackson Hole area of northwestern Wyoming reveal that most current stands of aspen and lodgepole pine regenerated following extensive fires between 1840 and 1890 and that widespread fires occurred in the 1600s and 1700s. White man's major effect on the fire incidence has been the successful suppression during the past 30-80 years. Successional changes in the absence of fire include the deterioration of aspen stands, massive invasions of subalpine fir in lodgepole pine stands, great increase in conifer cover, heavy fuel buildups in lodgepole pine and Douglas-fir stands, and increase in sagebrush and other shrubs. Steps are being taken, starting in 1972, to allow fire to play a more natural role in Grand Teton and Yellowstone National Parks. Teton National Forest plans experimental prescribed burning to determine whether fire can stimulate successful aspen regeneration in the presence of large numbers of wintering elk. The Grand Teton National Parks started in 1972 to let fire play a more natural role, when the park was first zoned.. All lightning-caused fires will be allowed to burn in Zone 1, except under prohibitive conditions such as a threat to human life. Man-caused fires will be extinguished. In Zone 2 prescribed fires may be used, naturally caused fires may or may not be allowed to burn according to the judgement of a fire management committee. All fires in Zone 3 will be extinguished, unless they can be managed as controlled burns. The natural fire frequency will be approximated with prescribed fire. Zone 4 lies around developed areas, logging and planting will be used to manipulate the vegetation to approximate the effects of fire.

LOOPE, L.L. and R.P. Wood 1975 'Fire management in Grand Teton National Park.' Tall Timbers Fire Ecol Conf Proc 15. Symp Fire & Land Manage (Missoula, MT, 1974) Proc.

A fire management program was initiated in the Grand Teton National Park in 1972. The purpose of the program is to restore fire to ecosystems within the "natural area" where a successful fire suppression program since 1929 has caused major ecological changes. Lightning fires are allowed to burn in about half of the park, while fires occurring in the remainder of the park are suppressed as dictated by considerations for human safety and protection of property. Limited prescribed burning will also be carried out during a 5-year period to determine the feasibility of extending the scope of the fire management plan in the future.

LOTTI, T., R.A. Klawitter, and W.P. LeGrande 1960 Prescribed burning for understory control in loblolly pine stands of the coastal plain. USDA For Serv S E For Exp Sta, Sta Pap 116. 19 p.

This report is concerned with the undesirable natural replacement of pine by hardwoods when fire is excluded. Test fires were studied over a period of a decade. Both winter and summer fires were effective in reducing the hardwoods without damaging pine, as long as the latter were of sapling size or larger.

LOUCKS, O.L. 1970 'Evaluation of diversity, efficiency, and community stability.' Am Zoologist 10: 17-25.

The natural tendency in forest systems toward periodic perturbation recycles the system and maintains a periodic wave of peak diversity. It is concluded that any modifications of the system that preclude periodic, random perturbation and recycling would be detrimental to the system in the long run.

LUNAN, J.S. and J.R. Habeck 1973 'The effects of fire exclusion on ponderosa pine communities in Glacier National Park, Montana. Can J For Res 3: 574-9.

Analysis of age data in these fire-dependent communities indicates that ponderosa pine is not reproducing itself as well as other mesophytic conifers invading these stands. In addition to these compositional changes, it was determined that fuel accumulations are greater in these park communities compared with similar wilderness area pine communities subject to more recent burning.

LUTZ, H.J. 1956 Ecological effects of forest fires in the interior of Alaska. USDA Tech Bull 1133.

This article has been cited by many authors as being the bible on fire effects on taiga or tundra communities.

Alaska has been subject, through historic time, to extensive and repeated fires. Dry forests and the lichen-moss-shrub ground cover readily carry fire. Climax white spruce on the better drained sites have been replaced with paper birch and quaking aspen. Revegetation usually is prompt. Spruce becomes prominent in the birch understory in about 80 years and becomes dominant in 100 to 200 years. Aspen sprouts and seedlings often come in abundantly, but are replaced by white spruce in about 60 years. Repeated severe fires in white spruce stands may result in treeless herb or shrub communities requiring 100-200 years for natural reconversion. Black spruce, occupying low, wet sites, usually regenerates to a pure stand even following an intense fire. Organic matter tends to remain unincorporated. It may become a foot thick under old stands. Earthworms are scarce. Permafrost is 12 to 18 inches below the surface. Even severe fires may not expose much mineral soil.

In general, fur-bearing animals appear to be adversely affected by most severe fires. Small mammals, many of which serve as food for fur-bearers, are killed when their habitat burns. The marten may be most vulnerable. Large fires destroy many fox, fisher, ermine and lynx. The finest furs come from the most densely wooded districts. Recurrent fires were considered a threat to the old fur trade. The effect of uncontrolled fires on moose is not clear. In certain areas the moose population has increased following fire. However, there are extensive areas which have burned repeatedly and which support much browse but few moose. Also, moose are moving into unburned areas. The possibilities of prescribed burning for moose habitat are recognized. The effects of fire on caribou are generally agreed to be harmful or even disastrous. Whereas the moose prefers vegetation in early stages of succession, the barren ground caribou normally lives in climax plant communities. Fruticose lichens and certain beard lichens growing on trees form the principal winter food of the caribou. These lichens are highly flammable and recovery is excessively slow. Recovery in usual situations will take 40 to 50 years. Full recovery of tall-growth lichens may require more than 100 years. Extensive fires have destroyed large portions of caribou range. Burned areas are avoided by caribou. Recurring fires that break up their range into small tracts adversely affect caribou.

LYON, L.J. 1966 Initial vegetal development following prescribed burning of Douglas-fir in south-central Idaho. USDA For Serv Res Paper INT-29, Intermt Forest & Range Exp Stn, Ogden.

Prescribed fires, particularly in logging slash, are not unusual in forests of northern Idaho. Natural vegetation recovers rapidly. Following an August burn on a logged Douglas-fir site, sprouting from shrubs doubled pre-fire density in two years. Maple recovered eight percent of pre-fire volume; willow 42 percent. Mountain ash was eliminated. Snowbrush produced many new seedlings. Elderberry resprouted and became third in shrub volume in two years. Serviceberry and snowberry lost volume between the first and second post-burn years. Irreversible patterns are set during the first two postburn years. Forage values for big game at least doubled within two years. Willow became most abundant and was all available, mountain maple was second; both will grow out of reach in a few years. Snowbrush, and other low shrubs with forage value, came in. Snowbrush could disappear in 20 years under a tree canopy. The wildlife habitat values will peak in the first 15 years and then decline. The stand should resemble preburn condition in 40 years.

LYON, L.J. 1969 'Wildlife habitat research and fir in the northern Rockies.' Tall Timbers Fire Ecol Conf Proc 9: 213-27.

Wildlife populations fluctuate with vegetation changes, especially big game. Recovery of burned forest coincided with game population reductions.

LYON, L.J. and P.F. Stockney 1974 'Early vegetal succession following large northern Rocky Mountain wildfires.' Tall Timbers Fire Ecol Conf Proc 14: 355-75.

The majority of plant species on site prior to the burn will survive or re-establish on the burn. The plant species that can be expected to dominate early succession will become established in the initial post-fire year. Thus the basic information required to predict early post-burn community composition is a pre-burn species inventory. Such an inventory should provide at least 75 percent accuracy, and this can be improved with a species inventory of the first post-fire growing season flora.

MacARTHUR, J.D. 1964 A study of regeneration after fire in the Gaspé Region. Canada Dep For Publ 1074. 20 p.

This study, made in 1961, concerns post-fire regeneration after a fire that occurred in 1940 in cut-over and uncut stands of white spruce, balsam fir, and white birch. New white birch seedlings appeared in the year following the fire and for several years thereafter. Spruce and fir seedlings first appeared 3 years after the fire; a greater number of new ones appeared every year to a maximum in the ninth year; there were very few new germinants in the eleventh year after the fire. In the original stand, fir outnumbered spruce 60 to 1; in the seedling stand the predominance of fir was reduced to 3 to 1. However, there were only about 500 per acre counting both species. The number of seedlings was closely correlated with distance from an unburned stand - the seed source; within 100 feet of the unburned stand up to 2000 conifer seedlings per acre were found.

MacLEAN, D.A. and R.W. Wein 1977 'Nutrient accumulation for postfire jack pine and hardwood succession patterns in New Brunswick.'
Can J For Res 7: 562-78.

Distribution of N, P, K, Ca and Mg in the tree, understory, forest floor, and mineral soil horizons was determined for two series of post-fire forest stands in northeastern New Brunswick. Twelve pure jack pine and eleven mixed hardwood stands aged 7-57 years were examined. The jack pine stands demonstrated variable stand density, but adjustment to normal stocking produced a sigmoid nutrient accumulation pattern in the tree layer during the 60 year period. Nutrient accumulation in the tree layer of both series of stands closely approximated biomass accumulation. Understory nutrients formed a significant fraction of the total aboveground pool, particularly in the younger stands. Organic and mineral soil horizon nutrients were found to be highly variable for both series of stands; this was postulated to be a result of the fire origin of the stands, with varying fire intensity and post-fire conditions resulting in different nutrient losses from the site.

MAINI, J.S. and Carlisle 1974 Conservation in Canada. Dept of the Env, Ottawa. 441 p.

This more general anthology has only occasional references to fire. Fire in relation to spruce budworm outbreaks in eastern Canada is discussed. The causes of fire in Canada are briefly outlined and fire and its effects on black spruce in northern Ontario is treated briefly.

MALONEY, J.E. and J.B. Todd 1974 The fire history tabulator. For Fire Res Institute, Info Report FF-X-50, Ottawa. 49 p.

A computer program available through the Forest Fire Research Institute of Canada is described. The fire history tabulator generates information useful for research and management. From 460 tables, one can determine: 1) the effectiveness of fire control operations; 2) severity of one fire season as related to past periods; 3) planting areas requiring further concentration; 4) trends and patterns of fire occurrence; and 5) relationships of various fire functions.

MARTIN, R.E., C.T. Cushwa, and R.L. Miller 1969 'Fire as a physical factor in wildland management.' Tall Timbers Ecol Conf Proc 9: 271-88.

Fire is described in terms of chemical equations and stages in fuel combustion. Physical characteristics of fire are related to fire effects such as fuel removal and chemical effects on soil.

MARTIN, R.E., D.D. Robinson, and W.H. Schaeffer 1974 'Fire in the Pacific Northwest - perspectives and problems.' Tall Timbers Fire Ecol Conf Proc 14: 1-24.

This article reviews successional theory, the nature of fuel, various effects of fire, and summarizes the effects of suppression of fire in the Pacific Northwest. In addition a section on effects of fire on insects is included. Long years of attempted fire exclusion have allowed unnatural fuel accumulations to buildup in some lands that were once visited frequently by fire. Vegetation changes allowed by fire control may have enhanced the potential for some forest pests. Protection costs have increased to the point in some instances that they exceed in value the resource protected. On the other hand a complex and dangerous intermixing of dwellings and heavy fuel accumulations means that the situation must be handled more effectively in the future. With all the need we have to understand the role of fire in our forests and rangelands in the Pacific Northwest, we still lack specific information on the effects of different kinds of fire on the terrestrial ecosystems, on water and air resources, and on the socio-economic system within which we must work.

MARTINKA, C.J. 1974 'Fire and elk in Glacier National Park.' Tall Timbers Fire Ecol Conf Proc 14: 377-89.

Data and observations from ongoing studies are utilized to discuss ecological relationships between elk and fire. The study area included 152,700 hectares of mountainous terrain, of which approximately 47,800 hectares have been burned by lightning or man-caused fires since establishment of the park in 1910. Secondary succession following burning of winter ranges has been characterized by developing mosaics of shrub and conifer communities in apparent relation to moisture gradients. Elk population trends suggest that development of young conifer stands enhanced habitat carrying capacity for elk and permitted maximum densities to utilize winter ranges. The status of elk relative to post-fire succession is discussed.

McCULLOCH, C.Y. 1969 'Some effects of wildfire on deer habitat in pinyon-juniper woodland.' J Wildlife Manage 33: 778-84.

An extensive crown fire burned pinyon-juniper-sagebrush type in the Grand Canyon plateau region. Burned areas were devoid of living trees. Thirteen to fifteen years after the fire, woody cover consisted of numerous dead trees, sparsely scattered clumps of sagebrush and rabbitbrush, and Gambel oak (8-10 ft. tall). There were also dense stands of seeded grasses. Deer intensively occupied both burned and unburned areas during summer, and the first fall-winter period. During a severe winter, pellet accumulation rate was appreciably greater on the burn. Rates were high in the burned zone up to 1/2 mile from live woodland. Green grasses were probably important deer foods on both the burn and non-burn in all seasons. Deer abandoned the burn for brief periods when snow was deep. Forbs and grasses were more abundant on the burn; browse forage-plants were more abundant on unburned woodland. Small burns would seem desirable if the area were to be managed only for deer because of the greater variety of cover and food than on large areas either burned or unburned. Livestock managers desire large blocks for treatment.

McLAUGHLIN, J.S. 1972 'Restoring fire to the environment in Sequoia and Kings Canyon National Parks.' Tall Timber Fire Ecol Conf Proc 12: 391-5.

Fires were effectively excluded from the Sequoia and Kings Canyon National Parks from 1890 until 1968. One of the results of this action was a change in plant communities from what they had been prior to the coming of European man to the area. The 1963 Leopold report pointed out these ecological changes and made suggestions that resulted in revisions to the National Park Service fire policies. In 1968 a program was initiated in the Kings Canyon NP with the objective of letting natural fires burn. All lightning fires above 8,000 feet elevation were permitted to burn. This area comprised about 15% of the two parks, but has since been increased to include about 70%. From 1968 to 1972 fifty-three fires burned themselves out under the program. The public has accepted the program; however, a problem to be confronted is smoke. Smoke has been a part of the environment since long before man, and it may well be an essential part of it. Air quality standards are being interpreted to imply that the environment can not stand any more smoke. The Sequoia and Kings Canyon program does restore fire to the parks and provides the only means of naturally maintaining the vegetative communities.

McTAGGART COWAN, I. 1977 Natural resources in Canada's National Parks: an evaluation. National Parks Branch, Parks Canada, Ottawa. 196 p.

A systematic review and evaluation of the research accomplished within or on behalf of the National Parks of Canada. Included in the report is the identification in a structured way of the research requirements for Parks Canada, and suggested means by which the known research expertise and resources in Canada can be best brought to bear on the research needs in natural history for Canadian National Parks.

MEENTEMEYER, V. 1974 'Climatic water budget approach to forest problems. I. The prediction of forest fire hazard through moisture budgeting.' Publications in Climatology 27(1), C.W. Thornwaite Associates Laboratory of Climatology, Elmer N.J.

Use of the water balance method to estimate moisture status of litter and duff and thence to fire hazard. Significant correlations found between the moisture status thus determined and fire occurrence in the Shawnee Forest of southern Illinois.

METHVEN, I.R. 1971 Prescribed fire, crown scorch and mortality: field and laboratory studies on red and white pine. Can For Serv Inf Rep PS-X-31. 10 p.

Describes lab and field work to evaluate the extent of crown damage following prescribed fire under forest canopy. Lab experiments indicated needles killed at 20°C below level lethal to buds, also that seedlings survived up to 95% crown scorch. Field observations on large trees, on the other hand, showed mortality commencing at 45 to 50% crown scorch, with equal probability of death or survival at 80 to 85% crown scorch. Concludes that gentle prescribed fire under mature pine is quite feasible with no serious crown damage.

METHVEN, I.R. 1973 Fire, succession, and community structure in a red and white pine stand. Can For Serv Inf Rep PS-X-43. 18 p.

Describes the effects of two consecutive annual light fires on the shrub and minor vegetation in a mature pine stand over two growing seasons. The pine canopy suffered little damage. Small balsam fir were eliminated, shrub and minor plant biomass reduced, but species composition little changed. The treatment appeared to be a minor perturbation in the life of the plant community, creating temporary conditions favourable to pine regeneration, but not of radical effect.

METHVEN, I.R. 1974 Development of a numerical index to quantify the aesthetic impact of forest management practices. Info Report PS-X-51, Petawawa For Exp Stn.

Develops a simplified numerical index to quantify the aesthetic impact of forest practices on particular stands or operating units. The index is constructed from six aesthetic variables which are assigned equal value in the form of arbitrary units, and which are selected on the basis of stated requirements and constraints. These variables or index components are: (1) species diversity or variety; (2) structural complexity; (3) forest view; (4) slash visibility; (5) pattern; and (6) boundary form.

A method for incorporating the index into a total economic-aesthetic evaluation is also presented.

METHVEN, I.R. 1975 The ecological rationale for fire management - unpublished paper. 2 p.

Three ecosystem factors - wind, fire and insects - are responsible for recycling and succession in North temperate forests, and none of these factors can be excluded. Only fire is sufficiently well understood and has the potential to provide a means whereby forest composition can be manipulated to provide the mix desired by forest and wildlife managers. This becomes especially true where logging and planting are excluded as in a national park setting.

METHVEN, I.R. 1977 A fire prescription for red and white pine.
Unpublished paper.

A fire prescription for red and white pine is outlined. Desirable conditions include a Fine Fuel Moisture Code of between 90 and 95; Initial Spread Index of between 8 and 16; Build-up Index of between 21 and 52; and Fire Weather Index of between 12 and 24.

METHVEN, I.R. 1977 Forest vegetation and fire in Northwestern Ontario.
Unpublished paper.

All habitats regenerated successfully to tree species after fire. Where on-site seed sources were inadequate due to short fire intervals, seedlings of aspen and white birch invaded from off-site seed sources. Changes in vegetation after fire are those of relative abundance and dominance rather than species composition, so that the process is one of forest development rather than forest succession.

METHVEN, I.R. and W.G. Murray 1974 'Using fire to eliminate balsam fir in pine management.' For Chron 50(2): 77-9.

Three plots in mature red and white pine with dense balsam fir understory were treated with gentle surface fire. The fir was killed everywhere fire passed, without affecting the pines. The stand now has an open trunk space, and several years later considerable pine regeneration is evident. Fire weather and characteristics of the fires are listed.

METHVEN, I.R., C.E. Van Wagner, and B.J. Stocks 1975 The vegetation on four burned areas in Northwestern Ontario. Info Report PS-X-60, Petawawa Forest Exp Stn. 10 p.

Four burned areas of different ages were briefly examined. The report describes the present condition of the areas visited, in terms of both forest cover and minor vegetation. Tentative hypotheses on the role of fire in this region of the boreal forest are put forward and several questions are raised about the interactions among the main tree species. Apparently in most cases the same dominant tree species return immediately after fire implying that cycling by fire rather than succession is the basic mechanism in this forest.

MILLER, H.A. 1963 'Use of fire in wildlife management.' Tall Timbers Fire Ecol Conf Proc 2: 19-30.

With only minor exceptions, upland wildlife has a marked affinity for subclimax plant associations. This indicates that disturbance has been a common occurrence through evolutionary time. For wildlife species to be perpetuated, the particular subclimax vegetation which is their natural habitat, must be maintained. Cover conditions for prairie chickens are best where woody cover does not exceed 25 percent; they require grassland (height and density are the important factors). Sharptails prefer less than 40 percent woody cover (semi-prairie); the woody cover should be in scattered small groups rather than evenly distributed. Controlled fire will maintain these conditions. Ruffed grouse require brushy openings (about 1/4 acre), well dispersed. Turkeys need larger grass-forb openings of 2 or 3 acres in mature timber with an open understory. Kirtland's warbler in Michigan jack pine has habitat requirements produced only by forest fires. Burning also improves food conditions for prairie chicken, sharptail grouse, bobwhite quail, turkey, and white-tailed deer.

MILLER, D.R. 1976 Wildfire and caribou on the taiga ecosystem of north central Canada. Ph.D. dis, U of Idaho Grad Sch. 131 p.

Caribou numbers declined in north central Canada during the mid-twentieth century and effects of wildfire on the taiga winter range were considered as a potential factor causing the decline. No supporting evidence was found for this hypothesis either during a study of the caribou population on the taiga winter range of northwestern Manitoba and north-eastern Saskatchewan or of another in northcentral Saskatchewan and southern Mackenzie District, Northwest Territories.

Wintering caribou use a range differently after it has burned. Caribou use recent burns as travel routes during migration and local movements when snow conditions are favorable. Unburned islands within the burn are used as feeding sites. Forest stands adjacent to recent burns become more accessible for feeding. Deflection of major caribou movements by large recent burns appears unlikely.

Without wildfire the taiga ecosystem would be less suitable for supporting wintering barren-ground caribou in northcentral Canada. Periodic wildfire helps maintain vegetative heterogeneity and lichen productivity. Caribou distribution, movements, and forage use in the taiga depend on existing snow characteristics which are influenced by wildfire history and its perpetual effect on the vegetative complex.

MILLER, I.D. 1971 'Effects of forest fire smoke on tourism in Mount McKinley National Park.' In Symp North Envir Proc. USDA For Serv Pacific N W For Range Exp Stn: 83-5.

In the summer of 1969 smoke from extensive wildfires in interior Alaska obscured much of the scenic attraction of the Mount McKinley National Park. During the period park visitation was higher than in previous years, but length of stay per visit was lower. Instead of complaining, visitors expressed concern for the land and fauna and appreciation of the suppression efforts.

MILLER, M. 1977 'Perspectives for fire management in Alberta provincial parks and wilderness areas.' Paper presented at the Fire Ecol in Res Manag, Workshop, Edmonton, Alberta, 1977. 14 p.

The paper outlines perspectives for fire management in Alberta and attempts to draw the U.S. experience in the parks system there. Environmental criteria for zoning and fire management in parks are given special attention.

MOORE, W.R. 1974 'From fire control to fire management.' West Wildlands 1(3): 11-5.

In conquering fire man removed a beneficial force from the environment. Prior to 1905 there was not fire control in the West. The period from 1905 to 1925 was one of learning about the land and about fire. From 1926 to 1959 fire control experts and managers were involved in "stopping the large fire". "Protection geared to resource value" characterized the fire planning and action during the sixties. The seventies are perceived to be an era of "fire management to support land-use plans". Fire management includes not only fire control, fuels management, etc., but also the use of fire to meet management objectives. A major effort along this line is the development and testing of fire prescriptions in the Selway-Bitterroot Wilderness. Fire has to be integrated more thoroughly into land-use planning. The public must be informed of fire's ecological role on the land. Federal, state, and local agencies should progress toward fire management together. Fire specialists need deeper professional and technical knowledge of fire.

MORISON, M.J. 1967 'Fuels.' From Symp on Prescribed Fire Proc sponsored by Ontario Dept of Lands and For. 6 p.

An introductory "lesson" on fuels which shows how an understanding of the basic characteristics of forest fuels and their influence on fire behaviour is necessary in order to solve problems associated with planning a fire prescription.

MOUNT, A.B. 1969 'An Australian's impression of North American attitudes to fire.' Tall Timbers Fire Ecol Conf Proc 9: 109-18.

An article contrasting Australian and North American perspectives on fire. The author discusses our common European forestry heritage, and outlines different views of fire as it relates to fuel accumulations, fuel protection, forest protection, erosion, pollution, and waste disposal. The author is particularly critical of the academic approach, in which complex interactions and natural environments are supposed to be represented in an ecology lab. A table is included which outlines different frames of reference which the author has noted in his travels in North America. He then relates these different frames of reference to noticeable shortcomings in different perceptions of fire.

MURARO, S.J. 1966 Lodgepole pine logging slash. Dept For Pub No 1153, 13p.

Crown and slash weights from 405 lodgepole pine trees in pure, even-aged stands were sampled. Graphical analysis showed that individual crown weights are directly proportional to diameter at breast height. Surface area per pound of slash was directly proportional to the average diameter of the original stand. This information is useful to land managers involved in logging or land-clearing operations where disposal of slash by burning for sanitation, regeneration or hazard abatement purposes is considered.

MURARO, S.J. and B.D. Lawson 1970 Prediction of duff moisture distribution for prescribed burning. For Res Lab Can For Serv, Victoria, British Columbia, Info Report BC-X-46. Dept Fish and For. 12 p.

Field measurements of moisture distribution in organic layers under mature stands and in exposed slash areas, and the effect of additional precipitation are presented and discussed. Implications of the moisture distribution to control of prescribed fires and their relation to the Stored Moisture Index and the Drought Code of the Forest Fire Behaviour system are presented in the form of guidelines for initiating the annual prescribed burning program.

MURARO, S.J. 1971 Prescribed fire impact in cedar-hemlock logging slash.
Dept Env, Can For Serv, Publication No 1295, Ottawa. 18 p.

Fire impact is defined as the change caused in an ecosystem by burning. Impact from prescribed burns on seven areas of tractor-skidded decadent cedar-hemlock in the Interior wet belt is related to stand-associated fuel characteristics and weather indices. Graphs are provided to predict total fuel loading from gross volume and the distribution of loading by species and diameter class. The impact of prescribed fires on the fuel complex is expressed in terms of slash-fuel depletion by diameter and species, and of depletion of the organic layer. The range of weather regimes included in this study is limited. It is recognized, however, that most operational prescribed burning in these fuel types will continue to be done under similar conditions.

MURPHY, J.L., L.J. Frithsches, and O.P. Cramer 1970 'Slash burning - pollution can be reduced.' Fire control notes 31(3): 3-6.

Forests have long been connected with air pollution, both as a cause and as a victim. Particulate matter or the visible part of the smoke of fires is probably most important in reducing visibility, sunlight and its effects on plant life. Prescribed burning counts for less than 2% of the particulate matter produced by all urban/industrial and rural/agricultural sources. Wild fires are more serious, producing possibly 5 times the quantity of particulate matter produced by prescribed burning.

Management of local fire behaviour by fuel treatment and meteorological timing in the management of slash burning will do much to reduce the threat of air quality impairment from burning in the forest.

MUTCH, R.W. 1970 'Wildland fires and ecosystems - an hypothesis.'
Ecology 51: 1046-51.

Fire is as closely related to many plant communities as other factors of their environments. Researchers have looked at the natural presence of fire in terms of fire climate and the influences of weather factors on fuel moisture; however, the author suggests that the "inherent chemical characteristics" are also important factors in determining the flammability of plant communities. Mutch presents the following hypothesis: "Fire-dependent plant communities burn more readily than non-fire-dependent communities, because natural selection has favored development of characteristics that make them more flammable." Controlled combustion tests with litter of eucalyptus (*Eucalyptus oblique* L'Herit), ponderosa pine (*Pinus ponderosa* Laws.), and tropical hardwood leaves provided the data used in deriving this hypothesis.

MUTCH, R.W. 1974 'I thought forest fires were black.' West Wildlands 1 (3): 16-21.

Although the ecological effects of fire have been well documented, fire has traditionally been viewed as a negative or destructive force. As a result it has been excluded from many ecosystems. Many wilderness and park managers now realize, however, that fire is a natural force in the ecosystem, and that the natural role of fire must be accommodated if their goals are to be fulfilled. To this end fire prescriptions were prepared for the White Cap Area of the Selway-Bitterroot Wilderness. The first wilderness management fire under the plan occurred on August 18, 1972, and burned less than 1/4 acre. The real test came on August 10, 1973, when the Fritz Creek Fire was started by lightning. This fire, which eventually burned 1,200 acres, was closely studied and yielded information which will be valuable not only for the Selway-Bitterroot but also for many similar areas in the West.

MUTCH, R.W. 1975 'Fire dependent wilderness ecosystems: A management strategy.' Tall Timbers Fire Ecol Conf Proc 15. Symp Fire & Land Manage (Missoula, MT, 1974) Proc.

Fire has historically been viewed in the negative sense. Yet the dependency of many ecosystems upon fire is widely recognized. In wilderness areas and national parks where management is aimed at maintenance of the naturalness, fire is being returned to its natural role. Managers are slowly overcoming the "protection" philosophy of the past. It is important to understand the role of fire, but to incorporate this understanding into an operational management program is a complex undertaking. For this reason a study was begun in the Selway-Bitterroot Wilderness in 1970. Inventory and planning procedures were developed, and a plan was prepared and successfully field tested.

MUTCH, R.W. 1976 'Fire management and land use planning.' Soc of Am For Nat Convention, Washington, D.C., reprinted in Western Wildlands: 13-19.

Emphasis is shifting from fire prevention and suppression to management of a total fire system. However, fire management still consists of pre-suppression, suppression, post suppression rehabilitation, and prescribed fire. We now need a new mix of these elements. Fire management must be as much a philosophy and attitude towards the land, as it is an action program.

The author emphasizes that fire is a process, a natural phenomenon marked by gradual changes that lead toward a particular result, and not a tool in the sense that it can be turned off and on quickly. This means that we must understand ecosystem processes and be more concerned with doing right things, than with doing things right.

MUTCH, R.W. and D.F. Aldrich 1973 'Wilderness fire management: Planning guidelines and inventory procedures.' USDA For Serv North Reg, Missoula, MT: 35 p. + Appendix.

The wilderness fire management plan is an integral part of any wilderness management program which includes the use of fire. It not only contains the fire management prescriptions and the supporting rationale, but it also provides the vehicle for review and approval by those with approval authority. This publication gives detailed step-by-step guidelines for obtaining and analyzing the supporting data and for preparing the fire management plan. These planning and inventory procedures were successfully used and field tested as part of the White Cap Wilderness Fire Management Study which was begun during the late summer of 1970.

MUTCH, R.W. and G.S. Briggs 1976 'The maintenance of natural ecosystems: Smoke as a factor.' Reprinted from "Air Quality and Smoke from Urban and Forest Fires.", p. 225-81. Proc Int Symp, 1973, Nat Acad Sci, Washington, D.C.

The specific management goal for fire in wilderness is that fire should play a more nearly natural role in the perpetuation of ecosystems. Little is known about the effects of wildland smoke on the life processes of organisms. The germination of spores of several rusts and fungi is inhibited.

Deer, elk, and black bears have been observed within the perimeter of the fire while the fire is still burning. A large majority of the letters received from groups and individuals during and following the fires in the Selway-Bitterroot Wilderness favored the concept of wilderness fire management, and even the observation of smoke and the burned area immediately after a fire has not created problems. The inevitability of fire in parks and wildernesses is followed by the inevitability of smoke.

NELSON, J.R. 1974 'Forest fire and big game in the Pacific Northwest.'
Tall Timbers Fire Ecol Conf Proc 14: 85-102.

Fire, whether wild or controlled, has been shown to benefit big game in a variety of ways. Following fire, understory vegetation usually reestablishes more luxuriantly than before, often increasing carrying capacity for big game. In addition, new growth following fire is more palatable and nutritious than on unburned areas. Brush field burning increases accessibility of game into dense brush areas, increases browse availability by killing back brush that has grown too tall for game, and rejuvenates decadent shrubs. Loose ash following fire provides an ideal seedbed for broadcast seeding herbaceous forage species. All told, burning promotes healthier and more productive big game herds.

NIKLEVA, S., P.M. Paul, and L.B. MacHattie 1972 Meteorological Services for Forest Fire Control Project Team Report, Atmos Env Ser Can. 54 p.

This report summarizes forest fire statistics for the years 1960-1969 for all provinces in Canada. It discusses principles of fire control and how weather factors interact with these principles. The form of weather forecasts and the fire danger rating receives special attention.

NORUM, R.A., N. Stark, and R.W. Steele 1974 'New fire research frontiers in Montana forests.' West Wildlands 1(3): 34-8.

"Fire occurs sometime during the life cycle of most forest species in the northern Rocky Mountains. It is an ecological force of great magnitude that has played an important role in present day ecosystems." If sound management decisions are to be made, a clear understanding of fire influences is a must. To this end fire research is providing answers in the areas of fuels management, air quality, and nutrient cycling. When research has provided the necessary knowledge, fire can become one of the most useful tools the modern land manager has at his disposal.

NOVAKOWSKI, N.S. 1970 Fire priority report Wood Buffalo National Park. Can Wild Ser. 5 p.

This report suggests specific areas within the Park that might benefit from fire. Areas that need protection are watershed areas burned over many times already where possible erosion is a problem. As well, areas where whooping cranes are found should be protected. Areas that might benefit from fire include the sand hills with jack pine, various grasslands, and prairie areas with stands of spruce which are generally wet. Roads should be protected from the aesthetic stand point and because they lead to important areas for public viewing of bison or unique natural features.

OBERLE, M. 1969 'Forest fires: suppression policy has its ecological drawbacks.' Science 165(3893): 568-71.

Some forest ecologists say that the artificial exclusion of fire has produced major changes in many forest plant communities that were dependent on fire as the chief regulator of vegetation types. Total fire suppression has made some woods easy targets for disastrous fires. Prescribed burning was developed to manage plant communities and to reduce fire hazards. It includes slash burning, fire breaks, and burning of undergrowth and litter to reduce fire hazards.

ODUM, E.P. 1971 Fundamentals of ecology, 3rd Ed. W.B. Saunders. 570 p.

A general text on ecology containing references to fire as an ecological factor in chaparral, in climax communities, in controlled burning as a decomposer in forest communities, in grassland communities, in tropical savanna, and as a management tool.

ONTARIO DEPT. OF LANDS AND FORESTS 1963 Instructions for completing prescribed burn report. Form F.C. 120.

This reference includes the form used by the Ontario Department of Lands and Forests when reporting on the prescribed burn. Information that is detailed is meteorological data, fire data, and postburn effects.

ONTARIO DEPT. OF LANDS AND FORESTS 1963 Instructions for completing prescribed burn plan. Form F.C. 119.

This reference includes the form and instructions for completing the form for a prescribed burn plan. Information that must be detailed on the form is purpose of the burn, stand description, slash description, organic layer description, various site descriptions, proposed burn procedure, and weather conditions.

PAPENFUS, R. 1971 'Prescribed burning from the tourism point of view.'
Symp on Prescribed Burning (Charleston, SC, 1971) Proc: 64-7.

A very brief discussion of the effects on tourism of prescribed burning. The author concludes that anything which creates a favourable impression on travellers is good for tourism and prescribed burning is no exception.

PARKS CANADA 1971 Forest fire control plan, Point Pelee National Park.

The purpose of this control plan was to assure that all fires in the Park could be effectively controlled and extinguished. The topography and vegetation of the Park is reviewed as is the history of fire in the Park.

PARKS CANADA 1972 Outline for fire control plan for Georgian Bay Islands National Park.

The purpose of this fire control plan is to keep the damage by fire to timbered areas and buildings within Georgian Bay Islands to the absolute minimum. The extent and vegetation of the Islands Park is described. The unique characteristic is the lone pine island with shallow soil. Eight fires were reported in the preceding 5 years. Only 4 were regarded as forest fires. One was 2 acres in size, the rest 1/4 acre or less.

PARKS CANADA 1975 National Parks policy. 23 p.

The purposes of National Parks are outlined, as is Parks Canada Policy on wildlife and nature, forestry, access permanent visitor accommodation, camping, research, education, culture, private dwellings, recreation, town sites, and park zoning.

PARKS CANADA 1976 National Parks. 6 p.

A short brochure that outlines the location and facilities of all of Canada's National Parks.

PARSONS, D.J. 1977 'The role of fire in park management.' Parks 2(1): 1-4.

A brief outline describing management alternatives including prescribed burning, using free burning fires and fire suppression. Various types of fires that might be utilized in prescribed burning in Parks and smoke impacts are given brief attention.

PATRIC, E.F. and W.L. Webb 1953 'A preliminary report on intensive beaver management.' N A Wildlife Conf Trans 18: 533-9.

Present high beaver populations of many areas are the direct result of the extensive clearcutting of timber and the widespread forest fires which were characteristic in the northern forests until recent years. Modern forest fire control and intensive forest management practices are gradually reducing the areas of suitable beaver habitat. The beaver is adapted to the early stages of forest succession, especially the post-fire types which include aspen and willow. The beaver will be eliminated from many areas when the forest is maintained in climax vegetation.

PERALA, D.A. 1973 'Prescribed burning in an aspen - mixed hardwood forest.' Can J For Res 4: 222-8.

The effects of prescribed burning and complete clearcutting on *Populus tremuloides* and associated hardwoods and shrubs are compared for 8 years after commercial harvest of a 60-year-old *Populus* stand. Because of the lack of suitable burning weather, *Populus* suckers were 2 years old before the burn could be made. All suckers were killed by fire and new suckers were more numerous but less vigorous, probably because of heat damage to shallow sucker-producing roots, loss of nitrogen, and reduced root carbohydrate reserves. Although prescribed fire can effectively control residual hardwood overstories detrimental to *Populus* sucker growth and survival, the long term effect of fire on sucker growth is unknown. Fire can be used to prepare sites for *Populus* regeneration when other methods are unavailable or impractical. Burning should be done during the first dormant season following logging. Effort should be made to distribute slash uniformly to provide even burning conditions. Burning prescription guidelines are given.

PERALA, D.A. 1974 Repeated prescribed burning in aspen. Research Note NC-171. USDA N Central For Exp Stn. 4 p.

Infrequent burning weather, low flammability of the aspen-hardwood association, and prolific sprouting and seeding of shrubs and hardwoods make repeated dormant season burning a poor tool to convert well established aspen to conifers. Repeat fall burns for wildlife habitat maintenance is workable if species composition changes are not important.

PERKINS, C.J. 1968 'Controlled burning in the management of muskrats and waterfowl in Louisiana coastal marshes.' Tall Timbers Fire Ecol Conf Proc 8: 269-80.

In Louisiana, fire plays a most important role in marsh management for muskrats. Ninety percent of their forage species must be burned at least every other year to maintain itself. Wildfires directly destroy many muskrats. Winter food of the blue goose can be improved by burning. Fall burning is recommended. Without annual burns neither normal nor peak muskrat populations can be reached.

PERKINS, C.J. 1971 'The effects of prescribed burning on outdoor recreation.' Symp on Prescribed Burning (Charleston, SC, 1971) Proc.: 59-63.

The author discusses prescribed burning applications for management of white tailed deer, turkey, bob-white quail, and other game species. Also discussed are such recreation applications as camping, picnicking, hiking, birdwatching, and outdoor photography.

The author concludes that prescribed burning is compatible with all of these activities.

PETERS, S.S. 1958 'The ecological effects of fire and its possible application to game management.' Symp on Prescribed Burning by Nfld Res Comm (1958) Proc, Mem U of Nfld: 41-49.

The author offers observations of fire effects on various kinds of vegetation found in Newfoundland. He is particularly struck by how little of the humus layer is actually burnt. He concludes with identification of some unanswered problems and emphasizes the importance of knowledgeable use of firing techniques.

PHARO, J.A. 1974 'Prescribed fires environmental impact - an assessment.' Paper for presentation at National Conference, 3rd, on fire and forest meteorology, Am Met Soc and Soc of Am For in April 1974.

A burn or no-burn decision method for prescribed burning is offered to forest management. The method is based upon a prescribed fire's air pollution potential. Solutions of mathematical expressions representing concentration of background airborne material, amount of smoke expected from a prescribed fire, and the atmosphere's dilution potential for their combination are presented in a single figure. The method requires a minimal amount of information from outside sources, and it assumes that all prescribed burning will be postponed or terminated whenever combination of background and fire generated particulate matter can reduce the horizontal visual range at ground level below 0.5 mile.

PHILLIPS, C.B. 1973 'Fire in wildland management.' J For 71(10): 624.

Fire use and fire protection are compatible. Fire-fighters still need to take swift and effective action against unwanted wildfires, while in certain areas and under prescribed conditions, fire can be a useful land-management tool. Fire is being restored to some of the ecosystems of the Sequoia and Kings Canyon National Park and the White Cap area of the Selway-Bitterroot Wilderness. Fire has been used for many years in the West for many purposes; however, land managers look on the use of fire with mixed emotions. The use of fire has not been without its mistakes. Researchers are working toward finding the answers to many fire management problems. Further research is needed.

PRASIL, R.G. 1971 'National Park Service fire policy in national parks and monuments.' Symp on Fire in the North (1971) Proc, USDA For Serv N W For Range Exp Stn, Portland, OR: 79-81.

The National Park Service has studied certain parks to determine whether or not natural fires should be allowed to burn. The Service policy includes suppression of natural fires where they cause a threat to other land agencies. Where human life or high value areas are involved, fire suppression will also be of prime importance. Natural fire is now being considered as a natural phenomenon and should be allowed to run its course where possible.

RANSEY, G.S. and N.G. Bruce 1975 Bibliography of Departmental Forest Fire Research Literature, 3rd ed Canada. Dep Envir For Serv Info Rep FF-X-2.

A listing of fire research literature written and published by members of the forest fire research staff of the Government of Canada. The publications cover the period from the early days of forest fire research in the Forestry Branch, Department of Interior to the present Department of the Environment.

Approximately 1,000 references are cited.

REDFIELD, J.A., F.C. Zwickel, and J.F. Bendell 1970 'Effects of fire on numbers of blue grouse.' Tall Timbers Fire Ecol Conf Proc 10: 63-83.

Grouse density was as high on logged and slash-burned areas as on burns. However, a large wildfire was followed by a spectacular decline in grouse populations. Large fires and a subsequent set back in plant succession are not sufficient to maintain densities of grouse. Clearcut logging, with or without slash burning, stimulated increases in grouse populations. The long-term effects of repeated burning in Pacific Coast regions may be harmful to the ecosystem. Fire is not a necessary prerequisite for high densities of blue grouse, nor can it prevent a decline. Time of burning and temperature may affect the release of nutrients differently. Fire may change the quality of plants on an area, the gross structure of the vegetation, the successional pattern, the microclimate, and alter other components of the ecosystem, including the animals living there. Blue grouse move from coniferous forest winter range to more open areas for the breeding season. Normally low populations increase rapidly following logging or burning. Effects last 10 to 25 years until the canopy closes. Hens with older broods seem to select burned areas. Populations of some species of wildlife increase following burning; probably due to opening the habitat or to setting back succession. Burning may not be bad for blue grouse populations in the shortterm view, but other methods of opening up the habitat may be better over the long term.

REEVES, H.C. 1977 'Use of prescribed fire in land management.' J Soil and Water Conserv 1977, Mar-Apr: 102-4.

The author defines prescribed burning as the scientific use of fire under well defined and controlled conditions in order to accomplish specific land management objectives. Objectives that are discussed include hazard reduction, control of undesirable species, site preparation, wildlife habitat improvement, range improvement, and disease control. Some environmental considerations are also outlined.

REQUA, L.E. 1964 'Lightning behaviour in the Yukon.' Tall Timbers Fire Ecol Conf Proc 3: 111-9.

In the Yukon, moose follow burned-over areas to new browse. Migratory birds nest in "fire type" vegetation and raise broods there. Herbivores are sustained by the fire type accompanied with predators. Migratory birds and certain other species favor specific phases of the cycle from fresh burn to stands of mature timber.

REYNOLDS, H.G. and A.W. Sampson 1943 'Chaparral crown sprouts as browse for deer.' J Wildlife Manage 7: 119-22.

Succulent crown sprouts have higher nutritive values than older, uncropped growth stages: repeated close browsing retards development of shrubs toward maturity. If excessive, however, plants may die. The higher moisture content of sprouts would favor their summer use by deer. Suggested management for deer is to burn or slash to produce crown sprouts.

RICHARDSON, J. 1970 Broadcast seeding a burned cutover after light scarification. For Res Lab St John's, Nfld, Info Report N-X-58. Can For Serv Dept of Fish and For. 20 p.

When balsam fir or black spruce cutovers are burned in Newfoundland satisfactory natural restocking to softwood species is frequently precluded. The most common reasons for this situation are the lack of a suitable seed source and the presence of a thick raw humus layer which restricts seed germination and seedling establishment. This experiment shows that satisfactory stocking of black spruce regeneration can be achieved on a wide variety of burned cut-over site conditions in central Newfoundland. Different techniques are required on different sites. Fresh to moist sites with an organic mantle 2 inches deep or less and a moss plus low herb type of vegetation will regenerate naturally if a seed source is present. In the absence of the seed source broadcast seeding black spruce at 100,000 seed per acre should prove satisfactory. On moist to wet sites with an organic mantle more than two inches deep supporting mosses, seed supply is again likely to be the only limiting factor.

ROE, E.I. 1963 Seed stored in cones of some jack pine stands, northern Minnesota. USDA For Serv Res Paper LS-1. 14 p.

Viable seeds stored in closed cones amounted to: 226,000 in a 40-year old stand, 759,000 in a similar stand that had been thinned, 381,000 in a 13-year old stand, 477,000 in a 13-year plantation. Trees produce viable seeds at least to age 200 years, but the number of good seed decreases with tree age. Cones more than 7 years old yielded less than half the number of seeds per cone compared to younger ones.

ROTHERMEL, R.C. 1972 A mathematical model for predicting fire spread in wildland fuels. USDA For Serv Res Pap INT-115. 40 p.

Rate of spread and fire intensity can be predicted with the use of Rothermel's mathematical fire model. No prior knowledge of the burning characteristics of the fuels is needed by those using the model. Inputs describing the physical and chemical makeup of the fuels and environmental conditions are required. The concepts used in this fuel model recognize that fuels have inherent characteristics that are repeatable.

ROUSE, W.R. 1976 'Microclimatic changes accompanying burning in sub-arctic lichen woodland.' Arctic and Alpine Res 8: 357-76.

A comprehensive report on microclimate changes associated with a burn sequence of 0, 1, 2, 24 and 82 years. Details of the vegetative cover, reflection coefficients, net radiation, soil temperature regimes and moisture budgets.

ROWE, J.S. 1956 'Uses of undergrowth plant species in forestry.' Ecology 37(3): 460-71.

This article contains a rather thorough table of understory vegetation for the southern boreal forest in the Riding Mountain area.

ROWE, J.S. 1966 'Phytogeographic zonation: an ecological appreciation.' The Evolution of Canada's Flora, R.L. Taylor and R.A. Ludwig (eds), U of Toronto Press: 12-37.

The vegetation zones of Canada are reviewed briefly, and possible migration patterns after the Pleistocene glacier melted are discussed. The role of fire in controlling the forest - prairie boundary and the forest - tundra boundary is effectively presented. "Almost all the native vegetation of Canada shows the influence of fire."

ROWE, J.S. 1970 'Spruce and fire in Northwest Canada and Alaska.' Tall Timbers Fire Ecology Conf Proc 10: 245-54.

Silvical characteristics of spruce and their relationship to fire are considered. Spruce on both upland and lowland sites are discussed.

ROWE, J.S. 1972 Forest regions of Canada. Canada, Dep Env, Can For Ser,
Publ 1300. 172p

This publication provides a general description of a forest geography of Canada. Forest vegetation in Canada is divided into Boreal, Sub-alpine, Montane, Coast, Columbia, Deciduous, Great Lakes - St. Lawrence and Acadian Forest Regions. Each region is then broken down into forest sections. These regions and sections are used for vegetation classification in this report.

ROWE, J.S., J.L. Bergsteinsson, G.A. Padbury, and R. Hermesh 1974
Fire studies in the Mackenzie Valley. A report for the Arctic
Land Use Res Prog Dept of Ind Affairs & North Dev Ottawa. 123 p.

The objectives of this study were to make a reconnaissance study of the Upper Mackenzie Valley, particularly along proposed transportation corridor routes, examining sites of recent fires in order: a) to relate fire intensity (as indicated by destruction of humus and organic layers) to surface stability (as indicated by degree of revegetation, erosion, slumping, thermokarst, etc.), to changes in depth of active layer, and to changes in moisture status; b) to determine the time interval in which soil stability is reestablished following fires to different intensities by observations of revegetation, composition of post-fire plant communities; to assess longer-term effects of fire; to derive data on fire frequency from air photographs; to identify regionally the terrain types that are particularly susceptible to fire; and to prepare fire susceptibility maps for selected areas where feasible.

ROWE, J.S. and G.W. Scotter 1973 'Fire in the boreal forest.' Quat Res
3: 444-64.

Direct destruction or injury of animals is seldom an important influence on a whole population. More important are indirect effects through destruction of habitat. Faunal succession follows plant succession and there are optimum stages of plant succession for every animal species. Therefore, fire exerts both short-term and long-term effects. Animals favoring early successional stages will be subject to loss of habitat for a short time following fire compared to species favoring late successional vegetation. Any influence tending toward diversifying the landscape will increase the diversity of the fauna as well as the population density of some species. By maintaining a mosaic pattern of vegetation, fire assists in the maintenance of diverse wildlife populations. The effects of wildfire are complex and must be related to the nature of the material burned, size of the area and intensity of the burn, distribution of unburned habitat types in relation to the burn, and the biology of all animals in the area. As to wildlife management, there is not enough quantitative information on the ecological effects of fire on the total environment on which to base effective management decisions. The present need is for an understanding of features and functions of ecosystems, not just on single resources.

ROWE, J.S., D. Spittlehouse, E. Johnson, and M. Jasieniuk 1975 Fire studies in the Upper Mackenzie Valley and adjacent Precambrian Uplands. A report for Arctic Land Use Res Prog, Dept of Ind Affairs & North Dev, Ottawa. 128 p.

The objectives of the report were to continue an analysis of fire records and of climatic correlates; to study fire recurrence on important terrain types in the Valley and on the Shield, using tree ring and stratigraphic techniques; to examine fire effects on peat plateaus and on permafrost mineral soils; and to study the responses of vegetation to fire with attention to the autecology of dominant species.

The report represents a detailed analysis of weather and fires, causes, sizes, numbers, and monthly distribution of fires in the North-western Territories, surface fuels and ignition, fire history, sedimentary record of forest fires, fire and terrain, identification of burned areas on ERTS photographs and conclusions regarding the environmental implications of a fire and fire control in the Upper Mackenzie Valley and adjacent Precambrian Uplands.

RUESS, J.W. 1975 'Fire "madness"?' Am For 81(4): 2-3.

In California and other states forest fires are attacked without determining whether it was caused by man or nature. After the fire is out, its cause is determined. If it is man-caused, the responsible person is brought to justice. On some federally-owned land this is not done. Both the National Park Service and the Forest Service are responsible for protecting and perpetuating forest resources. The author believes that herding fires violates this responsibility. He suggests that the persons "guilty of such practices on public land" should be fired. Fire prevention efforts may be negated when the public is told that employees of these two agencies are not only letting wildfires burn but in some cases are actually setting fires.

RUNGE, B. 1976 'Fire in western park forests.' Park News, December 1976: 18-21.

The author discusses the effects of fire on various areas in western Canada. Specifically mentioned are the Bow Valley in Banff where a large fire resulted in poor wildlife habitat. Had fires been smaller a mosaic of pine lands next to spruce would have created greater edge habitat. If fire is suppressed along the eastern slopes and lower elevations of National Parks, the author argues the result will be continuous spruce forests with minimal edge. In the Alberta Foothills, fire suppression has allowed aspen invasion of grasslands. In the Porcupine Hills Douglas-fir savannas are being lost with resulting negative effects on wintering ungulates. The author concludes that Parks Canada is moving in a direction which would give substantially more recognition to the ecological role of fire, and feels this is a desirable trend.

SACKETT, S.S. and D.W. Dale 1970 'Prescribed nighttime burns bring benefits.' Fire Control Notes 31(4): 9. Info Centre, For Fire Res Inst.

Prescribed burning if properly applied is the most economical means of eliminating the wild fire hazard created by slash left in pine plantations after thinning. If these prescribed burns can be conducted at night, the number of hours available for burning are increased.

This article reports the results of a cooperative study by the southern and southeastern forest experiment stations in a 20-year-old plantation of slash pine. A nighttime prescribed fire successfully reduced the wild fire hazard of the slash.

SAMOIL, H., L.N. Carbyn, and D. Sept 1977 Prescribed burn study of fescue grasslands in Prince Albert National Park. Prog Report No 2. Prepared for Parks Canada by the Can Wild Ser Edmonton, Alberta. 73 p.

The objectives of the study were to assess the distribution and relative abundance of small mammal and bird populations within forest, ecotone and grassland areas in the southwest corner of Prince Albert National Park. A second objective was to assess the relative use by ungulates of the above named habitats.

White-tailed deer appear to extensively utilize spring burned ecotone areas. Elk appear to select unburned grassland areas. Moose utilize ecotonal areas more than expected from occurrence of habitat categories. The effects of the burn program on ground squirrels are not clear. An increase in grassland area will favour elk populations. Number of bird species increases from grasslands to ecotone to forest.

SAMPSON, A.W. 1944 Plant succession on burned chaparral lands in northern California. Calif Agr Exp Stn Bull 685.

Fire destroys many small mammals, notably brush and tree dwellers, or they may die later from starvation. Destruction by fire of small surface-dwelling mammals, on the other hand, is mostly temporary; frequently, because of the increased food supply, mice and squirrels soon increase in numbers in excess of those present before burning. Because of their mobility, coyotes and certain other large predators are little affected by fires of ordinary size. Deer are seldom injured by small fires, but extensive burns have sometimes resulted in their starvation, injury, or death. Small openings may appreciably increase the forage for deer, but larger burns destroy the protective cover and temporarily deplete the food supply. Extensive brush fires are also adverse to bird life, whereas small, judiciously placed spot fires may be beneficial by providing secluded feeding areas adjoining the unburned cover.

SANDERSON, J.E. 1973 'The case for a go-get 'em fire control policy.'
In Let the forests burn: Technical sessions proceedings. Colo
 State Univ, Coll For Nat Resour, Dept For Wood Sci: 20-6.

Aggressive control of wildfires is a part of fire management. Historically this nation has been ravaged by fires which resulted in incalculable damage to timber, watersheds, wildlife, as well as loss of life. To counter these losses fire control efforts were begun and strengthened. As years passed fire control became more effective. The 10 a.m. Control Policy was established in 1935. Access and technology improved. Recently, emphasis has been placed on letting wildfires burn. Let-burn plans must consider the dangers of wildfire. The most logical alternative to let burn is prescribed fire. Except where it is known exactly what will be accomplished with free-burning natural fire, the policy should be "Go Get 'Em" rather than "Let the Forests Burn".

SANDO, R.W. 1969 Prescribed burning weather in Minnesota. N Central
 For Exp Stn, USDA For Serv. 12 p.

This study determines patterns of weather variables influencing prescribed burning in Minnesota during the period from April to mid-November. Variables discussed include weather both before and during the burn, air temperature, relative humidity, wind direction, windspeed, and precipitation. The combination of temperature and relative humidity will largely determine the moisture content of cured fine fuels. These fine fuels are important in fire spread and behaviour, particularly influencing the occurrence of spot fires. The build-up index which accounts for the cumulative effects of temperature, humidity, and precipitation is also discussed as a useful tool and indicator of the moisture content of coarse fuels.

SANDO, R.W. and R.C. Dobbs 1970 Planning for prescribed burning in Manitoba and Saskatchewan. For Res Lab Winnipeg, Man. 18 p.

This article lays out the purposes, weather conditions, firing techniques, preparation, execution, and appraisal of prescribed burns in Manitoba and Saskatchewan. Of particular interest is the detail outlined on firing techniques, which includes strip headfire, strip backfire, and area ignition.

SCHIMKE, H.E., J.D. Dell, and F.R. Ward 1969 Electrical ignition for prescribed burning. Pacific Southwest For & Range Exp Stn For Ser, USDA, Berkeley, CA. 12 p.

Under some circumstances it may be desirable to use multiple ignition to fire all or parts of a predetermined area simultaneously. Probably the best way to achieve multiple ignition is to use electrical firing techniques. Some of the advantages of this system are that it allows time for careful survey and layout of each ignition point, it permits the fire boss more positive control, as he may operate from a strategic point where he can observe and control firing. It requires only a few men to layout the circuits, and allows burning at night when conventional methods would require a crew to work in darkness or under conditions of poor visibility. Some of the drawbacks of this system include: the land manager becomes committed to a certain firing pattern and design, wired circuits can be damaged by animals or people, and detonation is possible if lightning strikes a circuit or if a near miss takes place.

SCHLICHTEMEIER, G. 1967 'Marsh burning for waterfowl.' Tall Timbers Fire Ecol Conf Proc 6: 41-6.

Nebraska sandhills. Fire was used to restore a reed-choked marsh. It was burned in February when frozen and snowcovered. It resulted in 85 percent reduction in density of reeds and 60 percent less bulrush. It was an important waterfowl breeding and hunting area. Dense reed (*Phragmites*) restricts movement of young broods; desirable plants diminish. Waterfowl use increased in burned areas the same year as the fire.

SCHROEDER, M.J. and C.C. Buck 1970 Fire weather ... a guide for application of meteorological information to forest fire control operations. USDA For Ser Ag Hdbk. 360 p.

This is the basic United States reference on the topic of fire weather and its effects on forest fire control operations.

SCOTT, J. 1967 Burning as a management tool. Ontario Dept of Lands & For Prescribed Fire Symp. 16 p.

This paper considers how prescribed burning may be fitted into the overall management of our forest resources in Ontario, based on information that is presently available on this subject.

The six main reasons cited for prescribed burning in Ontario are:

1. hazard reduction
2. site preparation for natural and artificial regeneration
3. elimination of undesirable understory or shrub layer
4. wildlife management
5. insect and disease control
6. blueberry management.

SCOTTER, G.W. 1964 Effects of forest fires on the winter range of barren-ground caribou in northern Saskatchewan. Wildlife Manag Bull Ser 1, Can Wildlife Serv, Ottawa.

Effects of fire on wildlife are both direct and indirect. In black spruce forests of Saskatchewan, caribou prefer older forests, whereas moose prefer younger stands. The tangle of fallen snags on recent burns probably impedes movement. Black bears frequent burns to obtain berries. Red squirrels generally were found only in forests older than 50 years. Fire apparently destroyed marten habitat. The snowshoe hare benefited from post-fire vegetation. Invasion of quaking aspen following fire benefited beavers. Sharp-tailed grouse increased. Spruce grouse were confined to mature black spruce. Slate-colored junco and white-crowned sparrows occupied black spruce or spruce-birch forest. Lichens preferred by caribou were found infrequently in forests less than 30 years old. In the study area, forest fires have been one of the principal causes in the decline of caribou populations. Caribou winter range is restricted largely to the coniferous forest belt. Browse is of limited importance in their winter diet. Deciduous shrubs other than willow have value as forage. Lichens make up about 50 percent of the caribou's winter food. Annual growth rates of two favored species (*Cladonia*) were approximately 4 and 5 mm.

SCOTTER, G.W. 1967 'Effects of fire on barren-ground caribou and their forest habitat in northern Canada.' N A Wildlife & Nat Res Conf Trans 32: 246-59.

Caribou movements may be deflected by recent burns. Lichens generally are regarded as the principal winter food of caribou. In northern Canada this amounted to about 60 percent of the diet. Lichen production increased from 3 lbs/acre air-dried in stands under 10 years old, to 725 lbs. in stands over 120 years old. It usually takes from 70 years to more than a century for the major forage lichens to recover to their former abundance and composition. Their average growth rate ranged from 3 to 5 mm/year depending on species. Arboreal lichens may be an important food source for caribou, particularly as emergency food during periods of deep or ice-crusted snow. Caribou, unlike moose, prefer habitats more than 50 years of age.

Forest fires have been one of the principal causes of the decline of caribou numbers. More prevention and control of forest fires would seem desirable.

SCOTTER, G.W. 1970 'Wildfires in relation to the habitat of barren-ground caribou in the taiga of northern Canada.' Tall Timbers Fire Ecol Conf Proc 10: 85-105.

Destruction of habitat by fire in the taiga might limit the range of barren-ground caribou in winter; however, fires are rare on the summer range in northern Canadian tundra and barren grounds. Caribou prefer older-age class forest. Fires at the southern limits of winter range sometimes are beneficial in improving production of lichens and other forage plants in the more closed forest stands. Muskeg fires destroying *Sphagnum* spp. may result in replacement by better forage species. It has been suggested that fire in black spruce forests, sphagnum peat lands, treeless bogs, or wooded muskegs, could increase the lichen supply. Fire may beneficially affect nutrient cycling, increase summer soil temperatures, remove excessive humus layers, and increase browse supply for moose. The vast flat stretches of northern Canada are not comparable to the rough Alaska terrain. Food preferences of caribou are largely met in climax plant communities. These caribou are the only native ungulate in the region adapted to using the lichen-rich components of the taiga. Caribou avoid young forests. Snow conditions, low forage production and wind-fallen trees make recent burns unattractive to caribou.

SCOTTER, G.W. 1972 'Fire as an ecological factor in boreal forest ecosystems of Canada.' Symp on Fire in the Env (Denver, CO, 1972) Proc: 15-9.

Fire is one of the important factors influencing the vegetation cover of the boreal region of Canada. It is partly responsible for maintaining extensive stands of jack pine, lodgepole pine, black spruce, trembling aspen, and white birch. Natural selection within these tree species has favoured development of fire survival characteristics that ensure maintenance of the species.

The boreal forest has been subject to extensive and repeated fires during prehistoric and historic times. Lightning is the principal cause of fire in the north but man is also an important agent. The net effect of fire on the ecosystem is complex and highly variable depending on site, frequency of fire, severity of fire, and a host of other factors. However, fire may serve a vital role in ecosystem functioning through periodic energy conversion. Such energy conversion, combined with the selected adaptations of plants to regenerate after fire, may add to the stability and viability of boreal forest ecosystems.

The influence of fire on animals in the boreal forest region cannot be easily evaluated. Certain members of the animal community are beneficially affected and others are at a disadvantage, at least over the short term.

As required ecological data becomes available we will find that fire, which is most often condemned as an enemy, can also be an effective tool and friend, and may well be necessary to add stability and viability to ecosystems of the boreal forest.

SELLERS, R.E. and D.G. Despain 1974 'Fire management in Yellowstone National Park.' Tall Timbers Fire Ecol Conf Proc 14. Symp Fire & Land Manage (Missoula, MT, 1974) Proc.

A fire management program was implemented in Yellowstone National Park in 1972. The program features the use of naturally-occurring fires in certain areas to restore the ecological balances which occurred prior to the arrival of white man in the region. These areas were chosen because they were being managed as wilderness, and fires there posed no threat to human life, physical improvements, or lands administered by other agencies. During 1972, 1973, and 1974, ten fires were allowed to run their course. They burned a total of slightly more than 800 acres. A comprehensive research program was also implemented to investigate the behaviour of the fires burning under the program and the subsequent ecological changes. The authors outline the steps taken to fit a proposed fire-management program to the area. They also discuss their preliminary conclusions regarding fire management at Yellowstone.

SHANK, C.C. 1971 Ecology of the Vermilion Pass fire: an annotated bibliography. Submitted to National and Historic Parks Branch, Dept of Ind Aff & North Dev. 37 p.

Two major reference types are included: (a) those describing the organisms, geology, pedology, meteorology, ecology, and history of the area, and (b) those describing the effects of forest fires in the Rocky Mountains. Three hundred and sixteen references are cited.

SHANTZ, H.L. 1947 The use of fire as a tool in the management of the brush ranges of California. Calif Div For, Sacramento.

With regard to wildlife, fire of the spot variety has benefited wildlife of certain types, especially deer, quail and turkey. Small fires with edge effects and fire breaks are favorite feeding grounds. But large broadcast fires might either destroy outright or starve seriously many types of game including deer, quail and turkey, as well as most of the other wildlife forms except mice and ants and probably the larger predators. By changing mixed types of vegetation to chamise, whole areas are made unfavorable for deer and other wildlife, and such is the tendency in most of the brush ranges.

SHARP, W.M. 1970 'The role of fire in ruffed grouse habitat management.' Tall Timbers Fire Ecol Conf Proc 10: 47-61

In Pennsylvania, wildlife management in the absence of controlled or prescribed burning creates only temporary or short term benefits to ruffed grouse. Normally one grouse per 10 or more acres is a reasonable population while units under fire management will carry one bird per 2 to 4 acres. The ruffed grouse appears to be a fire climax species or one that benefits from recurring fires in its habitat. Its key food plants are fire induced at crucial stages of development such as by stimulating seed germination and seedling establishment, by rejuvenating decadent plants, or by controlling plant disease. Fire retards or delays encroachment of the closed canopy forest. The grouse populations are found on areas having a history of recurring fires. Nests, on the ground, are placed in areas of little cover. Fire prior to egg laying would not affect quality of nesting cover. Later, fire would destroy clutches. Spring burns attract adults and later broods.

SHEARER, R.C. 1975 Seedbed characteristics in western larch forests after prescribed burning. USDA For Serv, Res Pap INT-167. 25 p.

Establishment of western larch seedlings is favored by site preparation that reduces both the duff layer and the sprouting potential of competing vegetation. A cooperative study of the use of fire in silviculture in northwestern Montana provided conditions to research the effectiveness of prescribed burning of logging slash from May through September for seedbed preparation. Greatest duff reduction, nonconiferous root mortality, and soil heating occurred when water content of duff and of soil was lowest. Slash must be burned in the summer when the duff is dry to significantly reduce the organic mantle.

Burning to prepare seedbeds for establishment of regeneration can be conducted over a wider range of time on east, south, and west-facing slopes. Duff on north-facing slopes dries more slowly than on other aspects.

SIDHU, S.S. 1973 Early effects of burning and logging in pine mixed woods. I. Frequency and biomass of minor vegetation. Can For Serv Info Rep PX-X-46. 47 p.

Presents detailed results of changes in minor vegetation during first growing season after partial logging with and without subsequent prescribed fire. A procedure for comparing changes in single species is proposed for cases where treated and control plots are not identical. Logging and fire each successively lowered plant biomass below the original level, and further altered the frequency pattern.

SIDHU, S.S. 1973 Early effects of burning and logging in pine mixed woods. II. Recovery in numbers of species and ground cover of minor vegetation. Can For Ser Info Rep PS-X-47. 23 p.

Second of a series begun in previous Report. After logging only, ground cover of minor vegetation increases and ranking of species importance is affected. After fire as well, ground cover and number of species reach pre-burn levels in one growing season. Again, order of importance is altered.

SIMARD, A.J. 1973 Forest fire weather zones of Canada. For Ser, Env Canada Ottawa.

Simard has compiled a map of forest fire weather zones of Canada categorized as minimal, very low, low, moderate, high, very high, and extreme. In general fire weather severity, as measured by the average fire weather index is highest in southern and western Canada, and lowest in eastern and northern Canada. The map is accompanied by an introduction that discusses the main weather factors that contribute to fire danger. In addition, Simard explains how the map was compiled and goes into some detail to describe what kinds of fires could be expected in each zone.

SIMARD, A.J. 1973 Wildland fire management - the economics of policy alternatives. Can For Ser Tech Rep 15, Ottawa. 52 p.

The purpose of the paper is to discuss the application of some basic concepts from the field of economics to the field of wildland fire management.

The historical development of practical and economic wildland fire management policies is briefly traced, the main emphasis of the paper is on an economic approach and fire control. The economic theory is a function of three elements: cost, production and net present loss. The production function is the key element of the theory. The importance of market processes in relation to damage assessment is also considered and the effect of beneficial impacts of wildland fire is discussed.

SIMARD, A.J. 1975 Wildland fire occurrence in Canada. Canada Dep Env, Can For Ser, Ottawa.

This is a one-sheet folder with a map of Canada showing the occurrence of fires for the period 1961-66 as contour lines based on number of fires per 1000 square miles per year. Most fires during the period were man-caused, they were located around population centres and along roads. Lakeshores and rivers often had higher occurrence density than the surrounding area.

SINCLAIR, G.A. 1962 'Progress report of prescribed burning in hardwood stands in Ontario.' Section Report No 45, Dept of Lands & For, Ontario. 21 p.

This report, the third of this series, describes the physiographic and biotic site conditions before burning and the climatic conditions and flame characteristics during the burning of the same area and another study area in the Bruton Township in October, 1960.

SINCLAIR, G.A. 1967 Burning patterns. Dept of Lands & For Prescribed Fire Symp Ontario. 9 p.

The author reviews types of fires and firing procedures for prescribed burning. A table is included which summarizes various applications of fire in terms of burning method, fuels, stand conditions, objectives, and possible problems.

SINCLAIR, G.A. 1967 Fire effects. Symp on Prescribed Fire, sponsored by Dept of Lands & For, Ontario.

The effects of fire on vegetation are discussed. The time - temperature relationships that can produce lethal results and the factors that increase susceptibility to damage are covered. Fire effects on soil are reviewed, and the points to consider in burn appraisal are raised.

SLAUGHTER, C.W., R.J. Barney, and G.M. Hansen (eds) 1971 Fire in the northern environment - a symposium. Symp on Fire in the North Env (Fairbanks, AK, 1971) Proc. USDA For Serv, Pacific Northwest For & Range Exp Sta, Portland, OR. 275 p.

The symposium was held April 13 and 14 at the University of Alaska, dealing with wildland fire in the subarctic in relation to environment and wildlife. Twenty-one papers are included: the most relevant ones are annotated separately under the names of their authors.

SLOANE, N.H. 1960 An appreciation of prescribed burning as a silvicultural tool in Ontario. Res Info Pap No 1, Ont Dept of Lands & For, Res Br, Ontario. 12 p.

Prescribed burning is defined as the controlled use of fire to achieve some pre-determined objective. The most important objective to foresters is the use of fire as a silvicultural tool of forest management. A general review of 11 possible purposes for prescribed burning is outlined. Contrary to popular opinion, fire in our forests is a natural occurrence in nature's scheme of things and can be beneficial as well as harmful.

SMITH, D.W. 1968 'Surface fires in northern Ontario.' Tall Timbers Fire Ecol Conf Proc 8: 41-54.

The direct effects of burning at two levels of intensity each of three durations were restricted to the surface 2 cm of soil. The chemical changes in the surface associated with the direct effects of burning resulted mainly from the combustion of the vegetation and surface litter. Increase in concentration of basic nutrients was mainly in the water soluble fraction. Large losses of basic nutrients from the surface during the first 4 months after severe burning occurred by leaching and wind erosion as well. The density and productivity of the blueberry species which formed the most abundant components of the pre-burn surface flora was reduced by severe surface burning. Increase in density and productivity of the blueberry species were evident following burning at durations of 40 sec/m².

SMITH, D.W., R. Suffling, D. Stevens, and T.S. Dai 1975 'Plant community age structure as a measure of sensitivity of ecosystems to disturbance.' J Env Manag 3: 271-85.

Sensitivity is defined on the basis of replacement time. More mature stages are less easily and less quickly replaced than pioneer types, and therefore older stages are given a higher sensitivity rating. It follows that older stages of vegetation are considered more sensitive to natural disturbance including fire.

SMITH, J.H.G. and D.E. Gilbert 1974 'Rates of spread and fire damage to timber cover types in B.C.' Tall Timbers Fire Ecol Conf Proc 15: 135-54.

Magnetic tape records made available to the University of British Columbia by the British Columbia Forest Service are examined. These tapes have data on more than 50,000 B.C. wildfires from fire records since 1950. The tables are computed to ascertain rates of spread in different timber types. The rate of spread indicates the amount of suppression effort necessary to control fire.

SMITH, J.H.G. and R.C. Henderson 1972 'Use of fire in Canadian forests.' Symp on Fire in the Env (Denver, CO, 1972) Proc, USDA: 77-87.

Uses of fire in land clearing and in disposal of agricultural and logging residues and in removal of unwanted leaves, grasses, and shrubs are well established in Canada. Little work has been done, however, to improve public understanding of the role of carefully prescribed and well managed fires for habitat maintenance and improvement. In the near future, most improvements in fire control and use will occur not as a result of more basic research or development of better guidelines, or from spectacular equipment inventions, but will arise because improved planning and operational systems have optimized the use of concepts and resources presently available.

SMITH, R.L. 1974 Ecology and field biology, 2nd ed. Harper & Row, New York. 849 p.

This textbook on plant and animal ecology deals with fire briefly but comprehensively.

SMITHERS, L.A. 1961 Lodgepole pine in Alberta. Can Dept of For Bull 127. 186 p.

This review includes the silvical characteristics of lodgepole pine, the effects of prescribed burning on its growth, and various succession patterns that follow fire in stands of this tree species.

SOUTIERE, E.C. and E.G. Bolen 1972 'Role of fire in mourning dove nesting ecology.' Tall Timbers Fire Ecol Conf Proc 12: 277-88.

A cool spring fire produced little effect on mesquite trees or their use as mourning dove nesting sites. Doves nested on the ground when trees were killed (herbicide). Current year burns made better ground-nesting habitat than did older burns except during drought. Density of nests decreased each year after the fire. Fewest nests were in the unburned area. Ground-nesting doves prefer open cover. Fire preceding a drought year is disastrous to dove nesting.

SPENCER, D.L. and E.F. Chatelain 1953 'Progress in the management of the moose of south central Alaska.' N A Wildlife Conf Trans 18: 539-52.

A large burn in 1947 on the Kenai Peninsula induced an increase in moose population of about four hundred percent between 1950 and 1953 - almost entirely due to aspen sucker growth. On some ranges forest succession advances faster than moose populations can build up to utilize the forage. All the important moose ranges in southern Alaska are the result of some disrupting influence that removed the original forest cover and allowed young second-growth browse species to become abundant. The most important of these influences has been fire. (Beaver activity is another influence.) The possibility of controlled burning is being investigated as a means of creating and preserving winter ranges. Present fire control programs are so effective in these areas that more moose range is being lost through forest succession than is being created. Controlled burning can partially alleviate the winter range problem but cannot completely remedy it.

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

In 1947 a 310,000 acre wildfire burned approximately one-fourth of the moose winter habitat on the Kenai National Moose Range. Historically this was stone caribou country but they were extropated early in this century. Earlier, widespread fires created habitat favorable to moose and a growing herd developed coincidental to disappearance of caribou. The current (1964) peak population is largely supported by forage in the 1947 burn. Important winter forage species are willow, birch, serviceberry, mountain ash, and viburnum. A high level of forage began about 8 or 9 years after the fire and has continued high for 8 years. The loss of the forage value of hardwood browse will occur some 30 to 35 years following fire. The burn is a favored calving ground with some preference for the muskeg or marshy areas. The moose population moves from the mountains into the wintering area early in December. Concentrations occur only during severe winter, at which time there may be 5 moose per square mile. Three years after the fire, 15 percent of the herd wintered in the burn. Ten to twelve years after, 55 to 60 percent wintered there. Calf ratios approximately doubled in 10 to 12 years. A timely reburn to reduce spruce reproduction may extend the period of browse production. However, repeated burns may favor grasses and forbs, and eliminate browse.

SPURR, S.H. and B.V. Barns 1973 Forest Ecology, 2nd ed. Ronald Press, New York. 570 p.

A general text on forest ecology which describes fire as it relates to tree adaptations, direct effects on forest communities; effects of fire on Douglas-fir, Eastern Hardwoods, Eucalyptus, and Pine; the effects of fire on nitrogen loss; and post-fire succession.

Some indirect effects of fire are also discussed, as is the role of fire in the tropics.

STANTON, F. 1975 Fire impacts on wildlife and habitat. An abstracted bibliography of pertinent studies. U S Dept of the Interior. 48 p.

This annotated bibliography was developed from library research for information needed to prepare Wildlife Section of the Bureau's Fire Management and Environmental Impact Statement. It is not a complete review of available literature, although approximately 175 references are cited.

STARK, N. 1974 'Fuel reduction - nutrient status and cycling relationships associated with understory burning in Larch/Douglas Fir stands.' Tall Timber Fire Ecol Conf Proc 14: 573-607.

In the context of burning in Larch/Douglas Fir stands, Stark outlines a theory for the biological life of soil. He then relates the effects of fire to this theory.

STEPHENSON, W.R. 1977 The role of fire as a resource management tool in Canada's National Parks: A Discussion Paper. Prepared for Fire Ecol in Resource Manage, A Workshop. Can For Ser Edmonton, Alberta. 15 p.

Fire as a resource management tool for vegetation is shown to be permissible and advisable in National Parks if it is a part of well thought out land-use plan. Planned fire is described in the context of attainable resource management in National Parks. A system-wide project to bring Regional initiatives together is discussed and a prospectus for the future offered. The author outlines three scales of management that relate to vegetation management, by fire in National Parks. Also included are possible wildlife management alternatives, as they relate to fire.

STOCKS, B.J. and J.D. Walker 1968 The effect of green vegetation on surface fire spread in the laboratory. Can Dep For & Rural Dev Inform Rep PS-X-5. 6 p.

Describes an experiment to test the effect of green herbaceous vegetation on the behaviour of fire in pine needle litter. Various quantities of fresh green material were set as realistically as possible into pine needle beds, 4 x 2 1/2 ft in size. Much of the flame was suppressed but rate of spread was surprisingly little affected. The fires were burned in still air, and it was surmised that headfires burning with the wind would be more affected, since they depend more on their overhead flame as a means of propagation than do still air or backing fires.

STOCKS, B.J. and J.D. Walker 1972 Fire behaviour and fuel consumption in jack pine slash in Ontario. Great Lakes For Res Cen, Sault Ste Marie, Ont, Info Rep O-X-169, Can For Serv Dept of Env. 19 p.

Results and analysis of 24 1-acre experimental fires in jack pine logging slash are presented. The behaviour parameters, such as intensity, rate of spread and fuel consumption, and their relationship to fire weather are discussed in detail.

STODDARD, H.L. 1931 The bobwhite quail, its habits, preservation and increase. Scribner, New York. Chapter 15.

The author makes the following points:

1. Dual use. Quail and timber can be raised on the same property (though usually not maximum crops of either).
2. Use of fire is justified to control vegetation of jungle-like growth, if fire is carefully controlled.
3. Burning in winter and at night with a creeping-type fire, in alternate years or as needed, may increase food supply, regulate density and extent of ground cover, aid in nest distribution, and aid in control of disease and parasites.
4. Uncontrolled use of fire is condemned. Fire should be used only under close supervision.

STODDARD, H.L. 1963 'Bird habitat and fire.' Tall Timbers Fire Ecol Conf Proc 2: 163-75.

Most marsh areas may be burned during fall, winter, or early spring to benefit waterfowl. This also reduces risk of wild fires during nesting season of resident birds. Summer fires damage bird nests and young. Seed and fruit crops of the year are reduced. Southeastern pine forests protected from fire become overgrown with understory brush of little value to birds. Over a long period, pine converts to hardwood. The hardwood is better bird habitat than overgrown pine - more for turkey, less for quail. Quail and turkeys are attracted to burning pines - pine seed, insects, and other food becomes available. Hawks are attracted during a fire. Small birds which are attracted include robins, bluebirds, doves, sparrows, and woodpeckers. There should be well-distributed small areas not burned frequently, for production of fruit-bearing shrubs. Few animals are found killed in fresh burns.

STORER, T.I. 1932 'Factors influencing wildlife in California, past and present.' Ecology 13: 315-34.

The policy of forestry officials in restricting burning on forest and chaparral areas became a deer problem. Fire was a common and repeated occurrence in earlier years. There were numerous small fires, there being less accumulation of fuel. The chaparral was more open but became impenetrable with reduced burning. Herbaceous vegetation became scarce.

STRIFFLER, W.D. and E.W. Mogren 1971 'Erosion, soil properties and re-vegetation following a severe burn in the Colorado Rockies.' Slaughter, C.W., R.J. Barney, and G.M. Hansen (eds) Symp on Fire in the North Env (Fairbanks, AK, 1971) Proc. 25-37

Observations indicate that erosion during the first summer after the burn was not a serious problem but that some erosion was occurring. The amount of rock exposed on the soil surface is more important than slope in initiating particle movement during low intensity storms but slope is the controlling factor during high intensity storms. Analysis of soil physical factors show that the burn had very little effect in spite of a complete destruction of litter and surface vegetation. This was attributed to the coarse textured soils. Revegetation after the burn showed a steady increase in spruce/fir seedlings, lodgepole pine seedlings, and aspen suckers.

SUMNER, E.L. Jr. 1931 'A life history of the California quail, with recommendations for conservation and management.' Calif Fish & Game 21: 167-256, 275-342.

The restricted burning policy for brush areas apparently has had an unfavorable influence upon quail in some foothill regions. The chief food items for quail have been largely choked out.

SWAIN, A.M. 1973 'A history of fire and vegetation in northeastern Minnesota as recorded in lake sediments.' Quat Res 3: 383-96.

Swain reports on the analysis of pollen and charcoal of annually laminated varves or sediments of Lake of the Clouds. Varves provide a time scale for dating any changes in the pollen or charcoal content that result from fire, logging, agriculture, or climatic changes. Swain's findings indicate that fire has been important factor in determining forest composition for at least the past 10,000 years in the Boundary Waters Canoe area. If the present vegetation types are to be perpetuated, fire, either natural or prescribed, will have to be incorporated into any management program for this area.

SWANSON, J.R. 1974 'Hazard abatement by prescribed underburning in West-side Douglas-fir.' Tall Timbers Fire Ecol Conf Proc 15: 235-8.

This study indicates that prescribed underburning is a safe, effective tool for abating wildfire hazard in section growth stands of West-side Douglas-fir. Significant reduction in fuel loading was achieved with fires which were easily controlled. Much work remains however to verify the long-term effects and economic feasibility of this management technique.

SYKES, J.S. 1971 'Effects of fire and fire control on soil and water relations in Northern Forests, a preliminary review.' Slaughter, et al. (eds), Symp on Fire in the North Env (Fairbanks, AK, 1971) Proc: 37-45.

There is disagreement regarding effects of fire on soil temperatures, permafrost degradation, destruction of the organic mat, soil erosion, and other factors. Some observers indicate more serious damage from past fire suppression methods than from the fires themselves. A brief preliminary review of work pertaining to the effects of fire in northern forests is presented.

SYLVESTER, T.W. 1975 'Fuel characteristics of plant communities in the Mackenzie Delta Region.' Vegetation Recovery in Arctic Tundra and Forest-Tundra After Fire, ALUR 1974-75, Ottawa: 63-91.

This article includes a table in which community fire susceptibility ratings of the interior Alaska fuel types under dry valley bottom condition is included. White spruce or birch spruce is rated high. Paper birch or birch aspen is rated high. Black spruce - extreme, aspen - medium, cottonwood - medium, willow-alder - medium, grass - flash, muskeg - high, and tundra - high in relative susceptibility rating.

TANGREN, C.D. 1976 'Smoke from prescribed fires: How it can be managed to minimize effects.' For Farmer 35(10): 6-7. South For Exp Stn U S For Serv, Macon, GA.

The author presents a check list of procedures that may be followed to minimize the effects of smoke from prescribed fires. Most of the detail pertains to the southeast United States.

TAYLOR, A.R. n.d. Fire ecology citation file. Northern Forest Fire Laboratory USDA For Serv, Missoula, MT. Unpublished.

A listing by title, author and key words of approximately 3500 references to fire ecology. Presently (1978) planned for publication in microfiche format under the title "Bibliography of fire ecology" by the Forest Conservation and Experiment Station Missoula, Montana under the authorship of M.J. Behan, R.K. Kickert, and D.H. Firmage.

TAYLOR, A.R. 1971 'Lightning: agent of change in forest ecosystems.' J For 69: 476-80.

The U.S. Department of Commerce estimates that approximately 8 million cloud-to-ground lightning discharges occur every day. These discharges bring about changes in forest ecosystems in both subtle and dramatic ways. Lightning can affect single trees or trees in groups. Structural damage may vary from removal of just a few flakes of bark to total destruction of the tree. Little is known about the physiological effects of lightning. It does serve as a precursor to insect and disease attack and wind damage. Lightning plays an important role in the nitrogen cycle. About 8% of all nitrogen fixation is brought about by lightning, but more important than this is the indirect role lightning plays. Its most dramatic role is igniting forest fires. These fires release nitrogen from forest fuels along with other elements and compounds essential to plant and animal growth. In addition these fires interrupt biotic succession as well as affecting soil, water, and other things present in the ecosystem. Of the lightning-caused fires occurring during the 1960's, 97% were less than 10 acres. How many would have remained that small without man's suppression activities is unknown. Experience in Sequoia and Kings Canyon National Parks indicates that most would have.

TAYLOR, A.R., R.N. Kickert, D.H. Firmage, and M.J. Behan 1975 Fire ecology questions survey: candid expressions of research needs by land managers and scientists in western North America. USDA For Serv Gen Tech Report INT-18. Contribution No 127, Ecosystem Analysis Studies, Coniferous Forest Biome Intermt For & Range Exp Stn, For Serv USDA, Ogden, UT. 111 p.

Over 900 questions are presented which reflect research needs expressed by the group polled. A total of 60 experts from academic institutions, Federal Government Research Labs, Provincial Fish and Wildlife Managers, private industry, and Provincial Foresters were polled from Canada. Two hundred and seventy-five questions are presented that were raised by Canadian experts from British Columbia, Alberta and Ontario.

TAYLOR, D.L. 1973 'Some ecological implications of forest fire control in Yellowstone National Park, Wyoming.' Ecology 54: 1394-6.

Seven recently burned areas in Yellowstone National Park were selected for study in order to document the successional trends in the development of lodgepole pine communities. The data indicate that excluding fire from these ecosystems will limit ecological diversity by reducing or eliminating certain plants and animals that are present only in the successional communities that appear before the forest canopy closes.

TAYLOR, D.L. 1974 'Forest fires in Yellowstone National Park.' J For Hist 18(3): 68-77.

Fire has historically played an important role in the natural succession within the major vegetation zones of Yellowstone National Park. Fire has affected plant regeneration, wildlife habitat, nutrient cycling, etc. Although man-caused fires were present, lightning is believed to have been the major cause of fires before the white man first visited Yellowstone. White man caused numerous fires after his arrival, but park administrators have diligently attacked the problem and become so effective that fire has been effectively excluded as a major force in the ecosystems. This resulted in unnatural changes in the ecosystems. Park managers, prompted by research and the 1963 Leopold Report, have begun to change their attitudes about lightning fires. In 1969 the National Park Service adopted a policy aimed at restoring the natural function of lightning fires to the park ecosystems. This is an important development in Yellowstone.

TESTER, J.R. and W.H. Marshall 1962 'Minnesota prairie management techniques and their wildlife implications.' N A Wildlife and Nat Res Conf Trans 27: 267-87.

In northeastern Minnesota, prairie fires frequently swept the uplands, spring and fall, and helped maintain the grassland. A burning study was conducted on ten-acre plots. Spring burning was done in April; fall burning in October. Burning at either season resulted in an advance of 10 to 20 days in development of vegetation, luxuriant new growth, an increase in forbs, and more abundant seed crops. There was no noticeable shift in species composition due to burning. Evidence is cited of woody plant invasion. Burning usually killed aspen, but willow resprouted. Populations of meadow vole (*Microtus*) increased with increasing litter, while the deer mouse (*Peromyscus*) decreased. Grasshoppers were most abundant in light or moderate amounts of litter; beetles preferred sparse litter. Prairie chickens prefer mixed vegetation of tall grass and brush. Nesting waterfowl select ponds having a medium amount of shoreline cover, rather than either bare ground or shorelines solidly filled with emergents. Pintails will nest on recent burns. Recommendations were to burn approximately one-fourth of the area each year. The best single management measure appears to be spring burning. However, nesting will be reduced the year following the burn due to lack of cover. It should then be suitable during the succeeding three years.

THOMPSON, G.A. 1964 'Fires in wilderness areas.' Tall Timbers Fire Ecol Conf Proc 3: 105-10.

Fire occurrence in two of the largest U.S. roadless areas (the Idaho Primitive Area and the Selway-Bitterroot Wilderness Area - 2,250,000 acres) ranges from 40 to 3,000 per year. About 90-98% of these are caused by lightning. The greatest concentration of fires occurred in 1940 when 2,000 fires started in a 3-day period. The most devastating fire hit the area in 1833. Sheepstealer Indians inhabited the area. These people feared forest fires and actually fought fire when it burned in the winter game ranges. A major damage, other than loss of winter game range, is caused by the mud and rock flows which result from heavy rains falling on burned areas. Scientists estimate that 100 years are needed to restore the salmon and trout spawning capacities of the streams involved. Natural processes in wilderness are wasteful. Wilderness areas must be managed. Managers should guard them against too many people, too much wildlife, and too many burned acres. To accomplish these objectives managers must limit people, harvest excess wildlife, and prescribe burns.

TOWELL, W.E. 1974 'Fire: Friend and foe.' Am For 80(8): 7.

The results of aggressive fire control are visible in the rejuvenated and productive forests in the East. Fire use also has its place among the tools of the natural resource manager, but there are some wilderness enthusiasts who state that all fires set by nature are good and should not be extinguished. The answer lies in moderation. Professional judgement is the key. When the place of fire in the ecosystem is fully understood, it can be used if good and rejected if bad. "The important thing is to know the difference."

U.S. CONGRESS 1964 The Wilderness Act (P.L. 88-557). 88th Congress, Washington, D.C. 7 p.

Among other things, this act established the National Wilderness Preservation System to be composed of federally-owned areas designated as "wilderness areas" by Congress. Wilderness "shall be administered for the use and enjoyment of the American people in such a manner as will leave the areas unimpaired for future use and enjoyment as wilderness, and so as to provide for the protection of these areas, the preservation of their wilderness character, and for gathering and dissemination of information regarding their use and enjoyment as wilderness". Wilderness is "undeveloped Federal land retaining its primeval character and influence ... which is protected and managed so as to preserve its natural conditions ...".

USDA FOREST SERVICE 1971 Fire policy meeting: Denver, Colorado, May 12-14, 1971. USDA For Serv, Washington, D.C. 17 p. + App.

In 1935 the "10 a.m. Fire Control Policy" was formally adopted by the Forest Service. The policy called for "fast, energetic and thorough suppression of all fire in all locations". In cases when suppression action did not result in immediate control of the fire, the policy required that the situation be analyzed and the fire be attacked so that it could be controlled in the "first work period". "Failing in this effort the attack each succeeding day will be planned and executed with the aim, without reservation, of obtaining control before 10 o'clock of the next morning". The Forest Service reaffirmed the "10 a.m. Fire Control Policy" in 1971; however, exceptions were authorized on a preplanned basis when approved by the Regional Forester and Chief. Specific examples of exceptions include approved authorizations to incorporate a deviation in wilderness management plans and the use of wildfire burning on areas not under conditions specified for prescribed burning. These exceptions are not contingent upon a specific ignition source such as lightning.

USDA FOREST SERVICE 1972 Fire in the environment, symposium proceedings. Published by USDA For Ser in cooperation with the Fire Services of Canada, Mexico and the U.S. FS-276. 151 p.

This is a collection of papers given at a symposium on fire in the environment held at Denver, Colorado, May 1 to 5, 1972. Topics covered included: fire in the forest ecosystem, man in the forest ecosystem, public attitudes toward fire and the shaping of policy, alternatives to conflagration, fire control technology, environmental protection, streamflow, and smoke.

USDA FOREST SERVICE 1973 The natural role of fire. USDA For Serv North
Reg Publ R1-72-033, Missoula, MT. 23 p.

Although man has seen fire as an enemy of the forest, he now is beginning to see it as a natural agent of change. Much of the diversity and uniqueness of the Rocky Mountains is the result of fire. Fire is neither all good nor all bad, but is a powerful natural occurrence. When put to proper use by professionals, fire is a valuable tool.

UNIVERSITY OF IDAHO 1973 Annual report. Forest, Wildlife and Range
Exp Stn Moscow, ID.

This report is on the effects of prescribed burning on four browse species: mountain maple, serviceberry, redstem ceanothus and willow. Crude protein was significantly higher the first year after spring burning in 83 percent of the burned vs unburned comparisons, although it was lower in redstem. Fat content was generally lower the first year but higher the second and third years after burning for all species: willow was highest, redstem lowest. Crude fiber was significantly lowered in 72 percent of the comparisons for all years; however, it increased in mountain maple. Production of available redstem on the Lochsa watershed burned sites exceeded the control after two years; but on the St. Joe production was lower, due primarily to heavy summer use. Utilization data showed higher summer and winter use by big game of burned compared to nonburned areas, and a higher preference for redstem than the other browse species. It was recommended that burning be done on scattered areas on a given tract of winter range rather than burning one large acreage on the premise that animal distribution and plant use may be more uniform.

VAN METER, W.D. and C.E. Hardy 1975 Predicting effects on fish of fire retardants in streams. USDA For Serv Res Pap INT-166, Ogden, Utah, 1973. 16 pp.

Ammonium sulfates and sulfates are being used as fire retardants. In general they are fertilizers and have beneficial effects unless dosage is too heavy. In these cases they can damage fish, especially when dropped directly into bodies of water.

VAN WAGNER, C.E. 1961 Brief report on trip to the Lake States Experiment Station. For Fire Res Institute Files, Ottawa, Canada. 6 p.

Mr. Van Wagner offers observations gleaned from a three day visit with Dr. R.E. Buckman in Minnesota. He offers observations on Buckman's experimentation with prescribed burning in red and white pine and black spruce.

VAN WAGNER, C.E. 1962 'On the value of a numerical concept of fire intensity.' Pulp & Paper Mag of Can, Woodlands Rev: 458-9.

Describes the rating of forest fire intensity in terms of energy output per unit length of fire front (after Byram).

VAN WAGNER, C.E. 1963 'Prescribed burning experiments: red and white pine.' Can Dept For Publ 1020: 27.

Eleven quarter-acre plots in a mature red and white pine stand were burned at different degrees of dryness. Intensity ranged from 25 to 370 Btu sec⁻¹ ft.⁻². Fires' effects were measured on crowns and subsequent mortality, shrubs and subsequent resprouting, and conifer regeneration. Conclusion was drawn that it is quite feasible and safe to control shrubs, prepare seedbed, and obtain satisfactory pine regeneration through the use of prescribed fire, all without serious damage to the overstory.

VAN WAGNER, C.E. 1964 'History of a small crown fire.' For Chron 40(2): 202-5, 209.

The course of a small (1/4 acre) experimental fire in a red pine plantation. Transition from still-air surface fire to crown fire with sudden increase in wind. Intensities at various stages in terms of energy output rate.

VAN WAGNER, C.E. 1965 Aids to forest fire control planning at Petawawa. Can Dep For Publ 1127. 20 p. Available in French as Pub 1127F.

Presents tables, graphs and maps that form the basis of forest fire control planning at the Station. Classified into those describing: a) patterns of fire weather, b) trends in fire occurrence, c) history of fire size and area burned, and d) features of the protected area. Examples given of procedures and processed information of possible interest to fire control agencies.

VAN WAGNER, C.E. 1965 'Describing forest fires - old ways and new.' For Chron 41: 301-5.

A review of traditional methods of rating forest fire behaviour and their shortcomings. The advantages of quoting fire intensity as rate of energy output per unit length of fire front are listed. The factors of fire intensity, namely rate of advance, fuel weight consumed, and heat of combustion, are discussed separately.

VAN WAGNER, C.E. 1965 Prescribed burning experiments - red and white pine. Dept of For Pub No 1020: 27.

The behaviour and effects of fire in red and white pine stands were studied by burning quarter-acre plots on three sites at four degrees of fire hazard, and observing the areas for a year after fire.

Provided the wind is light, fires can be set and controlled in mature pine stands at extremes of drought and fire danger. If crown damage is to be avoided, the fire intensity must be controlled, burning with backfire if necessary. Pines died quickly as a result of more than 75 percent crown scorch, but stem charring alone killed no trees during the first year. The bottom layer duff was appreciably reduced or removed only when its moisture content was less than 40 percent and the fire danger high or extreme. The first year regeneration and survival of pine and spruce seedlings was greatly favoured by severe fire.

VAN WAGNER, C.E. 1965 'Story of an intense crown fire at Petawawa.' Pulp & Paper Mag of Can, Woodlands Rev.

On May 7, 1964, an intense fire burned 375 acres of forest on the Petawawa Military Reserve, in several pine and aspen forest types. The weather was the most severe on record for that date (85°F, 16% RH, wind 16 mph), and the fire exhibited probably the most extreme behaviour likely in this region. Data are presented on weather, fuel, rate of spread and energy output rate. Control action is described, especially backfiring.

VAN WAGNER, C.E. 1966 Comparison of American and Canadian forest fire danger rating systems. Can Dep For Info Rep PX-X-2. 18 p.

An analysis and comparison of the two danger rating systems as they existed in 1966, pointing out some strengths and weaknesses in each. The separate functions of fine and heavy fuel moisture are quite different and both could not possibly be consistent in the same forest type. The Canadian index appears best suited to a closed forest with litter and duff layer, the American system to an open forest with grassy fine fuel. Because both systems have changed markedly since 1966, this report is now obsolete.

VAN WAGNER, C.E. 1966 Three experimental fires in jack pine slash. Can Dep For Pub 1146. 22 p.

This paper is a description in general and quantitative terms of three 4-acre experimental fires in an area of clear-cut jack pine slash, burned at different levels of fire danger. Their effects in reducing the fire hazard, cleaning the area for access or planting, and as preparation for seeding are described and rated. Weather and fuel conditions for different fire purposes are discussed along with control problems.

VAN WAGNER, C.E. 1967 Calculations on forest fire spread by flame radiation. Can Dep For and Rural Dev Pub 1185. 14 p.

Observation suggests that certain types of fire advance by preheating the fuel ahead with radiation from the flames. A mathematical model was devised to explain the rates of advance and energy output of such fires in terms of fuel amount and moisture content, flame length and angle, and the intensity of thermal radiation emitted by the flame. The theory was tested in a series of laboratory fires in beds of red pine needles at different slopes, with some confirmation of the basic concept.

VAN WAGNER, C.E. 1967 Seasonal variation in moisture content of eastern Canadian tree foliage and the possible effect on crown fire. Can Dep For & Rural Dev Pub 1204. 15 p.

Five conifer and two hardwood tree species were sampled for four years to determine the seasonal variations in the moisture content of their foliage. New conifer and hardwood foliage were very moist just after flushing, but dried progressively until midsummer. Old conifer foliage passed through a distinct minimum just before the new foliage appeared. According to heat balance calculations and flammability tests, these variations should have a substantial effect on crown fire behaviour.

VAN WAGNER, C.E. 1968 Duff moisture profiles at Petawawa. Can For Serv Intern Rep PS-8. 6 p.

Describes and portrays the variation in the moisture content of pine duff with depth found on six days of different average moisture content. The maximum moisture content was found somewhat above the lowest duff level rather than right next to mineral soil. Shape of profile varies with past history of rain and dry weather.

VAN WAGNER, C.E. 1968 'The line intersect method in forest fuel sampling.' For Sci 14(1): 20-6.

A method for estimating wood volume on the ground is derived and discussed mathematically. It requires only a diameter tally of pieces intersected by a sample line of known length, and application of a simple formula. The method was tested indoors with match splints on a 54-inch square, and outdoors on a 20-acre cutover. It produces reliable estimates of quantity of logging slash in much less time than area sampling.

VAN WAGNER, C.E. 1969 Combined effect of sun and wind on the surface temperature of litter. Can Dep Fish For Info Rep PX-X-10. 7 p.

Describes a laboratory experiment to measure the combined effects of thermal radiation and wind on the surface temperature of jack pine and aspen litter. Semi-empirical equations are derived from theory and results. The rise in surface temperature above ambient was found to be proportional to the radiant intensity, and its logarithm inversely proportional to wind speed. There is possible application in fuel moisture prediction and work on seedling mortality at higher temperature.

VAN WAGNER, C.E. 1969 Drying rates of some fine forest fuels. Can For Ser Fire Control Notes 30: 5, 7, 12.

In lab experiments, dead pine needles and aspen leaves with waxy cuticle intact dried much more slowly than bits of wood of comparable size. Also, removal of the wax and resin with solvent resulted in much faster drying. Drying runs were begun with wet samples, and there was no indication of different drying behaviour as moisture content passed from above fibre saturation to below. Drying was generally exponential.

VAN WAGNER, C.E. 1969 'A simple fire growth model.' For Chron 45: 103-4.

Expressions to predict the area of a forest fire and its rate of growth at any time since ignition are given, in terms of the linear rates of spread at head, flanks, and rear. A variable elliptical shape is assumed. Length of perimeter and its rate of increase are also derived. The model can be simplified to use whatever spread data are available.

VAN WAGNER, C.E. 1970 'Fire and red pine.' Tall Timbers Fire Ecol Conf Proc 10: 211-9.

A review of what specific properties of red pine make fire necessary for regeneration, how liable red pine stands are to fire, how red pine trees are affected by fire, what kind of fire is best for perpetuating red pine in a natural forest, and what kind of prescribed fire would be most useful in managing red pine. The three basic requirements of red pine are: that a good proportion of the duff layer be removed, that hardwood brush be controlled, and that a good proportion of the overhead canopy be removed.

VAN WAGNER, C.E. 1970 An index to estimate the current moisture content of the forest floor. Can Dep Fish & For Pub 1288. 23 p.

An index was developed to estimate day-to-day moisture content of duff layers of dry weight about 5 kg m^{-2} . It is based on four years' daily weighings of trays set into duff layers in pine stands. There were separate analyses of drying and rainfall effects. The drying phase is exponential with log slope depending on temperature, humidity and season. The rainfall effect provides that wetting effect per increment of rain decreases as amount of rainfall increases. The index is on a logarithmic scale, and was incorporated into the Canadian Forest Fire Weather Index as the Duff Moisture Code (DMC).

VAN WAGNER, C.E. 1970 New developments in forest fire danger rating. Can For Serv Info Rep PS-X-19. 4 p.

A non-technical description of the Forest Fire Weather Index suitable for introductory purposes.

VAN WAGNER, C.E. 1970 'Temperature gradients in duff and soil during prescribed fires.' Bi-monthly Res Notes 26(4): 42.

Temperatures in duff and upper mineral soil during surface fires in pine stands were measured with strips of temperature-sensitive paint on mica strips. Where some duff remained, the gradient in maximum temperature was 125°F per 1/10-inch; in bared mineral soil it was 45°F per 1/10-inch. The 212°F level was at a depth of about 0.4 inch in duff, and 0.8 inch in bared soil.

VAN WAGNER, C.E. 1971 Two solitudes in forest fire research. (Paper prepared for XV IUFRO Congress). Can For Serv Info Rep PS-X-29. 7 p.

This report compares the difficulties and advantages of indoor versus outdoor research on forest fire behaviour. The conclusion is drawn that theoretical and small-scale modelling of forest fire is so difficult as to render it unlikely that the main desired practical information on forest fire behaviour can be produced by these approaches; that observation and study of both accidental and experimental outdoor fires is required if valid progress is to be made.

VAN WAGNER, C.E. 1972 'Duff consumption by fire in eastern pine stands.' Can J For Res 2: 34-9.

Amount of duff (F and H layers) consumed by fire in jack pine and mixed red and white pine stands was found to be correlate well with duff moisture content at time of fire, and with the Duff Moisture Code, a component of the Fire Weather Index. Physical theory to account for the weight of duff consumed is presented in terms of a) downward heat transfer within the flaming front, and b) the energy required to heat the duff to ignition temperature at a given moisture content.

VAN WAGNER, C.E. 1972 Equilibrium moisture contents of some fine forest fuels in eastern Canada. Can For Serv Inf Rep PS-X-36. 11 p.

Presents data and curves of equilibrium moisture content for six fine fuels as it varies with relative humidity and temperature, and provides empirical equations for calculation. Concludes that EMC's of most kinds of leaf and needle litter are fairly similar, but EMC of wood is distinctly less.

VAN WAGNER, C.E. 1972 Heat of combustion, heat yield, and fire behaviour. Can For Serv Info Rep PS-X-35. 7 p.

Presents experimental heats of combustion of some forest fuels and discusses calculation of net heat yield from gross heat combustion. Also concludes that variation in heat of combustion among forest fuels is not an important factor affecting forest fire behaviour in Canada.

VAN WAGNER, C.E. 1972 A table of diurnal variation in the Fine Fuel Moisture Code. Can For Serv Inf Rep PS-X-38. 8 p.

Development and rules for use of a table to show how fine fuel moisture varies throughout the 24-hour cycle, for different starting values and varying current relative humidity. Permits determination of the Fire Weather Index at any time of day.

VAN WAGNER, C.E. 1973 'Forest fire in the parks.' Park News, June 1973: 25-31.

Van Wagner traces the beneficial effects of fire on jack-pine, lodgepole pine, black spruce, poplar, aspen, red pine, white pine, and Douglas-fir. He concludes that some fires should be allowed in parks. The park manager must decide where and when fire should be permitted to burn, and he must have the fire control foresters to backup his decisions within reasonable limits, instead of relying solely on accidental ignitions. It makes good sense to choose the time and place to start some fires deliberately. Once the bugbears of loss and damage are put in proper perspective, burned areas in various stages of development become fascinating places.

VAN WAGNER, C.E. 1973 'Height of crown scorch in forest fires.' Can J. For Res 3: 373-78.

Presents theory and field evidence to show that the height to which forest tree foliage is scorched and killed in forest fires is proportional to the $2/3$ power of line fire intensity. Gives equation to account for the additional effects of ambient temperature and wind. Results of potential use in damage estimation and prescribed burning operations.

VAN WAGNER, C.E. 1973 Rough prediction of fire spread rates by fuel type. Can For Ser Info Rep PS-X-42. 5 p.

Presents the general form of a power law equation linking the Initial Spread Index with rate of spread. Constants can be adjusted to suit individual fuel types wherever reasonable correlation exists. Examples are given for four fuel types based on Petawawa data; also three others from published references. Results are useful in converting relative index values to quantitative predictions.

VAN WAGNER, C.E. 1974 Annotated bibliography of forest fire research at the Petawawa Forest Experiment Station, 1961-1974. Can For Ser Info Rep PX-X-52. 15 p.

This report is a bibliography of publications on all aspects of forest fires produced during the period 1961 to 1974 at the Petawawa Forest Experiment Station. There are 52 items, listed chronologically in four categories. A short descriptive note accompanies each item.

VAN WAGNER, C.E. 1974 A spread index for crown fires in spring. Can For Ser Info Rep PS-X-55. 12 p.

This report describes the construction of an index of the relative rate of spread of crowning forest fires during spring and early summer. It depends on the proposition that conifer crowns are more flammable during this period because the moisture content of their foliage is lower than during mid-summer. The calculations are based on heat transfer theory and on the energy required to heat moist fuel to ignition temperature, and are supported by some field evidence. The starting point is the Initial Spread Index, a component of the Canadian Forest Fire Weather Index.

VAN WAGNER, C.E. 1974 Structure of the Canadian Forest Fire Weather Index. Can Dep Env Publ 1333.

The Forest Fire Weather Index (FWI) was issued in table form in 1970 after several years' work by a number of fire researchers in the Canadian Forestry Service. This paper describes its development, the concepts behind it, and its mathematical structure. The best features of the former fire danger index were retained and a link preserved between old and new. The FWI consists of six components: three moisture codes that follow the moisture content of three classes of forest fuel, two intermediate sub-indices representing rate of spread and fuel consumption and the final index representing line fire intensity in a standard pine fuel type. The FWI is found daily from noon readings of temperature, humidity, wind, and rain. It can be worked out from a set of nine tables or by direct computation through a series of 29 working equations.

VAN WAGNER, C.E. 1975 'Approach to a fire management scheme from ecological and fire behaviour viewpoints.' Unpublished paper. 2 p.

Starting with the basic premise that by and large the forest types present on a certain amount are the ones that belong there and should be perpetuated, the author asks and answers a series of questions that leads one towards a rational approach when it comes to fire management.

VAN WAGNER, C.E. 1977 'Conditions for the start and spread of crown fire.' Can J For Res 7: 23-34.

Some theory and observations are presented on the factors governing the start and spread of crown fire in conifer forests. Crown fires are classified in three ways according to the degree of dependence of the crown phase of the fire on the ground surface phase. The crown fuel is pictured as a layer of uniform bulk density and height above ground. Simple criteria are presented for the initiation of crown combustion and for the minimum rates of spread and heat transfer into the crown combustion zone at which the crown fire will spread. The theory is partially supported by some observations in four kinds of conifer forest.

VAN WAGNER, C.E. 1977 'Effect of slope on fire spread rate.' Bi-monthly Res Notes, Can For Ser 33(1): 7-8.

A graph of effects of slope on fire spread rate from 5 references is presented. This relation refers to up-slope effect on fire rate spread. Down-slope fires spread more slowly than level fires, and another relation would be required.

VEILLEUX, J.M. 1972 Effets d'un brûlage contrôlé sur les propriétés physico-chimiques de l'humus Memoire no 9, Service de la Recherche, Ministère des Terres et Forêts du Québec.

The use of prescribed burning to eliminate the latent risk of fire that slash constitutes seems effective while being not too costly. Resulting consequences are less interesting particularly regarding the changes occurring in the properties of the humus horizon and the establishment of new regeneration. The biological activity which seems stimulated by burning results in an accelerated process of mineralization and in losses of essential elements by leaching. Regeneration is slow to come and the danger that an inferior and competitive vegetation takes root is a real one.

VIERECK, L.A. 1973 'Wildfire in the taiga of Alaska.' Quat Res 3:
465-95.

There are many published reports on the detrimental effects of fire on caribou habitat in Alaska. These statements, mainly from Canada, were largely based on the caribou's heavy dependence on lichens. Skoog (1968) believed that in Alaska the irregular terrain and the interspersion of natural fire barriers permits many areas of good habitat to escape destruction by fire. Caribou stomach content analysis indicates less dependence on lichens in Alaska. Examination of over 500 rumina by Skoog showed a fall diet comprising 50 percent sedge-grass, and 30 percent lichens. During the winter, utilization of these foods is estimated to be equal. Skoog concluded that, in the area studied, caribou can utilize the extensive sedge forage on the tundra, alpine meadows, bogs and lake shores, and this greatly mitigates the losses due to fire. Leopold and Darling (1953) stated that up to 50 or even 100 years are required for lichens to achieve preburn levels of production. Scotter (1971), in Canada, found that when mature spruce-lichen forests are burned, major forage lichens usually take 70 to 100 years or more to fully recover. Various studies showed that fire improved habitat for moose, and they achieve highest densities in forest areas opened up to permit browse regeneration. Wild sheep and goats occupy range not generally subject to fire; however, some burned forest land converted to grass has improved sheep range. Following the large Kenai fire, the population of voles was about equal inside and outside the burn during the next year. Numbers of shrews probably were reduced. Fur bearers must move to new areas following fire. The best pelts are from unburned areas. The short-term effect on a beaver colony is destruction of the food supply; but over a long term the food supply is increased. Fire control contributes to the reduction of beaver habitat. Edwards (1954), working in British Columbia, concluded that fire removed marten for decades and found that decline in caribou restricted the use of forested lowlands by wolverine and grizzly bear. Likewise in eastern Canada, fisher and marten were practically absent from extensive, recently logged or burned areas. Spruce grouse brood production was reduced approximately in half the year after a fire, compared with the same area just before the fire. A number of insect species often are prevalent in fire-damaged trees. Changes in plant composition after fire are accompanied by changes in insect fauna.

VIRO, P.J. 1974 'Effects of forest fire on soil.' Fire & Ecosystems, Kozlowski, T.T. and C.E. Ahlgren (eds), Academic, New York: 7-45.

This chapter of the Kozlowski - Ahlgren monograph is based on prescribed burning experiences in Fenno - Scandia. Special detail is given to burning under spruce on wet and dry humus. Topics discussed include physical effects of burning, effects of burning on soil moisture, nutrient status, nitrogen availability, and acidity of Scandinavian soils. Attention is also given to succession pattern in spruce types in that area.

VOGL, R.J. 1967 'Controlled burning for wildlife in Wisconsin.' Tall Timbers Fire Ecol Conf Proc 6: 47-96.

Controlled burning has been initiated to check and push back the encroaching woody vegetation, to recreate openings, and to produce vegetational conditions similar to those present in pre-settlement times. Controlled burning for grouse, deer and ducks began in 1939 and became a common management tool by the 1950s. Burning in Wisconsin has benefited sharp tail and ruffed grouse, prairie chicken, bobwhite, pheasant, turkey, woodcock, Wilson's snipe, sandhill cranes, geese and ducks, various shore birds, song birds, and birds of prey, white-tailed deer, rabbits, muskrat, and others. The burning program for waterfowl habitat creates pioneer sites for establishment of waterfowl foods, more palatable regrowth, reduction of undesirable plants and better access. Burning of sedge meadows and wet marshy areas provides excellent grazing for geese, waterfowl, deer and sandhill cranes. Burning of forested uplands adjacent to marshes increases nesting potential for some waterfowl. Larger bogs are becoming important moose habitat. Burning improves feeding, loafing and nesting habitat by increasing sedges and grasses. The early stages of wetland succession are most desirable. Transitions between types are most productive. Fire is used to reduce pole-sized hardwood stands and stimulate jack pine regeneration for deer. Fires sometimes produce undesirable results. The greatest observed loss to wildlife has been the destruction of early woodcock and mallard nests in early April. Probably most birds re-nest. Early fires also destroy nests of ruffed and prairie grouse; and sometimes kill porcupines, rabbits, mink, muskrats, and mice. Fire should be used infrequently on nesting areas of prairie chickens; also, they may move booming ground locations following fire. Marshes may be converted to sterile weed-beds. The most effective fire management of wetlands is repeated surface fires, preferably while the marsh is still open. As plant succession progresses, wetlands become less productive for wildlife. If a burn is increased beyond a reasonable size, the desired effects for game may be decreased due to poorer edge distribution. Late fall burns may destroy winter cover. In general, the beneficial effects of burning far outweigh and offset any direct wildlife losses.

VOGL, R.J. 1973 'Smokey's midcareer crisis.' Sat Rev Sci 1(2): 23-9.

With the birth of Smokey the Bear came a massive "propaganda" campaign waged by the U.S. Forest Service - to the end that all forest fires are bad. Primitive man used fire as did European man. The abrupt change in attitude toward fire was a reaction, or overreaction, to the destructive burning of the early settlers and pioneers. The campaign has been too effective. Fire actually benefits wildlife, and the plant communities have "learned" to live with regularly-occurring fire. Recently, changes in attitudes have caused the pendulum to start to swing back. Land managers are beginning to view fire as a management tool. Emphasis is being placed on allowing lightning fires to burn in low-risk areas. Still there is a long way to go. People still argue that fire is bad. Professional fire fighters apparently oppose fire use because this will threaten their occupation. It is important to remember that fire is a natural part of the environment.

VOGL, R.J. 1974 'Effects of fire on grasslands.' Fire & Ecosystems. Kozlowski, T.T. and C.E. Ahlgren (eds), Academic, New York: 139-94.

This chapter of the Kozlowski - Ahlgren volume is probably the most thorough review of the effects of fire on grasslands since Daubenmire's famous article. Vogl defines grasslands and reviews the causes of fire in this habitat. He also gives attention to climate, topography, nature of fuel, and fire behaviour. The author reviews physical characteristics of grassland fires, effects of fire on productivity, effects of fire on vegetational composition, grasslands succession, discrepancies in evaluating the effects of fire, changes resulting from the cessation of fires, and current and future uses of fire in grassland management including range management, wildlife management, and natural area management.

VOGL, R.J. 1974 'Ecologically sound management: Modern man's road to survival.' West Wildlands 1(3): 6-10.

Land managers should strive to restore to the ecosystems the influences that have been removed. This might include reintroduction of fire and other natural factors including organisms. Proper management practices must work with nature rather than against it. Sound alternatives must be based on ecological principles. Current management appears to be working against nature. Many environments are out of tune because well meant practices such as fire exclusion have resulted in a disruption of inherent natural processes. "Ecologically-sound management is modern man's road to survival."

WARD, E. 1968 'Fire in relation to waterfowl habitat of the Delta Marshes.' Tall Timbers Fire Ecol Conf Proc 8: 255-67.

Fire is the most effective and economical tool for opening stands of tall reeds to increase area available for duck nesting at Delta marsh. Fires were a normal process and recurring burns performed a vital role in marsh ecology. Uncontrolled burning of nesting habitat during breeding season is destructive. Summer fires damaged roots and humus. Large scale autumn burning may be detrimental through loss of vegetation to catch and hold drifting snow. Spring fires are used before nesting season to remove old growth without affecting regrowth; summer fires are prescribed after nesting. Spring burning creates more edge for nesting and eliminates woody plants. Summer fires create lasting changes in plant composition. Both ducks and muskrats increased following fires. Unless the large marshes of Manitoba, managed for waterfowl, include use of fire they will deteriorate and may even cease to be marshes.

WEAVER, H. 1974 'Effects of fire on temperate forests: Western U.S.' Fire and Ecosystems, Kozlowski, T.T. and C.E. Ahlgren (eds), Academic, New York: 279-319.

This chapter of the Kozlowski - Ahlgren anthology, reviews the effects of fire on Douglas-fir, western larch, lodgepole pine, western white pine, and engleman spruce. Fire provides mineral soil seedbed and reduces competition for Douglas-fir. Western larch in middle age has a thick fire-resistant bark and usually is found as a component of Douglas-fir or other species stands. Lodgepole pine, though thin skinned and easily killed by fire, has serotinous cones. Western white pine prefers mesic sites which have fewer fires, but when they occur they are intense. This species germinates on ash and exposed mineral soil, and like the abundant overhead light provided by an opening in the canopy. Engleman spruce is found in higher elevations, usually in damp sites that don't burn. When they do, however, trembling aspen most often falls and the spruce slowly seed back in.

WEBER, G.M. 1975 'Nutrient budget changes following fire in Arctic plant communities.' From Vegetation Recovery in Arctic Tundra and Forest-Tundra After Fire, ALUR 1974-75. Ottawa: 92-115.

Successional patterns in nitrogen status following fire are summarized. A model for hypothetical nutrient flow within the various components of a plant community is also presented.

WEIN, R.W. 1975 'Vegetation recovery in arctic tundra and forest-tundra after fire.' ALUR 1974-75 (Arctic Land Use Research Program) Ottawa: 1-63.

Fire is instrumental in initiating soil movement in ice-rich, silty soil only if the soil is inherently unstable. If soil flows are present fire may cause more slumping. Burned areas are more susceptible to soil displacement and other disturbance by vehicular traffic during the summer than are unburned areas. Therefore, burned areas should be avoided in summer. In the winter, however, burned areas should be used by traffic where possible, because the additional disturbance does not deepen the active layer as much as does traffic in unburned areas. Fires in tundra and forest-tundra are carried by ground vegetation, which is fine-textured and continuous, rather than by tree crowns. Tundra fires are not uncommon and man is now increasing the frequency of these fires. Revegetation appears to occur quite fast in tundra vegetation, because many underground plant parts regrow during the same or subsequent years. Forested areas may take 50 to 100 years in the Inuvik vicinity before the community appears to be stable. Such areas may remain shrub-dominated for 25 to 50 years. Plants that recover slowly after fire are primarily the cryptogams and the coniferous species. The soil nutrient regime in burned areas is conducive to accelerated growth rates, but as yet we do not know how long this effect persists.

WESTEMEIER, R.L. 1972 'Prescribed burning in grassland management for prairie chickens in Illinois.' Tall Timbers Fire Ecol Conf Proc 12: 317-38.

Prescribed burning in August is proving to be beneficial for rejuvenating over-age grass sod. Prairie chicken nest density has increased. Burn cool season grasses (redtop and timothy) in the warm season, and warm season grasses (prairie grasses) in the cool season.

WHITE, C.F. 1972 'History of fire in North America from fire in the Environment.' Symp on Fire in the Env (Denver, CO, 1972) Proc: 3-23.

The author outlines discernable historical periods in man's attitude towards fire in North America. The period up to the end of the 19th century was a time when individuals and society adjusted to sporadic occurrence of fire from lightning. This was followed by a period of very sophisticated suppression technology and public education campaigns that taught the public that fire was bad. We are now entering a period when man must decide which fire he wants, and which he doesn't. The author reviews fire occurrence in North America in terms of causes and area burns, and concludes by suggesting new directions that fire management will be moving towards.

WILLIAMS, D.E. 1959 Report on experimental control-burn near Blackville, New Brunswick. For Fire Res Institute Files, Ottawa, Ontario, Canada. 11 p.

Williams reports on a prescribed burn in an area of almost pure jackpine, which has been cutover. The area had been clear cut but a scattering of small trees and a few patches of other trees has been left. The author describes preparation of the block for burning and fire behaviour once the prescribed burn was lit. He concluded that it was extremely doubtful that seedbed was improved anywhere on the block, and that in order to improve this effect areas of light burn over a large part of the block could be re-burned under higher danger conditions.

WILTON, W.C. 1963 'Black spruce seedfall immediately following fire.' For Chron 39: 477-8.

The fire occurred in Newfoundland in a black spruce stand on August 25, 1961. The trees were killed. Seeds began to fall immediately after the fire [presumably from cones that were at least 1 year old]. After 60 days, approximately half of the available seed had fallen, amounting to about 1.5 million seeds per acre. At that time seed viability had dropped to about 30%; it had been about 50% just after the fire.

WOLFE, C.W. 1972 'Effects of fire on a sand hill grassland environment.' Tall Timbers Fire Ecol Conf Proc 12: 241-55.

Nebraska sandhills-grassland with planted pines. A large fire occurred on the plantation. White-tailed deer utilized the plantation (80 percent of the time), but few were observed on the burn (5 percent use). Mule deer used the tree plantation and grassland about equally. After the fire, mule deer made about equal use of the burned and unburned areas, deer number on the prairie declined substantially (to about 10 percent). The following year, only about 28 percent of the mule deer were using the burned plantation. Prior to the fire, a large summer population of mourning doves occupied the plantation about 60 percent of the time; after burning, about half the doves utilized the burned area. Use of the plantation, both burned and unburned, dropped substantially the year after the fire. Bobwhite quail were observed in many new areas after the fire.

WOODS, G.T. and R.J. Day 1976 The forests of Quetico Provincial Park.
Ontario Min Nat Res, Fire Ecol Study, Rep 3. 75 p.

The forest stands are even-aged over large areas indicating a fire origin. The species are those favoured by fire: jack pine, white pine, red pine, trembling aspen and white birch. There are few zoning forests because fire has been excluded. Continued exclusion will eliminate the fire species. The stands will contain much more balsam fir and white spruce. Fire is necessary to maintain the natural conditions.

WOODS, G.T. and R.J. Day 1977 A fire history study of Quetico Provincial Park. Ontario Min Nat Res, Fire Ecol Study, Rep 4. 10 p.

Before fire suppression was initiated in 1920, about 10% of the area burned every 10 years with a return interval of about 78 years on a given area. Fire suppression has reduced fire to about one-tenth of its former frequency.

WRIGHT, H.E. 1974 'The Boundary Waters: Wilderness at stake.'
Living Wilderness 38(125): 21-31.

The virgin conifer forests of the BWCA are largely fire dependent. Significant ecological changes have been brought about the the Forest Service's long-standing fire suppression policy. If the area is to be maintained as natural wilderness, the proper course is to restore fire to the system - perhaps starting with prescribed fire.

WRIGHT, H.E. 1974 'Landscape development, forest fires, and wilderness management.' Science 186(4163): 487-95.

Erosion, vegetational development, and fire-dependency are discussed as they relate to landscape development. In some areas, like the Boundary Waters Canoe Area, upland vegetation is controlled by the incidence of fire rather than by topography. Yet, fire-exclusion policies of the wilderness managers may cause profound and unpredictable changes in ecosystem balances. Designated wilderness areas should be managed to reestablish the naturally occurring ecosystems for scientific research and visitor enjoyment. Completed, primeval ecosystems should persist, "whether for the benefit of more or not." Fire-suppression policies in wilderness areas must be changed to accomplish this. It is time for "serious experimentation with natural and prescribed fires ... so that true wilderness areas will be available for future generations of visitors".

WRIGHT, H.E. and M.L. Heinselman 1973 'The ecological role of fire in natural conifer forests of western and northern North America.'
Quat Res 3: 319-28.

This article outlines many ecological effects of fire. Methods of assessing fire history including fire scar studies and pollen analysis are reviewed. Factors that affect the progress of forest fire such as wind, temperature, humidity, precipitation, fuel characteristics, topography, presence of natural fire breaks, are also outlined. The early views of succession as represented by Clements are reviewed and the updated view that the temporary instability and perturbation of fire is a natural factor controlling long range vegetation patterns is offered. The authors argue that recurring fire maintains stability, rather than interrupting it. Fire as an ecosystem process in fire dependent northern coniferous forests is reviewed. Topics covered include fire as an influence on the physical-chemical environment, fire as a regulator of dry-matter accumulation, fire as a controller of plant species and communities, fire as the determinant of wildlife habitat patterns and populations, fire as controller of forest insects, parasites, fungi, etc., and fire as the controller of major ecosystem processes and characteristics. The article concludes with a discussion of management of natural areas in fire-dependent conifer forests.

WRIGHT, E. and W. Bollen 1961 'Microflora of Douglas-fir forest soil.'
Ecology 42: 835-8.

Microflora of a Douglas-fir forest were much reduced immediately after burning and did not approach normal for 14 months.

WRIGHT, J.G. 1932 Forest-fire hazard research as developed and conducted at the Petawawa Forest Experiment Station. Can For Ser For Fire Res Inst Info Rep FF-X-5, Ottawa. 64 p.

This publication defines terms used in Forest Fire Hazard Research, it reviews the influences of weather factors, the details of techniques employed to measure the moisture content of duff layers, fine and heavy fuels.

WRIGHT, J.G. and H.W. Beall 1968 The application of meteorology to forest fire protection. Can For Ser For Fire Res Inst Info Rep FF-X-11, Ottawa. 39 p.

A systematic study of the influence of weather upon forest fires. Topics discussed include factors affecting forest flammability, visibility range, measurement of forest fire danger, weather forecasting, and practical applications of forest fire research in Canada.

The original publication by this title was published in 1945. The revised edition includes an excellent bibliography up to that date, with an addendum updating references to 1967.

YEAGER, C.E. 1950 'Implications of some harvest and habitat factors on pine marten management.' N A Wildlife Conf Trans 15: 319-24.

Where forest stands are destroyed by fire, cover habitat for marten may be lost for many years. Mice and other small mammals, and birds may be abundant on burns. Where burns are bordered by spruce-fir, they undoubtedly provide excellent foraging grounds.

ZONTEK, F. 1966 'Prescribed burning on the St. Marks National Wildlife Refuge.' Tall Timbers Fire Ecol Conf Proc 5: 195-201.

On a southeastern marsh, a refuge for waterfowl, prescribed burning is an important management tool. With early, improved fire protection, a decided decrease in the upland game populations and in waterfowl use of the marshes became apparent. In the winter of 1940-41, 120 acres of marsh were experimentally burned and good use by geese was made of the new growth. Burning has been continued over a 25-year period. Burning is on a 3-year rotation. Geese prefer burned marshes. Burning followed by flooding is used to retard or control pest plants in fresh and brackish-water marshes. After prescribed burning practices were initiated, a notable increase in the turkey population was observed. The deer population appears to be increasing. Prescribed burning's principal accomplishments for wildlife are: 1) reduces wildfire hazard; 2) reduces the dense ground growth of perennial grasses and shrubs, leaving conditions suitable for legumes and annual weeds to become established; 3) removes small understory pines and hardwoods that are of little value.

