

30224/0A

SK
470
TH2
No. 315

**FIRE - CARIBOU RELATIONSHIPS: (VII) FIRE MANAGEMENT
ON WINTER RANGE OF THE BEVERLY HERD: FINAL
CONCLUSIONS AND RECOMMENDATIONS**

DON. C. THOMAS

Technical Report Series No. 315
Prairie & Northern Region 1998
Canadian Wildlife Service

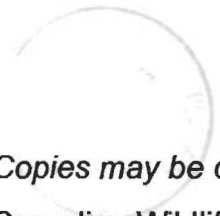
This series may be cited as:

Thomas, D.C. 1998. Fire-caribou relationships: (VII)
Fire management on winter range of the Beverly herd:
final conclusions and recommendations. Tech. Rep. Series
No. 315. Can. Wildl. Serv., Prairie & Northern Reg.,
Edmonton, Alberta. 100pp.



Issued under the authority of the
Minister of Environment
Canadian Wildlife Service

© Minister of Public Works and Government Services Canada 1998
Catalogue No. CW69-5/315E
ISBN 0-662-26505-X
ISSN 0831-6481



Copies may be obtained from:

Canadian Wildlife Service
Prairie & Northern Region
4999-98 Avenue, # 200
Edmonton, Alberta
T6B 2X3

REPORTS IN THIS SERIES

1. Thomas, D.C. and H.P.L. Kiliaan. 1998a. Fire-caribou relationships: (I) Physical characteristics of the Beverly herd, 1980-87. Tech. Rep. Series No. 309. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 178pp.
2. Thomas, D.C. and H.P.L. Kiliaan. 1998b. Fire-caribou relationships: (II) Fecundity and physical condition of the Beverly herd. Tech. Rep. Series No. 310. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 96pp.
3. Thomas, D.C., H.P.L. Kiliaan, and T.W.P. Trottier. 1998. Fire-caribou relationships: (III) Movement patterns of the Beverly herd in relation to burns and snow. Tech. Rep. Series No. 311. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 176pp.
4. Thomas, D.C. and H.P.L. Kiliaan. 1998c. Fire-caribou relationships: (IV) Recovery of habitat after fire on winter range of the Beverly herd. Tech. Rep. Series No. 312. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 115pp.
5. Thomas, D.C. 1998a. Fire-caribou relationships: (V) Winter diet of the Beverly herd in northern Canada, 1980-87. Tech. Rep. Series No. 313. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 41pp.
6. Thomas, D.C. and H.J. Armbruster. 1998. Fire-caribou relationships: (VI) Fire history of winter range of the Beverly herd. Tech. Rep. Series No. 314. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 94pp.
7. Thomas, D.C. 1998b. Fire-caribou relationships: (VII) Fire management on winter range of the Beverly herd: final conclusions and recommendations. Tech. Rep. Series No. 315. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 100pp.
8. Thomas, D.C. 1998c. Fire-caribou relationships: (VIII) Background information. Tech. Rep. Series No. 316. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 104pp.

SUMMARY

This report consists of a series of conclusions and recommendations concerning winter ecology of caribou and effects of fire on winter range of the Beverly herd of barren-ground caribou (*Rangifer tarandus groenlandicus*). The herd summers mostly in the drainage of the Thelon River, Northwest Territories (NWT), and winters from northern Saskatchewan and the northwest corner of Manitoba to the Great Slave Lake region of NWT. A study in 1980 through 1988 focused on caribou diet and forage digestibilities, on fat reserves and physical characteristics in early and late winter, on winter movements and distribution in relation to burns, snow characteristics, and regeneration of lichens in forests after fire. Performance and behavior of caribou, as measured by fat reserves and responses to burns and snow, was considered to be the best indicator of the state of winter range. Main conclusions were that lichens comprised the main forage of the herd in winter; that range was not limiting current herd numbers; that fat reserves remained about constant from December to March, while the herd was on winter range; that fire had markedly influenced winter distribution of the herd because lichens preferred by caribou were absent or sparse in young forests; that caribou were not reluctant to travel through burns of various sizes and ages; that snow affected use of habitat on regional and local scales; that the herd used areas of greater snowfall early in winter before snow restricted forage availability; that 41-60 years were necessary after fire to recover adequate cover and biomass of lichen species generally favored by caribou; and that highest use was made of forests 151-250 years post fire. Zones of priority for fire suppression were mapped based on current caribou management plans. A change in caribou management strategies to more-intensive management, for example to optimum sustained yield, would necessitate a change in recommendations for fire management and herd monitoring.

RÉSUMÉ

Nous présentons une série de conclusions et de recommandations au sujet de l'écologie hivernale du troupeau de Beverly de caribous de la toundra (*Rangifer tarandus groenlandicus*). Le troupeau estive surtout dans le bassin du fleuve Thelon et hiverne dans la région qui part du nord de la Saskatchewan et de l'extrémité nord-ouest du Manitoba et s'étend jusqu'à la région du Grand lac des Esclaves, dans les Territoires du Nord-Ouest. L'étude effectuée de 1980 à 1988 a porté sur le régime alimentaire des caribous et la digestibilité des aliments, les réserves de graisse et l'état physiologique au début et à la fin de l'hiver, les déplacements hivernaux et la répartition en fonction des caractéristiques de la neige et des brûlis et la régénération des lichens dans les forêts détruites par le feu. Le rendement et le comportement des caribous, évalués d'après les réserves de graisse et les comportements en réponse aux caractéristiques de la neige et des brûlis, ont été considérés comme étant les meilleurs indicateurs de l'état des aires d'hivernage. L'étude a permis de tirer les conclusions suivantes : les lichens constituent le principal aliment du troupeau en hiver; le nombre de caribous n'a pas été limité par l'aire d'hivernage; les réserves de graisse sont restées relativement constantes de décembre à mars pendant que le troupeau se trouvait dans l'aire d'hivernage; les incendies ont eu un effet marqué sur la distribution hivernale du troupeau à cause de la rareté des lichens préférés des caribous dans les jeunes forêts; les caribous n'hésitaient pas à traverser les brûlis de taille et d'âge variables; la neige avait un impact sur l'utilisation de l'habitat aux échelles régionale et locale; le troupeau fréquentait les régions où la neige était plus abondante au début de l'hiver, avant que celle-ci ne réduise la disponibilité de la nourriture; une période de 41 à 60 ans après l'incendie était nécessaire pour que la couverture et la biomasse des espèces

de lichens préférées des caribous soient reconstituées; les caribous utilisaient le plus intensivement les forêts régénérées de 151 à 250 ans. Par ailleurs, des zones de priorité de lutte contre les incendies ont été établies en fonction du risque d'incendie et de la répartition des caribous, à partir des plans de gestion du caribou en vigueur. Une modification des stratégies de gestion du caribou, dans le sens d'un rendement optimal durable par exemple, nécessiterait également une modification des recommandations relatives à la prévention des incendies et à la surveillance du troupeau.

TABLE OF CONTENTS

Page

REPORTS IN THIS SERIES	i
SUMMARY	ii
RÉSUMÉ	iii
LIST OF CONCLUSIONS	v
LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF APPENDICES	xiv
ACKNOWLEDGEMENTS	xiv
INTRODUCTION	1
CONCLUSIONS 1-39	8-90
LITERATURE CITED	91
APPENDICES	95

LIST OF CONCLUSIONS (Some shortened)

Page

Conclusion 1. The quantity and quality of usable winter range was adequate for the Beverly herd in the 1980s	8
Conclusion 2. Burns in the past 50 years have influenced winter distribution of the Beverly herd to a considerable extent	17
Conclusion 3. Caribou were not reluctant to pass through spot (to 1 ha), tiny (1.1-10 ha), very small (11-100 ha), small (101-1000 ha), or medium-sized (1001-10 000 ha) burns of all ages; however, sometimes they stopped or changed direction after entering large (10 001-100 000 ha) or very large (100 001-1 000 000 ha) burns (Table 3) seemingly because of lack of forage in them	24
Conclusion 4. Maximum use by caribou was of forests 151-250 years old	27
Conclusion 5. Terrestrial lichens are the main food source for the Beverly herd throughout winter	30

LIST OF CONCLUSIONS (continued)	Page
Conclusion 6. Recovery of lichen species favored by caribou does not occur until 41-60 years after fire and recovery of highly-productive lichen mats, suitable for extensive grazing by caribou, does not occur until 61-80 years after fire	32
Conclusion 7. Biomass of lichens preferred by caribou remained about constant from the 61-80 year class to the oldest forests in age class 251-300 years (abbreviated)	35
Conclusion 8. There is a time lag between re-establishment after fire of lichen species preferred by caribou and their extensive use by caribou	37
Conclusion 9. Fire over the past 50 years and in particular the historically high rate since 1970 has reduced, to a considerable degree, the capacity of historic winter range to support caribou	38
Conclusion 10. Overuse of winter range by caribou will be difficult to assess by evaluation of caribou forages. Range condition is best monitored by periodic assessment of nutritional status of a herd in conjunction with snow conditions	39
Conclusion 11. Snow appears to influence movements and distribution of caribou in at least three ways: (1) by use of deep snow zones early in winter before forage accessibility is affected, (2) by avoidance of snow deeper than 60-70 cm, and (3) avoidance of areas with hard snow or icy layers on lichen mats	41
Conclusion 12. The Beverly herd usually uses eastern range early in winter and western range later, possibly an adaptation to greater average snowfall in the east (Table 6)	43
Conclusion 13. An increase in herd numbers will not necessarily result in expansion of forested winter range occupied by the Beverly herd because some areas formerly occupied by the herd contain little suitable range as a result of fire	45
Conclusion 14. Lichens are more important to the Beverly herd in forested habitats than indicated by composition of plants in rumens and feces	46

LIST OF CONCLUSIONS (continued)

Page

Conclusion 15. Some terrestrial lichen species are preferred over others by caribou and certain lichen growth forms permit easier foraging under snow than others. Any conclusions about optimum ages of forests for caribou winter range must consider preference, palatability, nutritional, and accessibility factors 48

Conclusion 16. Tree lichens proportionally are insignificant in diets of caribou in most winters but they become an emergency food supply in winters of exceptionally deep snow or when ice layers or hard snow on lichen mats severely restrict access to terrestrial lichens 50

Conclusion 17. The late-winter period (February-April) is the most critical time for caribou on forested winter range because forage accessibility decreases and travel becomes more difficult as winter progresses 52

Conclusion 18. The optimum burn rate to produce range with highest carrying capacity for caribou probably ranges between 0.25% and 0.5% annually, considering a need for diversity caused by fire, and proportion of land that is productive for caribou at various burn rates 53

Conclusion 19. Assuming fire management is necessary, there should be varying geographic goals for percentage of range that is maintained at ages suitable for grazing by caribou. The ecoregions and ecodistricts of Bradley et al. (1982) are probably the most appropriate management units 54

Conclusion 20. Fire management decisions cannot be made in isolation; they must be matched to management plans for the Beverly and other caribou herds, management plans for other wildlife species, and, preferably, integrated resource management plans. There must be an ecosystem approach rather than a single-species approach to caribou winter ranges 55

Conclusion 21. If fire management is deemed necessary to satisfy caribou management goals, there is need for priorities on where to control fires and priorities regarding intensity of control measures 59

Conclusion 22. To ensure future conservation of the Beverly herd, a core area of the herd's winter distribution should be managed such that at least 50% of that area is in successional stages older than 50 years (abbreviated) 60

Conclusion 23. Retraction in the south and west of the maximum, usual, and core winter range dictates that fire management will be necessary in those areas if caribou managers want to restore caribou to their former range 62

LIST OF CONCLUSIONS (continued)

Page

- Conclusion 24.** The Athabasca Plain, a Precambrian sandstone area of northern Saskatchewan, should be viewed as potentially excellent caribou winter range but undependable because of its short fire return interval 64
- Conclusion 25.** Slave River Lowlands south and west of the Taiga Shield (Precambrian Shield) and a Transitional Zone (Fig. 20) along the periphery of the Shield should be managed for moose, bison, and furbearers rather than for caribou 66
- Conclusion 26.** Until more information on fire-caribou relationships is obtained, fires should not be controlled in regions where less than 12.5% of winter range has burned in the last 50 years, that is, the average annual fire rate is below 0.25% annually 68
- Conclusion 27.** The cause of high and very high fire rates has more to do with size of burns than frequency of burns. Burns tend to be largest in regions with high burn rates and smallest in regions with the low burn rates. Control of fire will be difficult when burns are large 70
- Conclusion 28.** Use of forested winter ranges in the NWT appears to be influenced directly or indirectly by surface materials in that caribou seem to prefer regions covered with till or alluvium over regions with exposed bedrock 72
- Conclusion 29.** Barren-ground caribou is basically a tundra species and when it ranges into forests, it prefers open spaces and open forests 74
- Conclusion 30.** Forest stands younger than 50 years are (1) little used by caribou at any season and especially in late winter, and (2) their ignition index and flammability are low compared with older stands 75
- Conclusion 31.** Fires should be more easily controlled in stands 51-100 years old than in older ones. Forests that are now 51-100 years old will be valuable to caribou in the next 51-100 years 77
- Conclusion 32.** Large tracts of forests older than 50 years in regions with high burn rates may become important winter foraging areas in the next few years and their continuance as potential winter range provides for the maximum winter distribution of caribou under the present burn mosaic. Such areas tend to provide corridors to pockets of productive winter range and they will be "stepping stones" to regions that will return to productive status in the next 10-50 years 79

LIST OF CONCLUSIONS (continued)

Page

- Conclusion 33.** Collation of conclusions and recommendations 21 to 32 is a basis for setting priorities on where fires should be controlled on winter range of the Beverly herd in the NWT, provided that future caribou managers deem it is necessary 81
- Conclusion 34.** More data are needed on fire behavior in the primary study region, such as fire susceptibility and flammability of stands of various ages and cover types, ignition points, lightning frequencies, fire intensities and useful indices of intensities, burn directions, and spread rates in various habitat types and under various weather conditions, burn completeness, causes of extinguishment, and long-term effects of suppressing fires 85
- Conclusion 35.** There is need for detailed studies of plant ecology in the study area to learn more about relationships among fires, habitat type, terrain, weather, and other factors and their effects on plant succession, cover, productivity, and biomass. Emphasis should be placed on ecology of *Cladina mitis* 86
- Conclusion 36.** There is a need to annually map all burns over 1000 ha (1 km²) on winter range (historical maximum in Fig. 9) and a further need for more data on each fire including ignition point, direction of spread, proportion not burned, and their cover types and topographic class (upland or lowland) 87
- Conclusion 37.** This study is concerned with fire-caribou relationships. However, any fire management plan should look at effects of fire on a multi-species basis and there is little information on how other species including moose and furbearers respond to various successional stages and mosaics of stands in various successional stages in the study area 88
- Conclusion 38.** Fat reserves, body weights, and skeletal size of the Beverly herd should be monitored periodically in order to assess range quality. Health of the herd in terms of parasites and diseases should be monitored every few years through special organized sampling 89
- Conclusion 39.** If the Beverly herd is to be managed or intensively managed at a high sustainable level, there is need to improve data collection techniques through use of conventional and satellite collars and other modern technology 90

LIST OF TABLES

	Page
Table 1. Relationships among average annual burn rates, fire return interval, and productive caribou range assuming (A) a negative exponential distribution, and (B) all forests burn at the fire interval (rotation year)	20
Table 2. Percentage of landscape units estimated to have burned since about 1940 based mostly on 1983 aerial transect data and on mapped burns verified by use of satellite images	23
Table 3. Burn size classes adopted for this study	24
Table 4. A selection of major burns crossed by caribou in the Beverly herd between 1980 and 1988	25
Table 5. Plant fragment relative densities (%) in pooled rumen and fecal samples from three habitat types on winter range of the Beverly herd of caribou, 1982 through 1987	31
Table 6. Average depths (cm) of snow in the study area in March each year from 1980 through 1988	43
Table 7. Apparent digestibilities (dry matter disappearance) of major plant species eaten by caribou as estimated in several <i>in vitro</i> trials using test tubes and flasks, with and without urea (U)	47
Table 8. Order of preference of caribou for lichen species in tests conducted in Quebec and Alaska	49
Table 9. Average ordinal rating of arboreal lichen abundance in forests in 13 age classes at 176 sites on winter range of the Beverly herd of caribou	51

LIST OF FIGURES

	Page
Figure 1. The primary study area (60°N to 64°N, 104°W to 112°W), additional areas surveyed (hatched), and ecozones (Environment Canada 1986)	4
Figure 2. Comparative overwinter changes in weight of male and female caribou collected from the Kaminuriak (Dauphiné 1976) and Beverly herds (this study)	9
Figure 3. Overwinter changes in back fat depths (solid lines) of female caribou >2 years old and males 2.5-5 years old, sampled from the Beverly herd each December (1982-86) and March (1980-87) (two samples in 1984)	10
Figure 4. Overwinter changes in kidney fat weights (solid line) of female and male caribou >3 years old, sampled in December (1982-86) and March (1980-87) from the Beverly herd (two samples in March 1984)	11
Figure 5. Body weights of four age classes of male (M) and female (F) caribou sampled from the Beverly herd each winter from 1979-80 through 1986-87 (two samples in winter 1983-84)	13
Figure 6. Back fat depths in three sex/age classes of male (M) and female (F) caribou sampled from the Beverly herd each winter from 1979-80 through 1986-87	14
Figure 7. Relationship between body weight in 5 kg intervals and pregnancy rate of female caribou >1 year old in pooled samples from 1980 through 1987 (sample size beside each point)	15
Figure 8. Relationship between depth of back fat and pregnancy rate of caribou in pooled samples from December and March, 1980 through 1987	16
Figure 9. Maximum western and southern distribution of the Beverly herd at various periods according to several sources	18
Figure 10. Southern and western distributional limits of the Beverly herd in winters 1979-80 through 1986-87 in relation to locations of burns <40 years old	19

LIST OF FIGURES (continued)

Page

Figure 11. Percentage of landscape, lakes deleted, that burned between about 1944 and 1983 based on data from aerial transects in 1:250 000 scale map units	21
Figure 12. Proportions of forests younger than 40 years in 1984, based on aerial transect data, with water deleted, in ecodistricts in High Boreal (HB), Low Subarctic (LS), and High Subarctic (HS) Ecoregions (Bradley et al. 1982)	22
Figure 13. Densities of caribou pellet groups at 50-year intervals after fire at two locations on winter range of the Beverly herd	28
Figure 14. Biomass of all lichens (total), "weighted lichens", (all lichens with <i>Cladonia uncialis</i> and "other <i>Cladonia</i> spp." reduced by 50% and <i>Stereocaulon</i> spp. reduced by 75%) and "caribou lichens" (<i>Cladina mitis</i> , <i>C. stellaris</i> , <i>C. rangiferina</i> , and <i>Cetraria nivalis</i>) on upland sites at 20-year intervals (to 100 years) and 50-year intervals after fire on winter range of the Beverly herd of caribou	33
Figure 15. Biomass of <i>Stereocaulon</i> spp. (S), <i>Cladonia</i> spp. (C), <i>Cladina mitis</i> (Cm), <i>Cetraria nivalis</i> (Cn), <i>Cladina rangiferina</i> (Cr), <i>Cladonia uncialis</i> (Cu), and <i>Peltigera</i> spp. (P) on upland sites at 20-year intervals (to 100 years) and 50-year intervals after fire on winter range of the Beverly herd	34
Figure 16. Deviations of water equivalents (mm) from sample means for all other winters in snow cores for individual winters, 1965-66 through 1992-93. Data from Water Survey of Canada for 11 stations on winter range of the Beverly herd of caribou	42
Figure 17. Densities of moose pellet groups at 20-year (to 100 years) and 50-year intervals in taiga west and east of 107°W.....	56
Figure 18. Categories of use by caribou on forested winter range of the Beverly herd since about 1940. Only core range in Saskatchewan was used from 1982-83 to 1986-87	61

LIST OF FIGURES (continued)

Page

Figure 19. Location of Tundra, Transitional Forest, Boreal Forest (after Rowe 1972), and the Athabasca Plain in relation to distributional limits of the Beverly herd, 1982-87	65
Figure 20. Slave River Lowlands and a transitional zone between lowlands and Taiga Shield where fire management should not focus on caribou (abbreviated).....	67
Figure 21. Regions of no, very low (cross hatched), and low (hatched) priority for fire suppression based on multiple factors listed in recommendations 1-32	69
Figure 22. Subjective evaluation of average, annual burn rate categories based on burn maps and forest age distributions: low = <0.5%, moderate = 0.5-1%, high = 1-5%, and very high = >5%	71
Figure 23. Regions of winter range of the Beverly herd where till is thick, thin, discontinuous, or confined to lowlands between exposed bedrock	73
Figure 24. Areas of winter range of the Beverly herd that were burned between about 1940 and 1987	76
Figure 25. Large areas of winter range of the Beverly herd in the NWT that are known or estimated to be of medium age (51-100 years)	78
Figure 26. Forests not burned in the last 50 years (hatched), with the exception of recent burns (cross hatched) in a zone of moderate or high burn rates (Fig. 22)	80
Figure 27. Priority ratings (# 1 highest) for fire suppression in the next few years with the present burn pattern based on conclusions 1-32	82
Figure 28. Generalized high priority areas for fire suppression if it is deemed necessary by caribou managers in future. Enclosed within the area are low priority areas (Fig. 27)	83
Figure 29. Priorities for fire management in ecoregions and ecodistricts (Bradley et al. 1982) based on relative use by caribou in winter	84

LIST OF APPENDICES

Page

Appendix 1. Objectives from "Winter Range Relationships of the Beverly herd: a Research Proposal", May 1982 (Revised January 1983)	95
Appendix 2. Reports and publications arising from a study of Beverly herd caribou and their winter range, 1980 through 1987	97

ACKNOWLEDGEMENTS

I am grateful for long-term financial support provided by the Canadian Wildlife Service (CWS) and Indian and Northern Affairs Canada (INAC). The Northwest Territories (NWT) Department of Renewable Resources provided financial support in 1980, use of their laboratory facilities in Fort Smith, and access to burn maps, NOOHA, and LANDSAT imagery. The NWT Remote Sensing Centre and Helmut Epp permitted use of their LANDSAT imagery and analysis equipment. The Canadian Forest Centre and Walt Moore supplied burn maps based on LANDSAT interpretation, images, and analysis equipment. Loans of equipment also were obtained from INAC and Ernie Kuyt of CWS. Collections of caribou would not have occurred without excellent support of the Fort Smith Hunter's and Trapper's Association (HTA). Jim Schaefer of that group was instrumental in getting the project started and Ken Hudson continued that support. Help in field camps was provided by numerous members of the Fort Smith HTA. I particularly thank several members who were on several collections and helped collect the necessary samples: Jim, Curtis, and Ronnie Schaefer, Ken Hudson, Noel Abraham, and Gabe Sept. Others who participated on one or two collections included Raymond Beaver, Darcy Grier, Henry Beaver, Joe McGillis, Philip Cheezie, Ernie Burke, Tim Trottier, Joe Martin, Corm Gates, Alex Hall, Doug Heard, Red Noyes, Fred McDonald, Chan Dong, Billy

Schaefer, Joe King Beaulieu, Ernie Loutitt, John Tourangeau, Karl Hoffman, and Randall Glaholt. Special thanks go to Earl Evans, an extraordinary marksman and hunter, who participated in all collections and organized and supervised camp logistics. Eric Broughton collected blood from caribou from 1982 to 1984 and examined organs for parasites. Jack Van Camp, Murray Lankester, Bob Gainer and members of Thebacha (Arctic) College provided information on caribou they sampled in March of 1982, 1983, 1985, and 1987. Field support of a demanding nature under rigorous conditions was obtained for summer work from many individuals including Trinity Macdonald (four summers), Miranda Haupt (two summers), Lisa Munroe, Cornel Yarmoloy, Lloyd Greer, Marie Nietfield, Robert Tordiff, Tom Macdonald, Rick Camire, Gerry Aiudi, Chan Dong, Gord Peterson, and Kim Seto. Laboratory support was provided by Trinity Macdonald, Anne Weerstra, Marie Nietfeld, and Joe McGillis. Billy Bourque of Loon Air Ltd., Fort Smith, and Merlyn Carter of Carter Air Services, Hay River, provided superior aircraft support for the caribou collections. Sam Barry provided expertise on computer entry of data and statistical testing. Project co-ordination with Indian and Northern Affairs Canada was provided by Dr. Kaye MacInnes of the Yellowknife office and Rick Lanoville in Fort Smith. Henk Kiliaan participated in all field work, did most of the laboratory work, and conducted some statistical tests. Improvements to supporting data reports were made by Frank Miller, Doug Heard, Mark Williams, Tim Trottier, Harry Armbruster, Kevin Eberhart, and R. Edwards. I thank my wife, Alice, for processing most of the words in this report.

INTRODUCTION

Concern for effects of forest fires on winter range of barren-ground caribou (*Rangifer tarandus groenlandicus*) was expressed over 50 years ago by Clarke (1940) and others cited by him. Banfield (1954), after the first major study of caribou in Canada, described large burned areas in the Northwest Territories (NWT), Saskatchewan, and Manitoba. This concern led to studies of caribou winter diet (Scotter 1967a) and recovery of caribou forages after fire in northern Saskatchewan (Scotter 1964), and northwestern Manitoba (Scotter 1965). Scotter's main conclusions (Scotter 1967a, 1967b, 1971a, 1971b) were that recovery of lichens, a preferred food of caribou, took about 40 years after fire; the highest use by caribou was in forests older than 60 years; caribou tended to stay out of areas recently burned; and fire could be one of the factors controlling herd size.

Reports arising from a major study in 1957 through 1962 of what is now known as the Beverly herd also expressed concern about effects of burns on the herd (Pruitt 1959; Kelsall 1960, 1968). As a result, fire control was extended to what was termed the "caribou range" for an experimental period of 6 years beginning in 1967. Bases were constructed at Porter and Sandy lakes and operated throughout the fire season. Fires were uncommon in the experimental period and fire suppression on caribou winter range ceased in 1972.

Further fire suppression was not justified without strong proof that fires were detrimental to caribou. The Canadian Wildlife Service (CWS) and the Department of Indian and Northern Affairs (DIAND) commissioned two further studies of caribou winter range in the 1970s. The first study led to a conclusion that interfering with natural processes of range renewal through fire suppression could not be justified

(Johnson and Rowe 1973, 1975; Johnson 1979, 1981a).

The second academic study examined lichen ecology in only one habitat type, the tops of drumlinoid ridges at Carleton Lake, located between Abitau and Dunvegan lakes (Makinow and Kershaw 1976, Kershaw and Rouse 1971, 1976).

Range studies were part of a major study of the Kaminuriak herd from 1966 through 1968 (Parker 1972) and a study in northern Manitoba and Saskatchewan was extended to 1973. Main conclusions were that lichens only made up about 50% of diet; that all forests older than about 50 years were equally suitable for caribou range; and that fires were not a problem to caribou in the Kaminuriak and Beverly herds and probably were beneficial by creating diversity (Miller 1976a, 1976b, 1980).

The conflicting data and interpretations of data on effects of fire on caribou winter range led CWS to propose additional studies in 1978. The 1979 fire season was the worst on record to the east and northeast of Fort Smith. The Fort Smith HTA under President James Schaefer requested that fires be fought and demanded a review of fire policy and fire suppression methods. That request was answered by appointment by the DIAND Minister of a three member review panel headed by P.J. Murphy. Their report (Murphy et al. 1980) suggested that more work was needed on effects of fire on caribou winter range. Specific information was needed on effects of burns on caribou distributions and movements, the natural burn rate, and whether it should be managed through fire suppression.

Preliminary work was done on caribou diet and forage digestibilities in March 1980 and 1981 (Thomas and Kroeger 1981, Thomas et al. 1984). Those studies were necessary to determine which forage species should receive most attention in subsequent range studies.

Our primary study began in March 1982 when funds came available for sampling caribou and establishing fuel caches for the duration of the study. Four years of intensive study were followed by a gradual phasing out in 1986 and 1987. The primary study area was 60°N to the limit of trees and from 104°W to 112°W (Fig. 1). That area, except for the Slave River Lowlands, was termed the "caribou range" by fire management people in Fort Smith. In practice it was necessary to expand surveys east to 102°W, west to 110°W (north of Great Slave Lake), and to the tundra.

Major questions and means of addressing them were as follows:

1. Was winter range adequate in quantity and quality for the caribou population? An answer was sought by measuring changes, from November/December to March, in fat reserves of caribou and comparing results with other studies where fire was not a factor.
2. Was general distribution of the herd influenced by burn patterns? Monthly to bimonthly surveys were conducted the first three winters to record distribution of the herd in relation to burns, and all other data were reviewed.
3. Were caribou movements (migrations or range shifts) influenced by burns? An answer was sought in the manner in which caribou reacted to burns of various sizes, shapes, and ages as recorded in snow by their trails as well as observations of caribou from airplanes and ground positions.
4. What foods did caribou eat throughout winter and of what relative value were they to caribou? Craters of caribou and feeding sites were examined throughout several winters and rumens and feces of caribou were analyzed for composition of plant fragments. Major forages on winter range were evaluated for percent digestibility.

Figure 1.

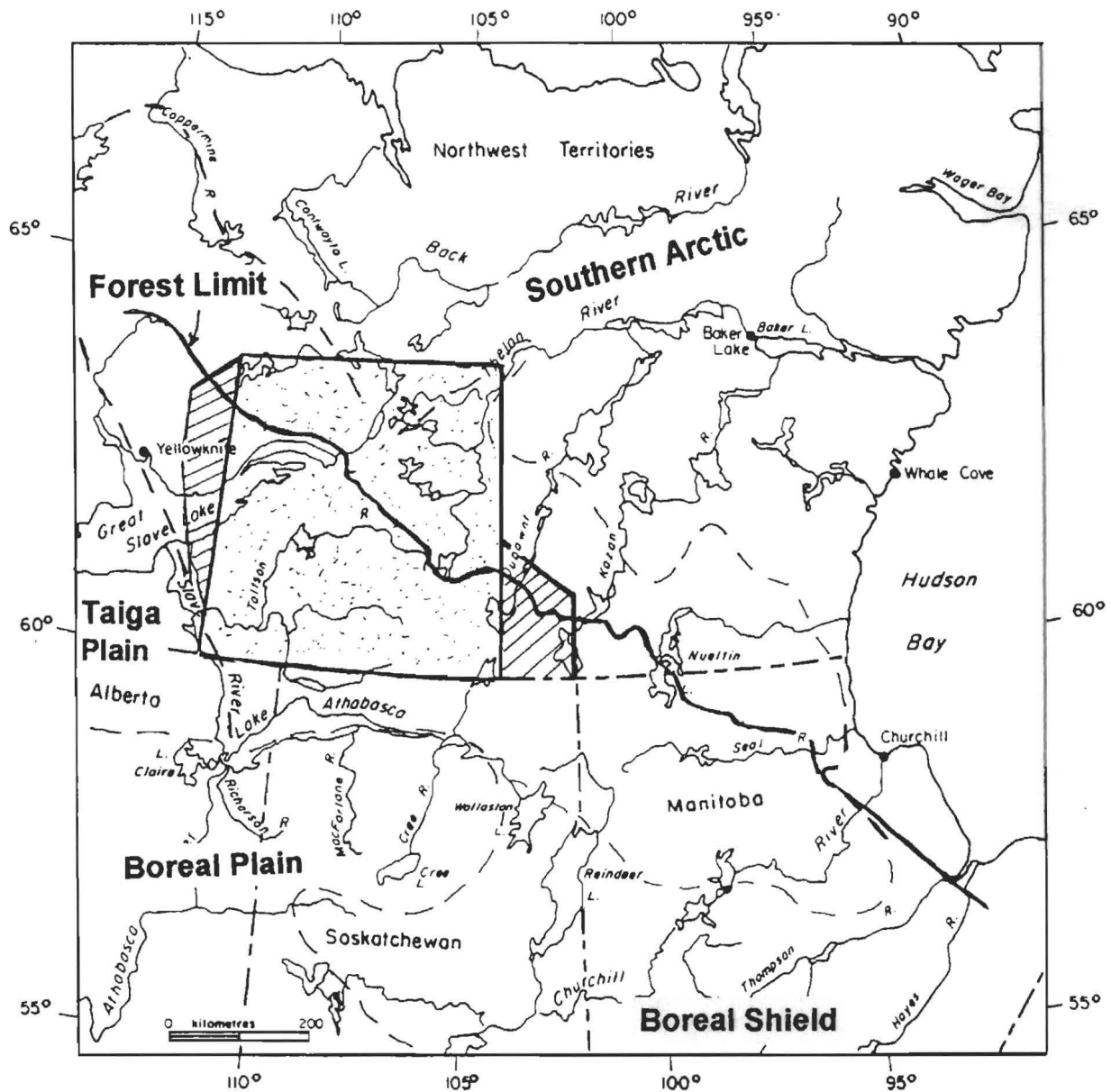


Figure 1. The primary study area (60°N to 64°N, 104°W to 112°W) additional areas surveyed (hatched), and ecozones (Environment Canada 1986).

5. What were recovery times of caribou forages after fire? Cover and biomass of caribou forages was measured in forests of all ages after fire with emphasis on paired comparisons of two ages across fire edges.

6. What was relative use by caribou of forests of various ages and characteristics? Indices of past use were obtained by measuring pellet-group densities in forests of all ages.

Those questions and potential solutions were part of three major study phases: over-winter changes in fat reserves, effect of burns on movements and distribution, and rates of recovery of caribou forages after fire. These are a condensation of original objectives established in 1987 and revised in 1982 (**App. 1**).

Conclusions in this report are based to a large extent on data in seven completion reports containing summarized data (**App. 2**), on further analysis of data for publication, and some additional information in 10 progress reports on field studies from 1982 through 1987 (**App. 2**). Conclusions also draw on results of previous studies in Canada and elsewhere and discussions with local residents of caribou range.

There should be no expectation that this study provides all answers concerning fire management on winter range of the Beverly herd of caribou. For example, relationships between age of forest and standing crop of lichens were only measured at about 100 locations. That relationship will vary with climate, topography, surface materials, tree species and densities, and other factors. No data were obtained on productivity (annual growth) of lichens.

Information was not obtained on forage biomass in lowland regions characterized by hummocks, abundant mosses, and spotty lichen cover. The selection of lichen species by caribou can only be estimated from field observations of use patterns and sketchy data from other studies. Indices of past use by caribou of forests of various "ages" after fire were incidental to vegetation studies and could be improved with sampling designs specific for such surveys. In general, most of the conclusions and recommendations could apply to other herds of barren-ground caribou in north-central Canada whose winter ranges include forested regions.

Somewhat different conclusions would have been drawn had the analysis been done 10 or 15 years earlier. In such an ever-changing system, future events are influenced by largely unpredictable weather patterns and herd dynamics. There can be, therefore, no accurate prediction of how certain fire and caribou management practices will shape winter range of the Beverly herd.

The conclusions and recommendations refer almost exclusively to the range in terms of caribou habitat, although any fire management policy must also consider other wildlife species and socio-economic values.

There is an underlying, unrealistic assumption that fires can be managed: that is, that most fires can be controlled in most years, if a reasonable level of attack is mounted. There is almost universal agreement that control will be of limited effectiveness in years such as 1979 in the taiga zone northeast of Fort Smith. Such severe-fire years may only occur every 50-100 years but they have great influence on fire regimes and patterns. Most of an area burns in 3 or 4 years out of 20. Can suppression be effective in those years?

There is also an assumption that available forage on winter range will limit this

caribou population if caribou numbers were allowed to increase. Alternatively, some specific food item or dietary element may become a limiting factor on winter range. There is a possibility that spring, summer, or autumn range may become limiting before available winter range slows or stops population growth. Predation might control caribou numbers if alternate prey were readily available. There is always a possibility that some epidemic disease will limit population growth. Usually a number of factors such as hunting, predation, and weather-related factors combine to keep caribou numbers well below carrying capacity of range. A conclusion is that the ecology of caribou in northern Canada is still poorly understood because there never has been a comprehensive study that examined all factors affecting caribou over a period of years.

There follows a series of conclusions accompanied by brief supporting data, explanatory remarks, and recommendations. Their initial sequence is related to major phases and objectives of the study. Each set is limited to one or two pages for brevity and ease of review.

Conclusions 1 through 17 provide background information on winter ecology of caribou with a focus on effects of burns. Conclusions and recommendations 18 through 33 consider priorities for fire management and numbers 34 through 39 consider information needs.

Conclusion 1. The quantity and quality of usable winter range was adequate for the Beverly herd in the 1980s.

Data. If winter range was inadequate in quantity or quality under normal snow conditions, we expect a greater than normal deterioration in energy reserves in most age classes of caribou from November to March. The literature (e.g. Dauphiné 1976) suggests that some deterioration in fat and muscle is normal on forested winter range with a low burn rate. Body weight and fat reserves of adult females and juveniles of both sexes in the Beverly herd remained about constant from November-December to March in most winters 1982-83 through 1986-87 (**Fig. 2-4**). There was an increase in amount of internal fat in some winters. This compares favorably with data for the Kaminuriak herd from November to March 1967-68 (Dauphiné 1976) where fat reserves of those classes of caribou generally decreased. The average annual burn rate in northern Manitoba from 1956 to 1967 was 0.15% (Miller 1976a, Manitoba Wildlife Branch 1983), compared with 1% on the winter range of the Beverly herd in the NWT for the period 1966 to 1982 (Ferguson 1983) and 1.1% for the period 1973 to 1982 for portions of winter range in Saskatchewan (MacAuley 1983). Those data include water areas and must be increased by about 20% ($\times 1.25$) to express the rate in terms of land surface of the Taiga Shield (Environment Canada 1986).

Poor quality winter range should result in high mortality of calves because they have low fat reserves. Such was not the case. Recruitment (production of calves to 1 year of age) was relatively high in the 1980s (Heard pers. comm.).

Poor winter range should reduce pregnancy rates. Pregnancy rates were comparable to those of other caribou herds (reviewed by Dauphiné 1976 and Thomas and Barry 1990a).

Figure 2.

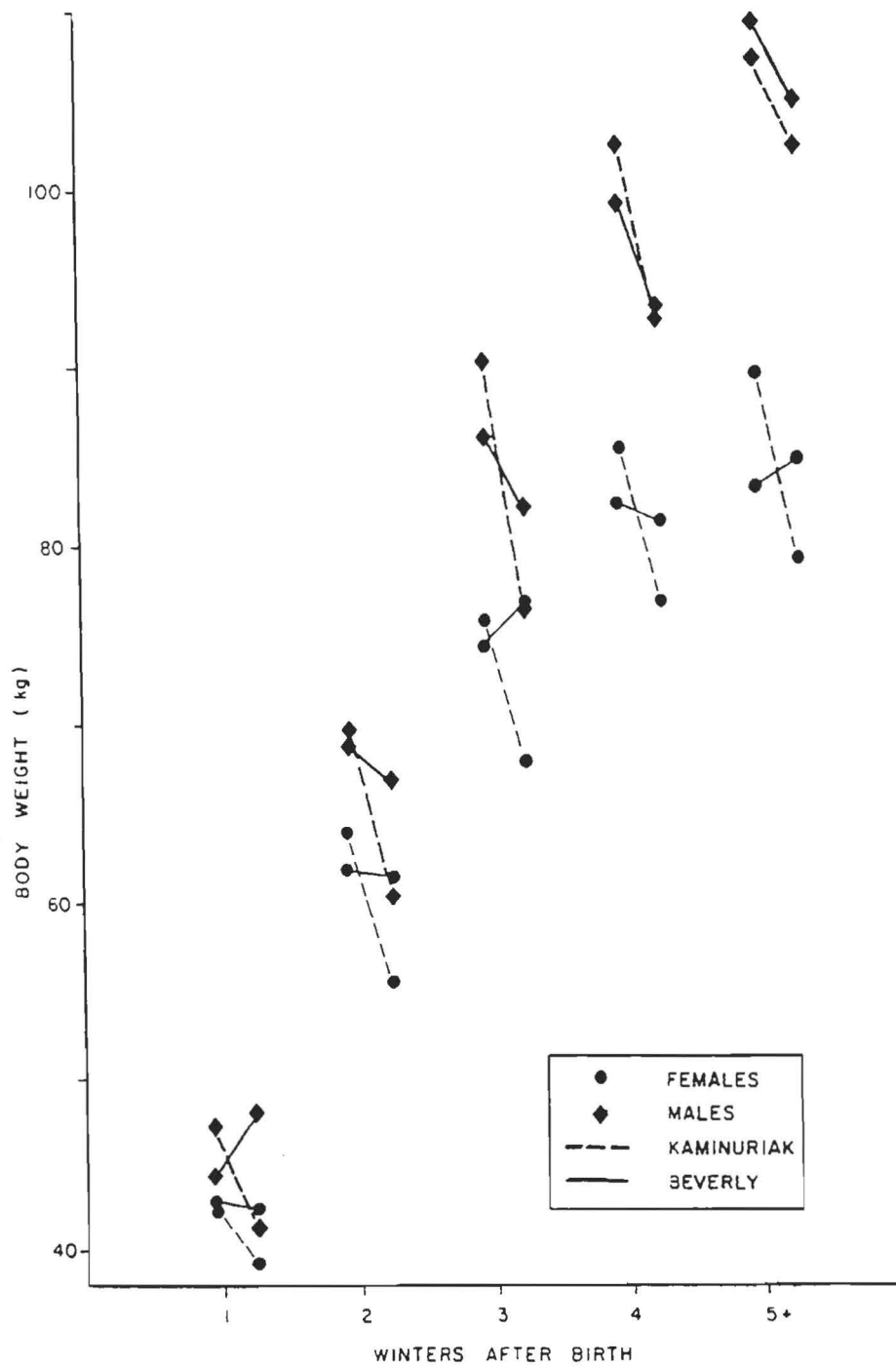


Figure 2. Comparative overwinter changes in weight of male and female caribou collected from the Kaminuriak (Dauphiné 1976) and Beverly herds (this study).

Figure 3.

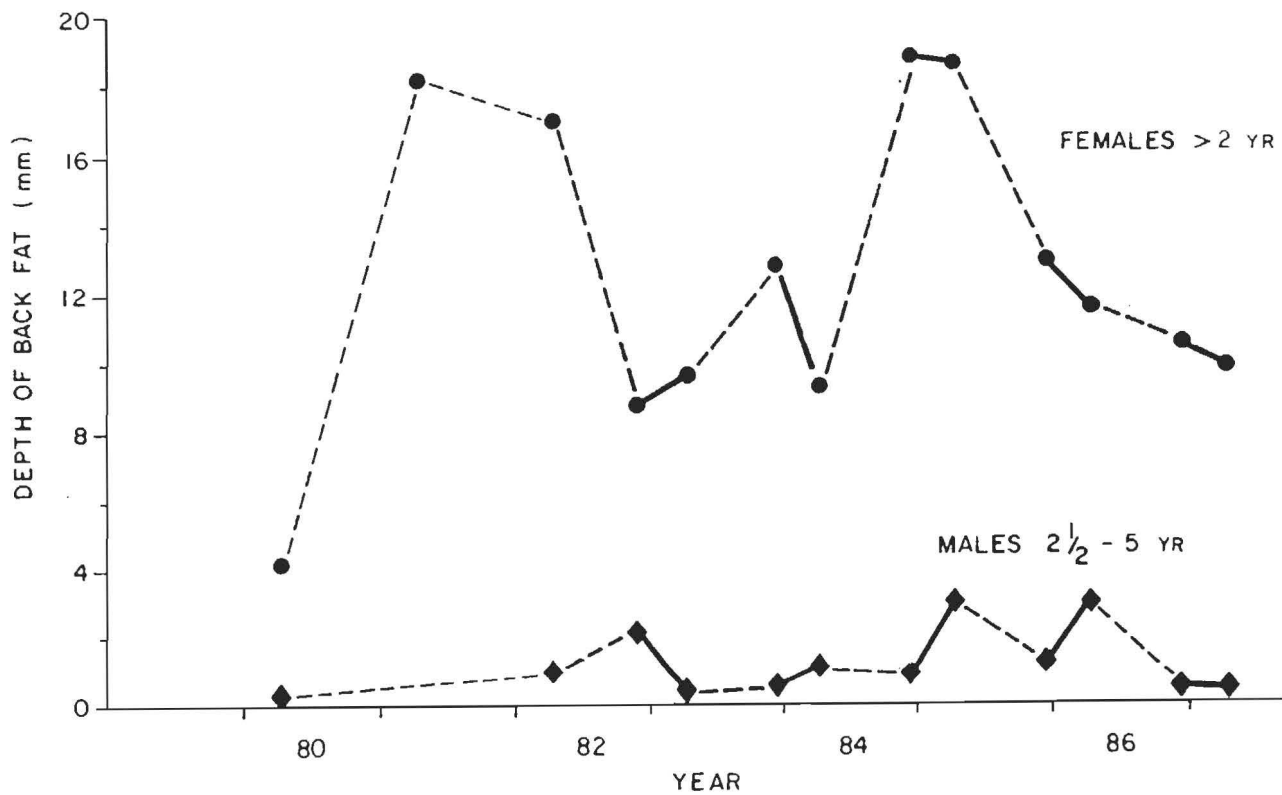


Figure 3. Overwinter changes in back fat depths (solid lines) of female caribou >2 years old and males 2.5-5 years old, sampled from the Beverly herd each December (1982-86) and March (1980-87).

Figure 4.

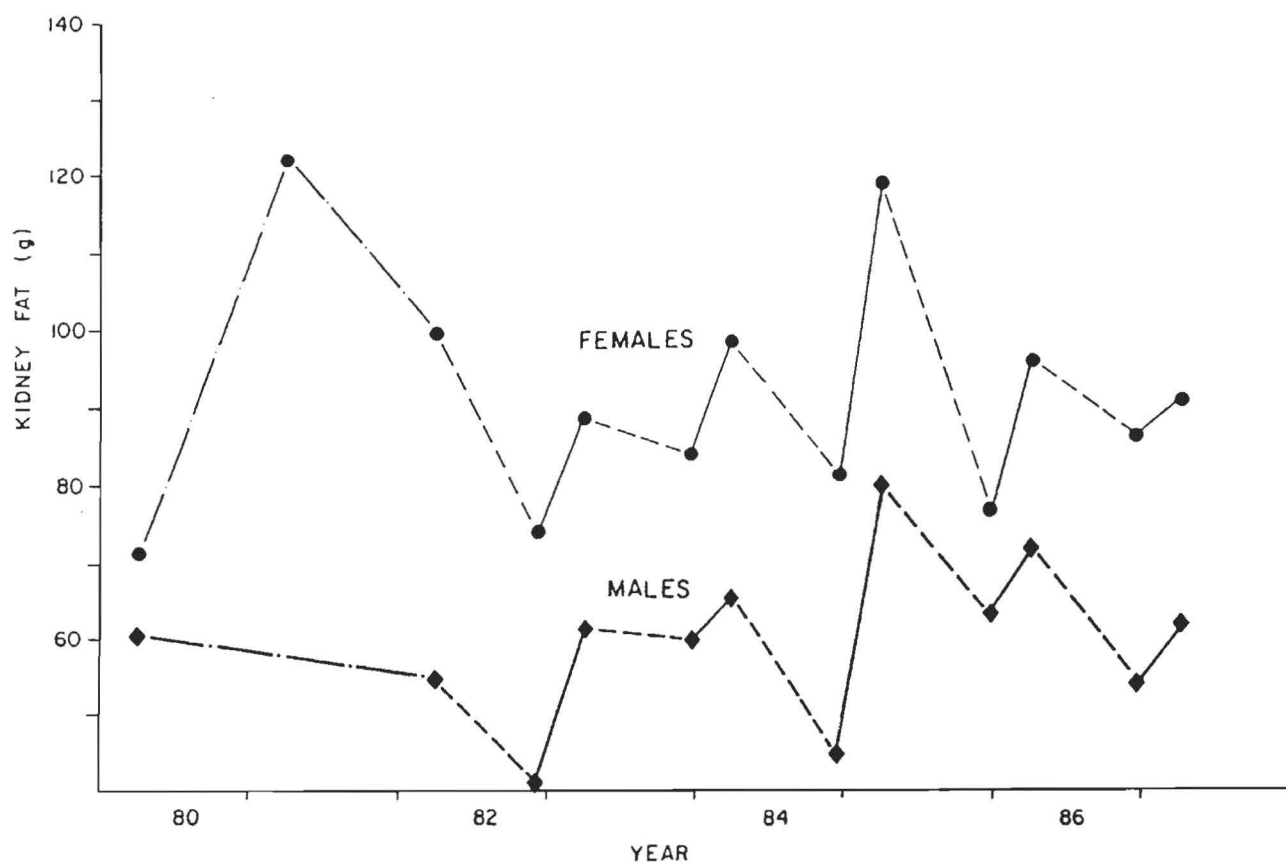


Figure 4. Overwinter changes in kidney fat weights (solid lines) of female (F) and male (M) caribou >3 years old, sampled in December (1982-86) and March (1980-87) from the Beverly herd.

Annual variations in weight and fat reserves (**Fig. 5 & 6**) were caused mainly by factors in spring, summer, and autumn and not in winter. Pregnancy rate was directly related to muscle and fat reserves (**Fig. 7 & 8**) so we must look at annual variations in variables in spring, summer, and autumn.

Remarks. A complication in assessing the adequacy of forested winter range for the Beverly herd in winters 1982-83 through 1986-87 is that components of the herd spent part of both winters on tundra. The herd also traveled further to the east and west than previously recorded or acknowledged. For example, in 1984 the herd traveled east of Snowbird Lake and probably as far as Nueltin Lake. In 1983-84, 1986-87, and apparently in 1988-89 and 1989-90, the herd traveled west across the East Arm of Great Slave Lake. In 1983-84, the herd was followed from eastern parts of the range to as far west as Gordon and MacKay lakes. The herd also traveled and fed on the tundra for several weeks each winter. This behavior was virtually unknown for the Beverly herd in earlier times (Banfield 1974, Kelsall 1968). Such movements undoubtedly occurred before but their frequency in the 1980s may indicate that the herd is seeking new range.

Recommendation 1. *Fire control is not needed at the present population level if only the welfare of the herd is considered. It may be required if the high burn rate of the 1970s and 1980s continues or the Beverly herd is allowed to increase in numbers. Wide-ranging movements in winter, including use of tundra for feeding, should be monitored whenever possible because they may be an early indication that caribou are reacting to a shortage of winter range (size or quality) and are attempting to expand their range.*

Figure 5.

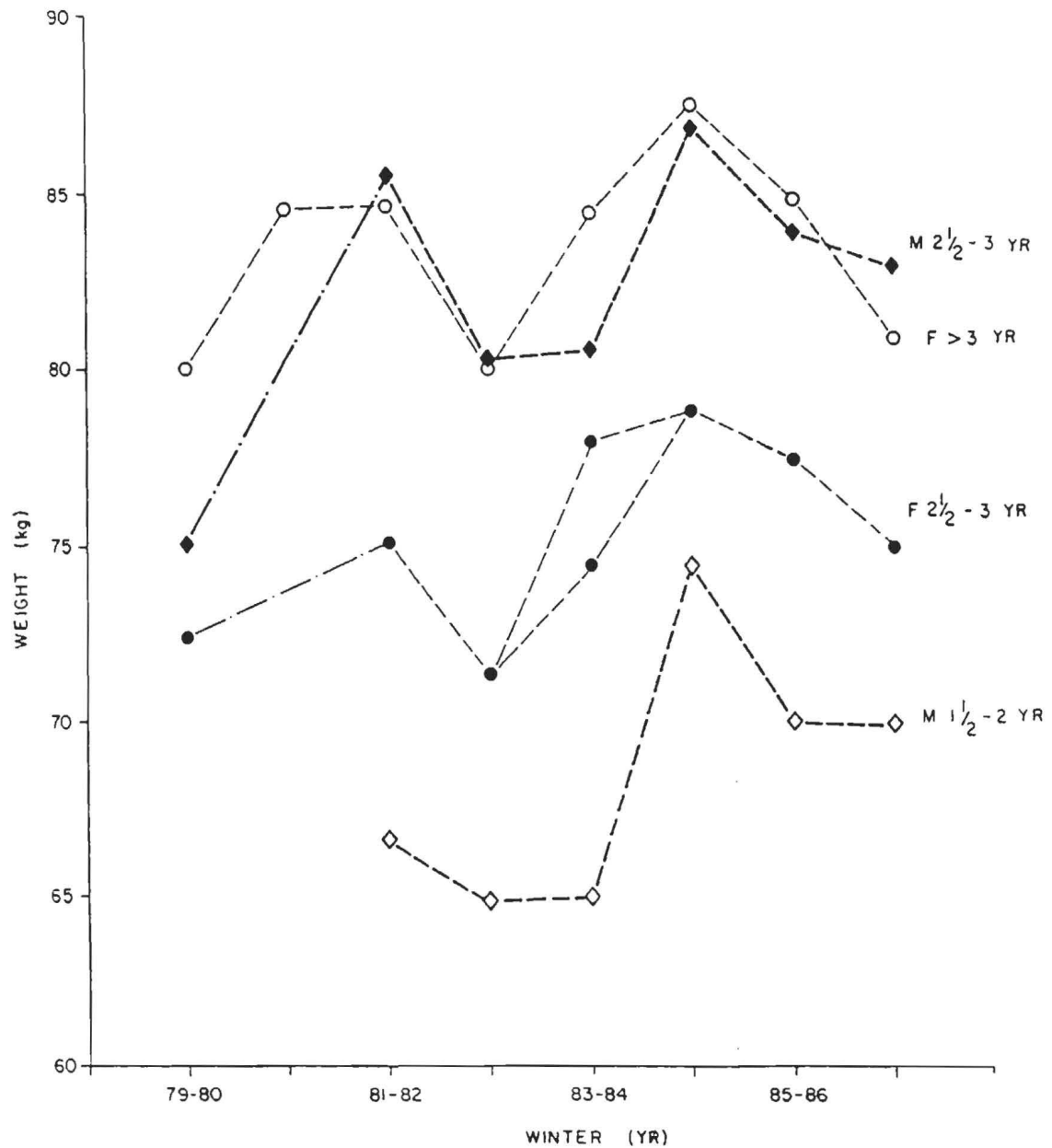


Figure 5. Body weights of four age classes of male (M) and female (F) caribou sampled from the Beverly herd each winter from 1979-80 through 1986-87 (two samples in winter 1983-84).

Figure 6.

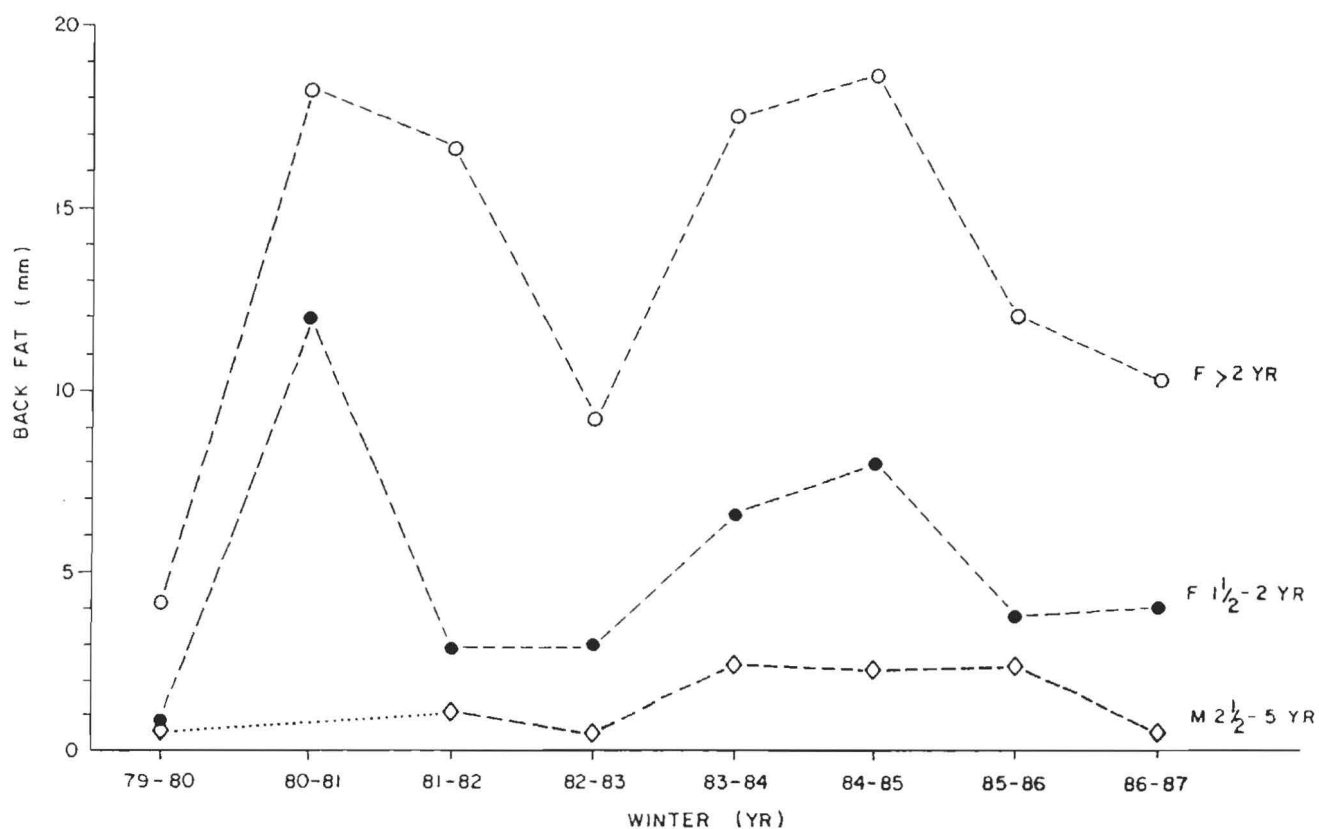


Figure 6. Back fat depths in three sex/age classes of male (M) and female (F) caribou sampled from the Beverly herd each winter from 1979-80 through 1986-87.

Figure 7.

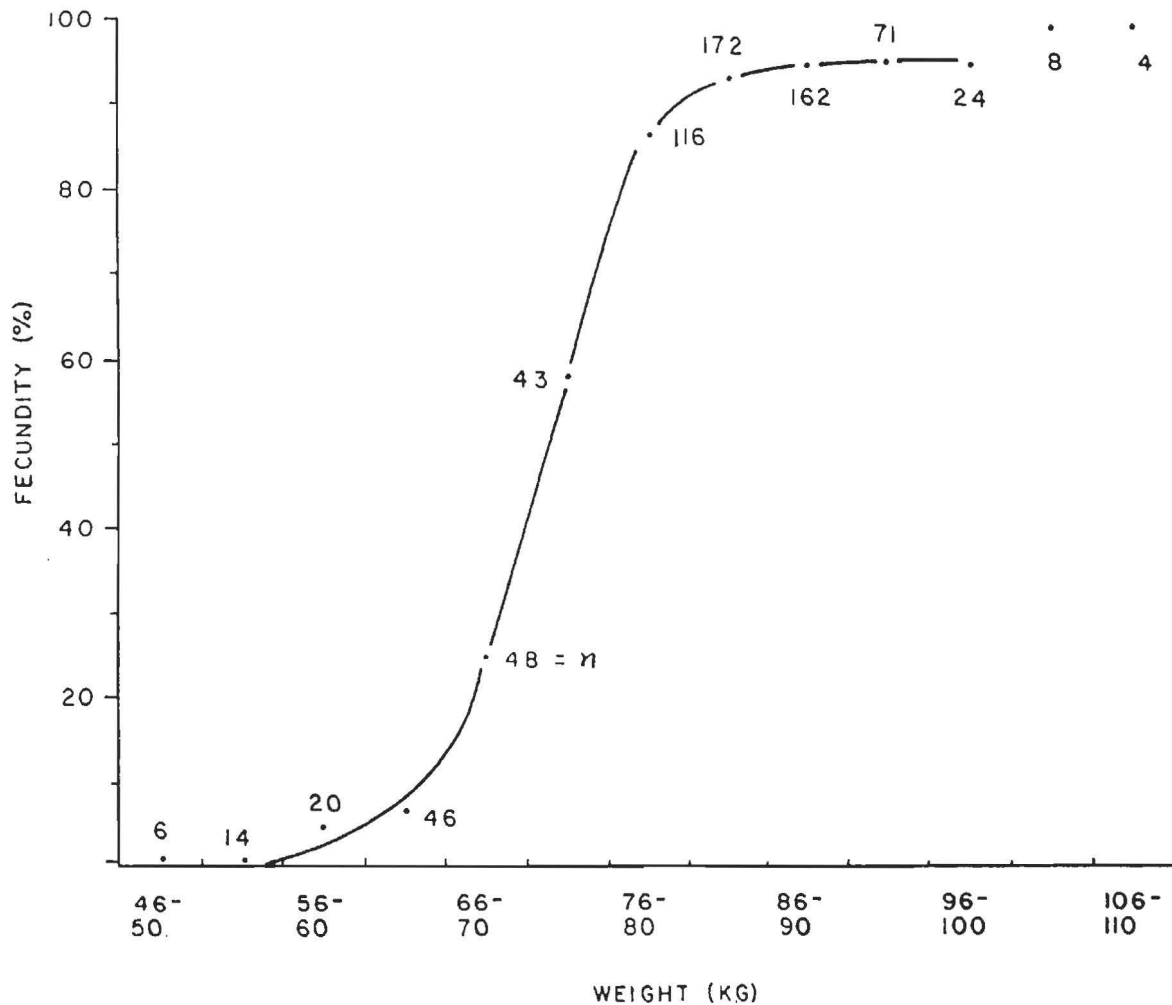


Figure 7. Relationship between body weight in 5 kg intervals and pregnancy rate of female caribou >1 year old in pooled samples from 1980 through 1987 (sample size beside each point).

Figure 8.

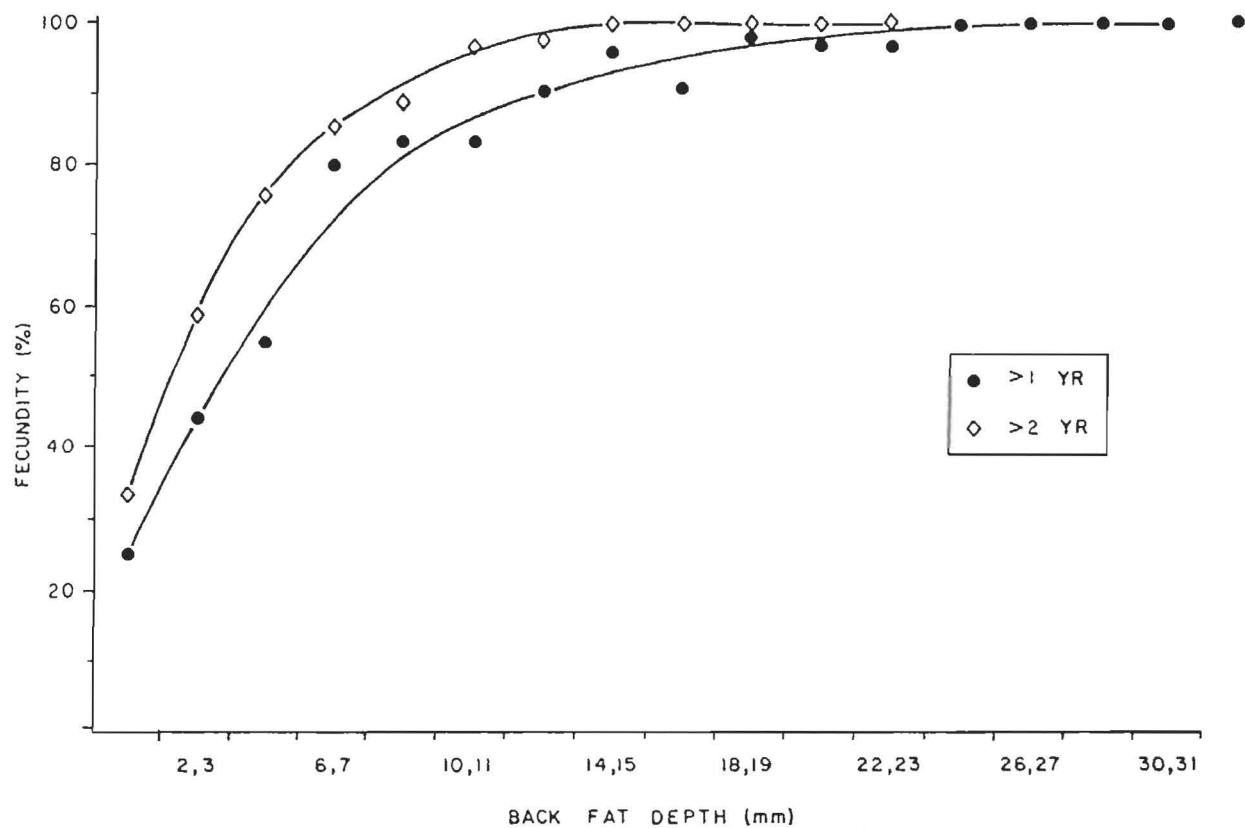


Figure 8. Relationship between depth of back fat and pregnancy rate of caribou in pooled samples from December and March, 1980 through 1987.

Conclusion 2. Burns in the past 50 years have influenced winter distribution of the Beverly herd to a considerable extent.

Data. From the 1940s to the 1980s, southern limits of caribou winter distributions has shifted northward in Saskatchewan and Alberta (**Fig. 9**). There is agreement among wildlife managers and hunters that range retraction was caused by burns. Southern and western limit of caribou distributions in 1982 through 1987 approximated the zone where percentage of the range that was burned in the last 50 years increased rapidly from less than 25% to more than 50% (**Fig. 10**). That is, the average annual burn rate changed from about 0.5% to about 1.0-1.5% (**Table 1**). In terms of caribou winter range, where highly variable amounts of range are burned annually, use of average annual burn rates is better replaced by proportions of range that have forests old enough to support caribou or, conversely, too young to support caribou. Such percentages were calculated for 1:250 000 map sheets and for ecodistricts based on aerial transect data and mapped burns verified by LANDSAT imagery (**Fig. 11 & 12, Table 2**). These percentages are only indices to relative burn rates because water (15-25% of landscape in mapped units) and unburned lowlands including meadows and fens were not included in data that yielded burn percentages. Adjustments for lowlands etc. increases proportions burned by 25-30% (**Table 2**). Ecodistricts (**Fig. 12**) probably should be further subdivided and proportions calculated for suitable caribou range. There are several problems with this approach: it is labor intensive unless a Geographical Information System (GIS) is used; boundaries of various burn-rate classes are difficult to establish without bias after-the-fact; and calculations would have to be updated annually after the fire season. Use of GIS systems will make such monitoring of winter range much easier.

Figure 9.

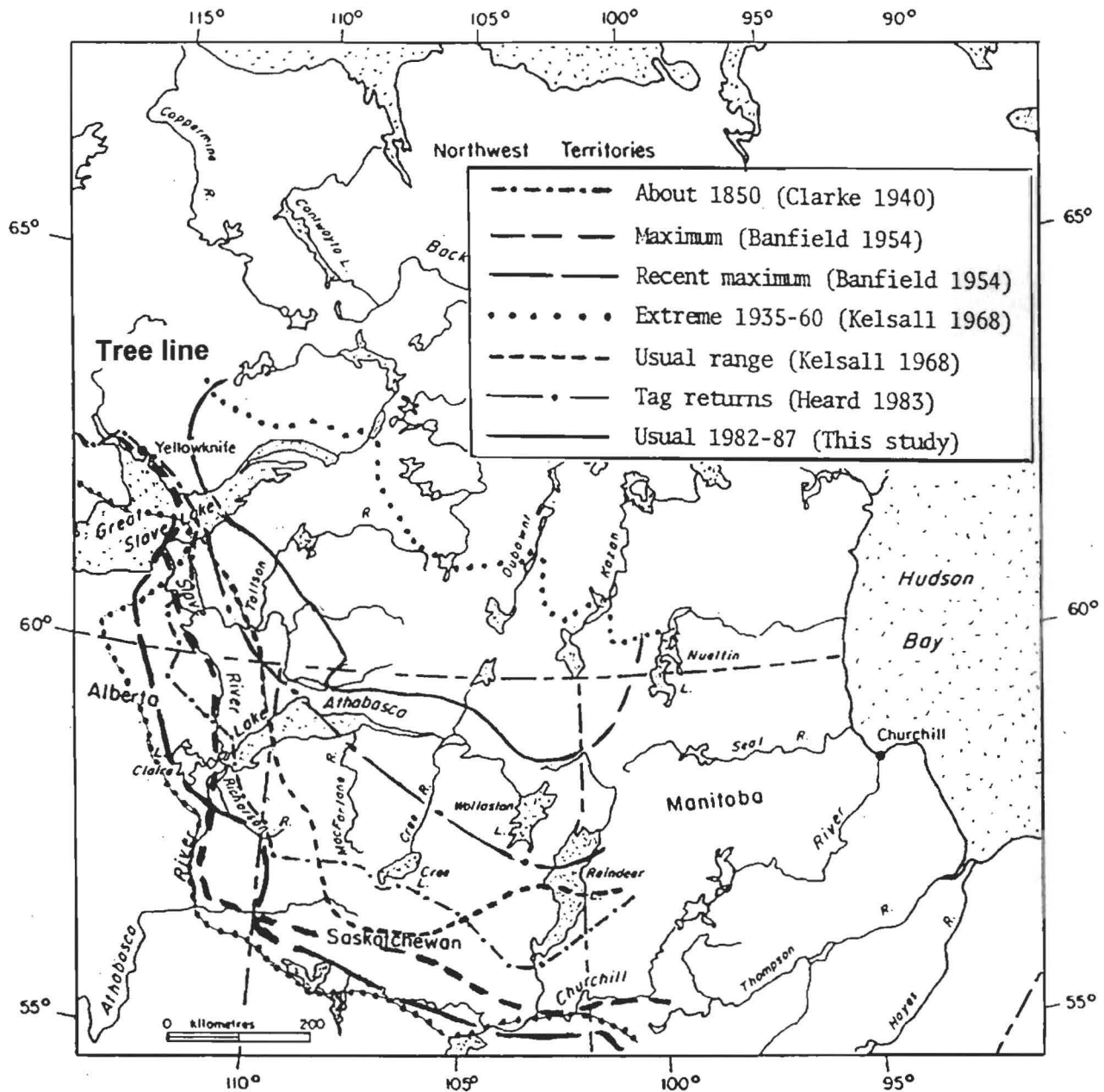


Figure 9. Maximum western and southern distribution of the Beverly herd at various periods according to several sources.

Figure 10.

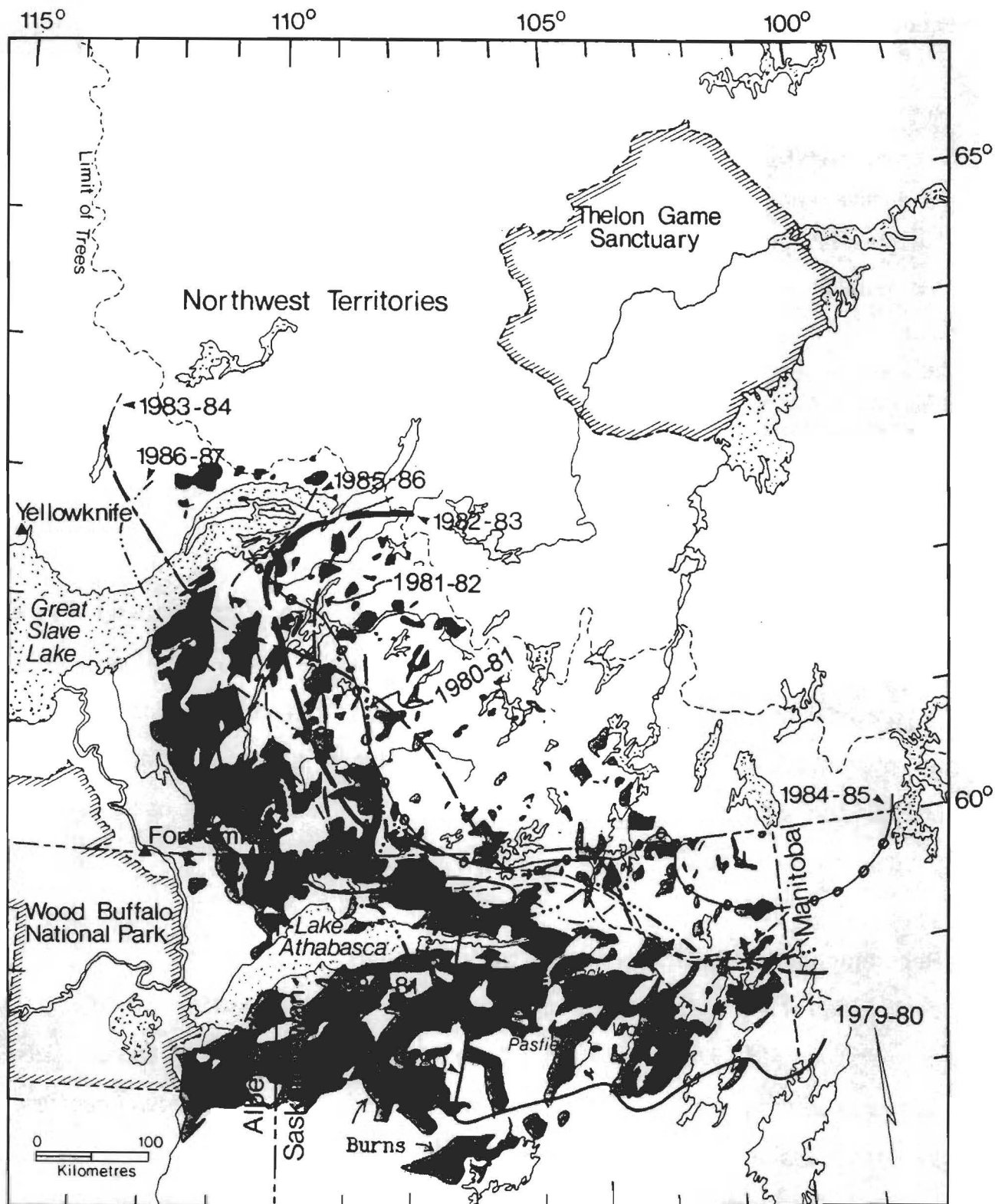


Figure 10. Southern and western distributional limits of the Beverly herd in winters 1979-80 through 1986-87 in relation to locations of burns <40 years old.

Table 1. Relationships among average annual burn rates, fire return interval, and productive caribou range assuming (A) a negative exponential distribution, and (B) all forests burn at the fire interval (rotation year).

Burn rate (%) ¹	0	0.25	0.5	0.75	1.0	1.5	2.0
Fire interval (yr) ²	inf.	400	200	133	100	66	50
Productive range ³ (%)							
A. Neg. exponent. ⁴	100	88	78	68	61	47	37
B. Rotation year ⁵	100	88	75	62	50	25	0
Burn rate description	No	V. low	Low	Moderate	High	V. high	Extreme

¹ Average, annual proportion burned.

² Mean age of forest by negative exponential whereas mean age is half of rotation age.

³ Herein defined as forests older than 50 years.

⁴ Proportion older than 50 years = $e^{-[(\text{burn rate}/100) \times 50]}$

⁵ This is equivalent to logging rotation cycles.

Remarks. There is general agreement by wildlife biologists and managers and by hunters and trappers that from the 1940s through the 1980s there was progressive withdrawal of caribou from ranges in northern Saskatchewan and Manitoba. Fire was an apparent cause of this reduction in range size. Hunting and wolf predation are possible contributing factors. The changes could not be attributed to smaller populations of caribou.

Recommendation 2. *Management of caribou and fire should be based on expected continuation of winter distributions largely in regions of very low (<12% burned in last 50 years), low (13-25% burned in last 50 years) and moderate (26-38% burned in last 50 years) areal burn rates (Table 1). It will be necessary to control distribution of fire if a caribou management objective is to reestablish caribou throughout former usual range of the herd (Banfield 1954, Kelsall 1968) and to ensure that villages potentially have easy access to caribou.*

Figure 11.

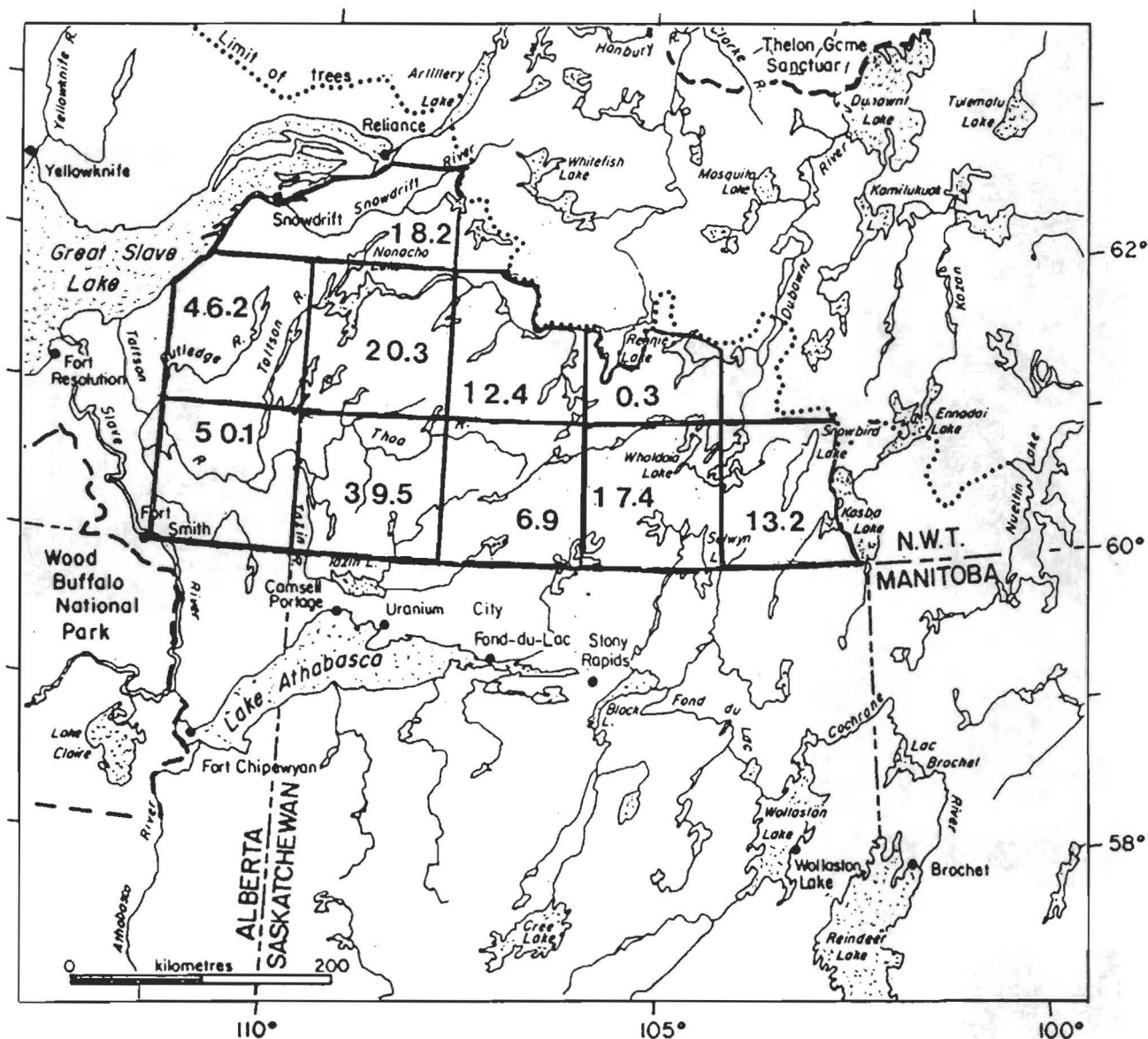


Figure 11. Percentage of landscape, lakes deleted, that burned between about 1944 and 1983, based on data from aerial transects in 1:250 000 scale map units.

Figure 12.

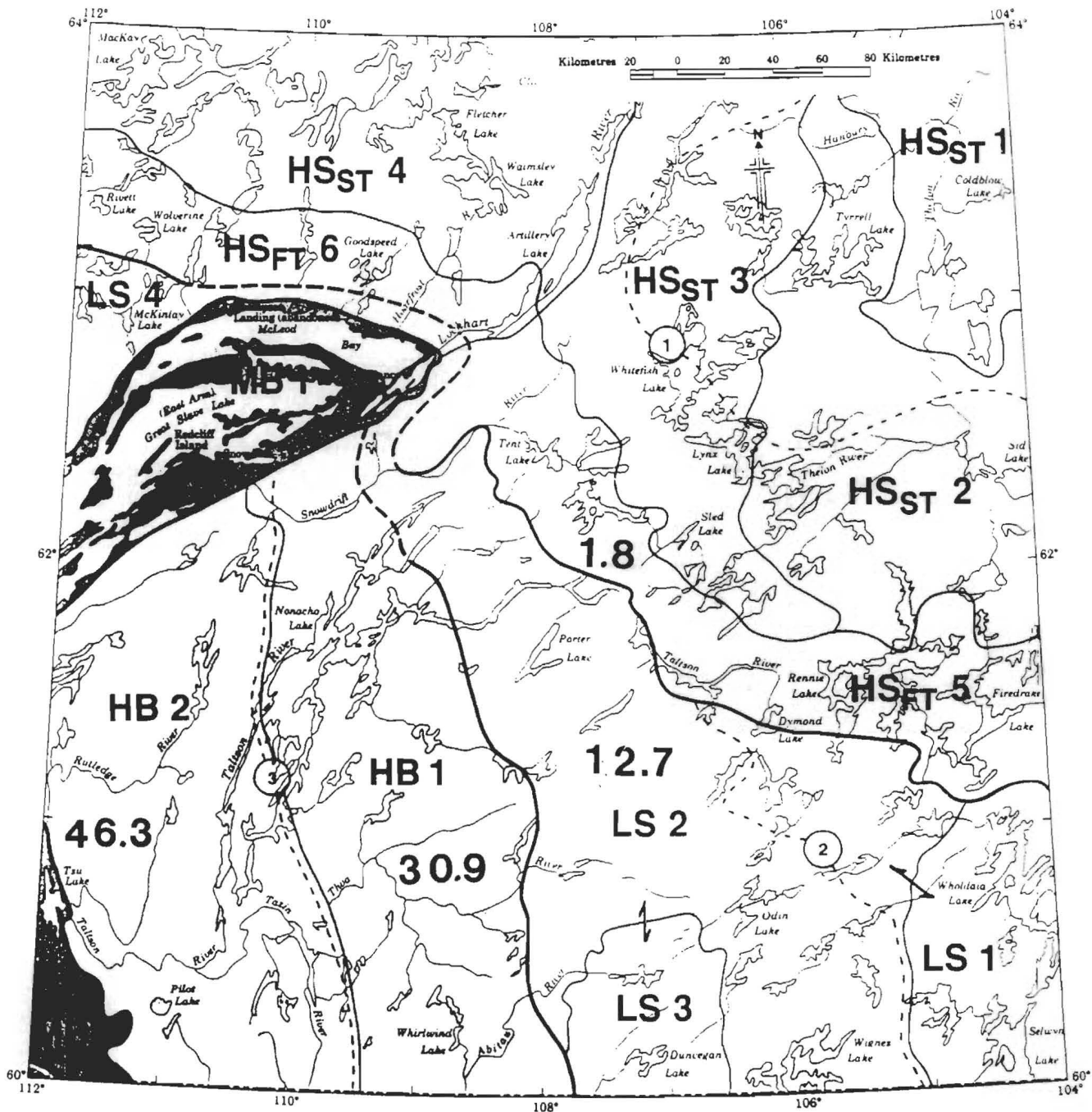


Figure 12. Proportions of forests younger than 40 years in 1984, based on aerial transect data with water deleted, in High Boreal (HB), Low Subarctic (LS), and High Subarctic (HS) Ecoregions (Bradley et al. 1982).

Table 2. Percentage of landscape units estimated to have burned from about 1944 to 1983 based on aerial transect data and on mapped burns verified by use of satellite images.

Map unit	Percentage of forest <40 years old in 1983			
	Unadjusted	Adjusted (lakes) ¹	Adjusted (non forest) ²	Adjusted (inclusions) ³
1:250 000				
Fort Smith	41.6	50.1	56.6	48.1
Taltson Lake	34.4	46.2	51.0	43.4
Snowdrift/Reliance	14.6	17.7	18.6	15.8
Nonacho Lake	15.9	20.3	20.8	17.7
Hill Island Lake	33.4	39.5	40.9	34.8
Abitau Lake	5.4	6.9	7.2	6.1
McCann Lake	10.2	12.4	13.7	11.6
Rennie Lake	0.3	0.3	0.4	0.3
Wholdaia Lake	12.8	17.4	18.9	16.1
Snowbird Lake	9.1	13.2	15.9	13.5
Biophysical				
High Boreal 2	36.4	46.3	50.3	42.8
High Boreal 1	25.0	30.9	31.7	26.9
Low Subarctic	9.7	12.7	13.7	11.6

¹ Data in Appendix 7 of report 6 in this series.

² Includes tundra.

³ Adjusted for 15% unburned inclusions.

Conclusion 3. Caribou were not reluctant to pass through spot (to 1 ha), tiny (1.1-10 ha), very small (11-100 ha), small (101-1000 ha), or medium-sized (1001-10 000 ha) burns of all ages; however, sometimes they stopped or changed direction after entering large (10 001-100 000 ha) or very large (100 001-1 000 000 ha) burns (**Table 3**), seemingly because of lack of forage in them.

Table 3. Burn size classes adopted for this study.

Size class	Size (ha)	Size (km ²)	Upper size as a square	Common term
1	>1	to 0.01	100 x 100 m	Spot
2	1-10	0.011-0.1	333 x 333 m	Tiny
3	11-100	0.11-1.0	1 x 1 km	V. small
4	101-1000	1.1-10	3.3 x 3.3 km	Small
5	1001-10 000	10.1-100	10 x 10 km	Medium
6	10 001-100 000	100.1-1000	33.3 x 33.3 km	Large
7	100 001-1 000 000	1000.1-10 000	100 x 100 km	V. Large
8	>1 000 000	>10 000		Huge

Data. Observations made on monthly aerial surveys from October to May, 1982-83 and 1983-84, and October to January, 1984-85. A sample of burns crossed by caribou from 1980 through 1986 (**Table 4**) indicates crossings of burns of all ages and sizes up to 161 170 ha (burn periphery mapping).

Table 4. A selection of major burns crossed by caribou in the Beverly herd between 1980 and 1988.

Year of burn	Mo/yr trails observed	Years since burn	Ave. burn length (km)	Ave. burn width (km)	Size of burn ¹ (ha)	Approx. snow depth (cm)	Location (center) (N lat./ W long.)
1979	Oct 82	3	38	26	161 170 ¹	5	W. Delight L.
	Mar 86	7			(136 847) ²	55	(6035,10845)
1970	Mar 80	10	38	16	81 000 ²	43	Portman L. (6002,10905)
1979	Dec 85	6	26	25	69 282	34	W. Halliday L.
	Mar 86	7			(54 720) ²	55	(6128,10917)
1976	Jan 84	8				26	
	Dec 85	9	26	11	24 567 ²	38	N.W. Siltaza L.
	Feb 86	10				58	(6226,10954)
	Dec 86	10				35	
1980	Mar 86	6	25	10	27 254 ²	66	N. Taltson R. (6151,10833)
1980	Mar 86	6	22	9	24 291	65	S. Taltson R. (6142,10833)
1980	Mar 84	4	19	16	36 327	51	N. McArthur L. (6148,10704)
1979	Feb 84	5	19	16	69 768 ¹	49	W. Powder L.
	Dec 85	6			(55 350) ²	34	(6058,10919)
1976	Mar 84	8	19	10	15 817 ²	52	W. Manchest. L. (6134,10747)
1979	Mar 80	1	19	6	70 000	40	N. Brazen L. (6007,10809)
1976	Feb 83	7	16	13	22 575 ²	34	N. Noman L. (6228,10859)
1966 & 1980 ³	Mar 83	17&3	13	12	18 163	45	N. Porter L.
	Mar 85	19&5	13	12	18 163	52	(6155,10750)
	Mar 86	20&6	13	12	18 163	66	

¹ Data from Mychasiw 1983.² Data from Ferguson 1983.³ Adjacent burns.

Remarks. Caribou in autumn or spring migrations are less likely to be deflected by large burns than those shifting their winter distributions. For example, in early winter 1979-80, caribou traveled long distances through 1979 burns between Lady Grey and Hill Island lakes. In March 1980, caribou were migrating distances up to 22 km through a 1971 burn east of Van Dyke Lake. Only a few trails, made when the surface crust of snow was soft during the warm part of the day, were used by hundreds of caribou who walked in prints of leaders. Caribou usually travel on lakes and in drainage systems (rivers, streams, meadows, and lowlands) between lakes. For this reason, there would be little difference in ease of travel, if caribou were in migration, whether they were traveling through forested or burned terrain. A large difference in the two cases is in food supplies and presence of an established trail. More case histories of reactions to large burns are needed. Eventually we may be able to predict responses of caribou to large and very large burns.

Recommendation 3. *If a goal of caribou managers is to maintain potential caribou winter range throughout the historical "usual" range, large burns (>10 000 km²) should be prevented, if possible, because they can affect winter distributions of caribou and they may affect caribou movement patterns. Future discussions would be facilitated if burn sizes were standardized, such as in Table 3.*

Conclusion 4. Maximum use by caribou was of forests 151-250 years old.

Data. Densities of caribou pellet groups in 50-year age classes of forests after fire at two sample areas revealed highest use in 151-200 and 201-250 year classes (**Fig. 13**). There were regional differences. For example, high densities of caribou pellets occurred in forests 151-300 years post fire at Nonacho Lake and at 51-200 years at Porter Lake. Analysis of all data at 20-year intervals indicated little difference in pellet group densities after 60 years post fire (Thomas and Kiliaan 1998c). Such pooling of data suffered from small sample sizes and high variation because degree of use at Porter and Nonacho lakes and vicinity was much higher than around Thekulthili, Beauvais, and Selwyn lakes, the major centers for vegetation sampling.

Remarks. This conclusion seems to hold true even in early winter when snow does not significantly affect forage availability. In late winter, forage is less accessible in medium-aged stands (51-100 years) than in older ones because younger trees intercept less snow (some of which is lost by sublimation) and therefore average snow depths are greater in young stands. Snow is usually about 10 cm shallower under large spruce trees than in openings among trees. Crusts or icy layers sometimes form just above lichen mats as a result of the partial melting of an early snowfall or a freezing rain after snow covers much of the ground. In each case, trees influence degree and extent of surface crusting. Ice layers in snow just above the ground often are absent under or to one side of trees with thick branches. Surface crust formation in late March and April is more of a problem for caribou in young and medium-aged stands than in old ones. A crust is slower to form in old forests

Figure 13.

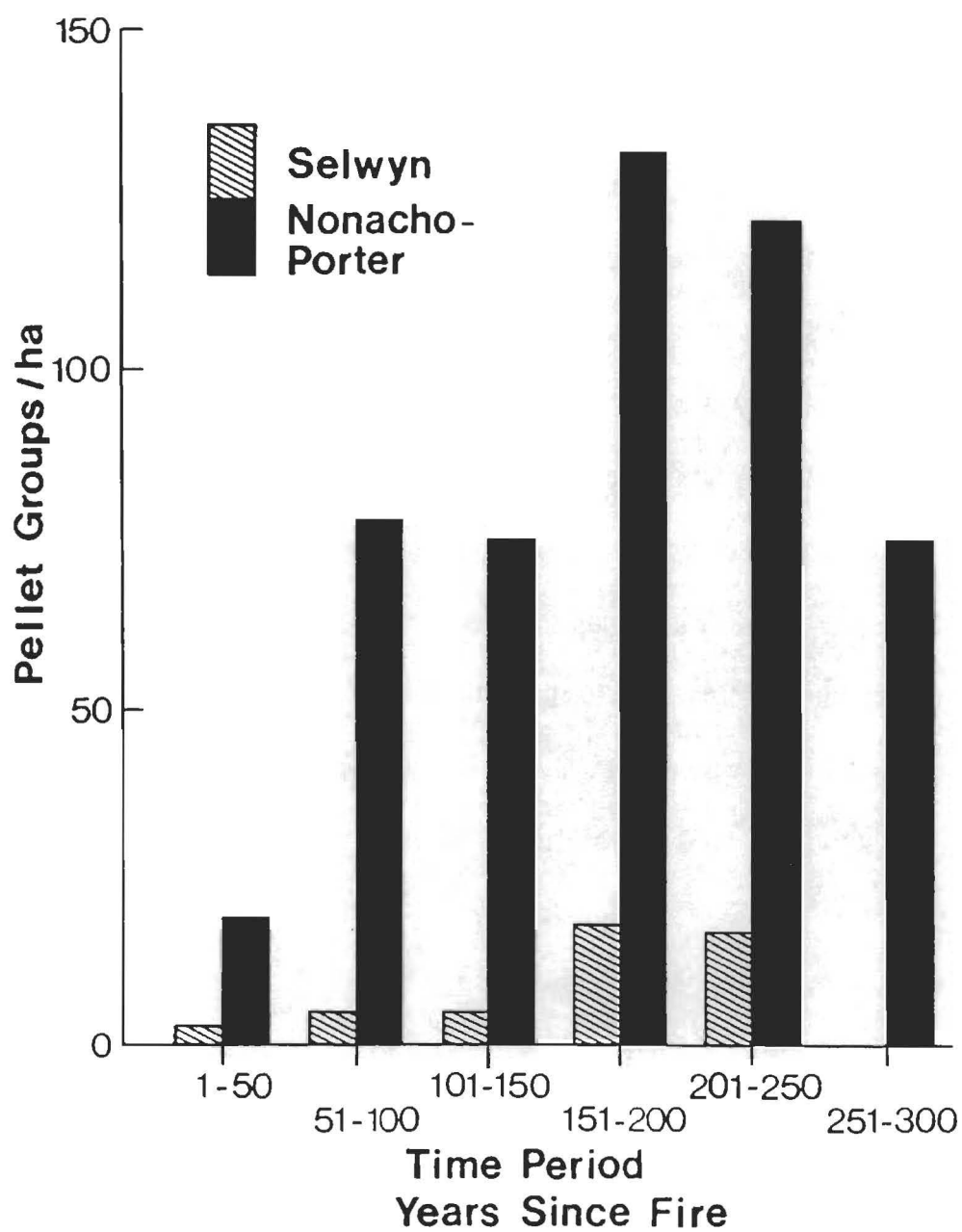


Figure 13. Densities of caribou pellet groups at 50-year intervals after fire at two locations on winter range of the Beverly herd.

because a low sun angle in March and April does not penetrate tall forests as readily as in shorter younger ones. These snow factors could explain a time lag between re-establishment of good lichen mats and their use by caribou in late winter. A second explanation is that it may take caribou a few years to find and extensively use sites that are returning to high productivity. A third reason is that lichen distribution is more patchy in forests 51-100 years old than in older ones. In some sites 40-60 years post fire, circular clumps of fruticose lichens favored by caribou occur here and there on suitable microsites. Those clumps generally are 5-20 cm in diameter. With time, those clumps enlarge until cover is 70-90%. At other sites, clumping is less pronounced and mats develop from scattered tiny lichen podetia over larger areas. Caribou in the herd did not test snow with their nose as is characteristic of woodland caribou (*R. t. caribou*). They seem to know that lichens are present almost everywhere that they dig in mature and older forests in the taiga.

Old forest provide more thermal cover on extremely cold and windy days. However, caribou on the tundra in winter only seek shelter by lying down on the lee sides of hills when the temperature is below -30° C and there is a strong wind.

Recommendation 4. *More information is needed to test apparent preference of caribou for old forests and to explain such preferences. The information is best obtained by sampling specifically for pellet-group densities. Any calculation of optimum burn rates for caribou winter range must take the caribou's feeding behavior into account, although it is difficult to obtain such information.*

Conclusion 5. Terrestrial lichens are the main food source for the Beverly herd throughout winter.

Data. Lichens comprised 87-91% of the relative densities of plant fragments in rumens and feces of caribou in November/December and March samples from forested parts of winter range (**Table 5**) (Thomas and Barry 1991). *Cladina*-type lichens, including *Cladina*, *Cladonia*, *Stereocaulon*, and *Alectoria* usually comprised 72-82% of rumen and fecal samples. Lichen species within this group are not readily separated to genera or species by a microhistological laboratory. The proportion of lichens decreased and proportions of low shrubs and grasses/sedges increased in the sequence forest, forest/tundra ecotone, and tundra (**Table 5**). Analyses of rumens from 104 caribou obtained in March, 1980 and 1981, at 18 locations on winter range of the Beverly herd revealed that 69% of contents were terrestrial lichens (Thomas and Hervieux 1984). Other studies on the central mainland of Canada produced comparable results for samples obtained from January to April (Scotter 1967a, Miller 1976a).

Remarks. Diet composition based on analysis of washed rumen samples such as those of Miller (1976a), Scotter (1967a), and Thomas and Hervieux (1986) are believed to underestimate proportions of lichens eaten for several reasons (Thomas and Barry 1991). High and rapid digestibility of lichens further enhances their value as an energy source.

Recommendation 5. *If a large population of caribou is to occupy much of its former winter range, caribou managers must give high priority to maintenance of healthy and productive mats of terrestrial lichens on a high proportion (>75 %) of winter range commonly used by caribou.*

Table 5. Plant fragment relative densities (%) in pooled rumen and fecal samples from three habitat types on winter range of the Beverly herd of caribou, 1982 through 1987. (Number of slide "fields" in parentheses).

Plant group	Forest (<i>n</i> =180)		Forest-Tundra (<i>n</i> =200)		Tundra (<i>n</i> =20)	
	Mean	SD	Mean	SD	Mean	SD
Major groups						
Lichens	91.1	5.19	86.9	7.53	78.6	8.49
Shrubs	3.2	2.52	8.8	7.02	12.4	7.19
Conifer leaves	2.1	2.37	0.5	0.99	0.0	0.00
Graminoids	1.9	3.04	2.2	2.53	6.4	5.25
Forbs	0.1	0.42	0.1	0.48	0.2	0.66
Moss	1.5	1.51	0.6	1.02	2.6	2.33
Genera						
<i>Cladonia</i> type	81.2	8.55	80.8	10.01	69.8	7.96
<i>Cetraria</i> type	6.0	4.57	4.7	6.25	5.9	4.27
<i>Peltigera</i> spp.	2.8	3.22	0.9	1.92	0.7	1.22
<i>Usnea</i> spp.	1.2	1.93	0.5	1.42	2.0	2.66
<i>Ledum</i> spp.	1.9	2.11	3.3	2.81	6.8	3.75
<i>Loiseularia</i> spp.	0.3	0.72	4.3	5.91	3.0	4.05
<i>Empetrum</i> sp.	0.9	1.60	0.5	1.32	2.6	2.73
<i>Equisetum</i> spp.	0.1	0.30	<0.1	0.24	0.0	0.00

Conclusion 6. Recovery of lichen species favored by caribou does not occur until 41-60 years after fire and recovery of highly-productive lichen mats, suitable for extensive grazing by caribou, does not occur until 61-80 years after fire.

Data. Biomass of total lichens and lichens favored by caribou increased to moderate levels by the 41-60 year class (**Fig. 14**). Only *Cladonia* spp. and *Peltigera* spp. attained highest biomass in the 41-60 year class (**Fig. 15**). Patchy but abundant *Cladonia* spp. are present 21-30 years after fire but these individual stalk-like forms do not seem to be sought after by caribou in the Beverly herd. They are not sufficiently concentrated to provide caribou with an adequate food supply under 51-60 cm of snow that often contains hard layers in wind-exposed habitats. At 41-60 years post-fire, many lichen species eaten by caribou are of patchy occurrence, although highly productive as judged by their long and robust growth forms.

Growth of one component of the diet, grasses and sedges, is stimulated by fire but some of the species are tall and coarse and not favored by caribou. There is some evidence that winter-green leaves of sedges, because of their high protein content, may aid in digestion of lichens. There is an assumption that caribou can obtain sufficient quantities of those plants in old stands. They occur at the edge of lakes, along water courses, and in meadows. Caribou utilize them but there was no indication that they actively sought out such sites.

Recommendation 6. *Forests less than 40 years old should be considered essentially unproductive as caribou range, especially in late winter, and usable late-winter range should be based on occurrence of forests older than 50 years.*

Figure 14.

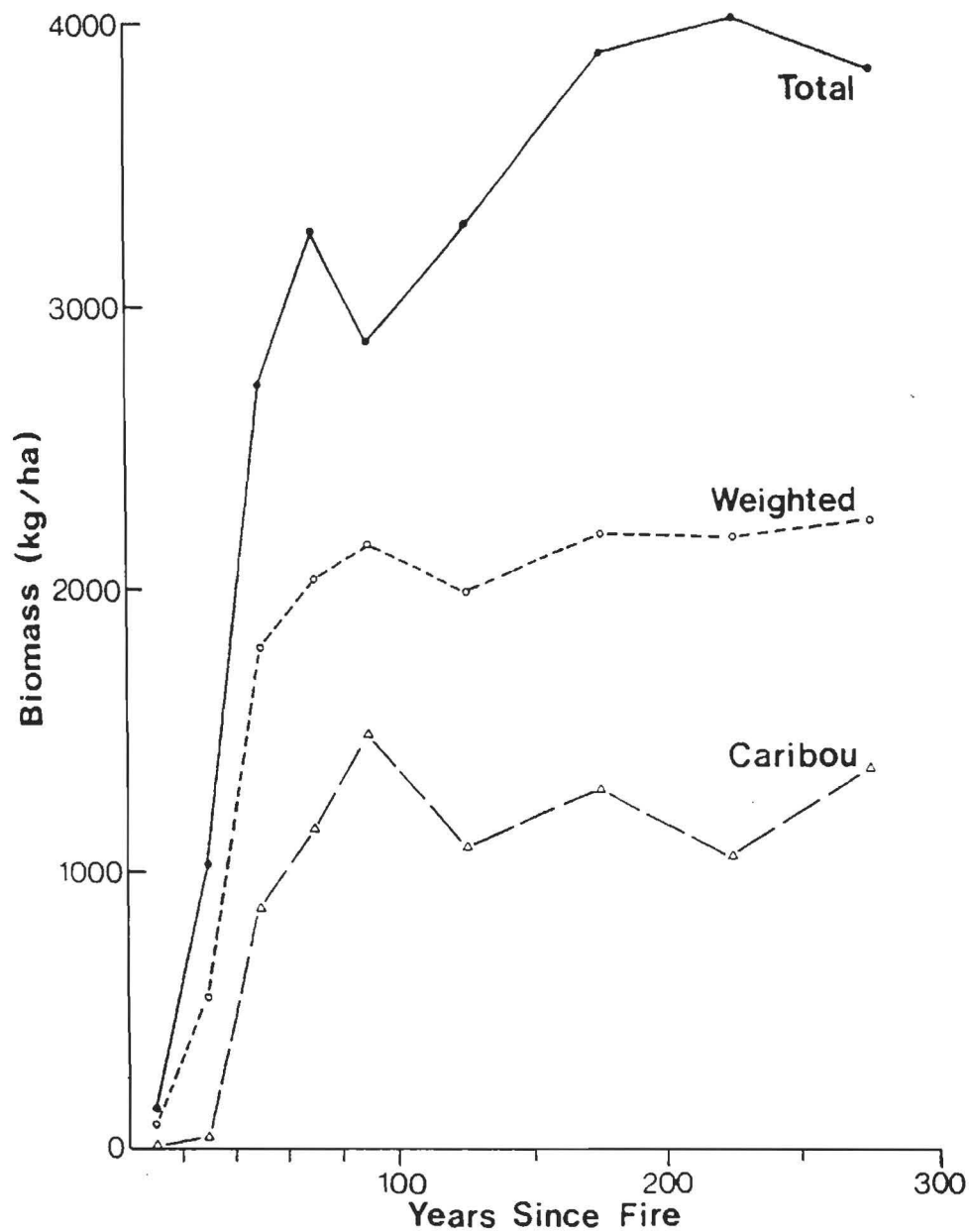


Figure 14. Biomass of all lichens (total), "weighted lichens", (all lichens with *Cladonia uncialis* and "other *Cladonia* spp." reduced by 50% and *Stereocaulon* spp. reduced by 75%) and "caribou lichens" (*Cladina mitis*, *C. stellaris*, *C. rangiferina*, and *Cetraria nivalis*) on upland sites at 20-year (to 100 years) and 50-year intervals after fire on winter range of the Beverly herd of caribou.

Figure 15.

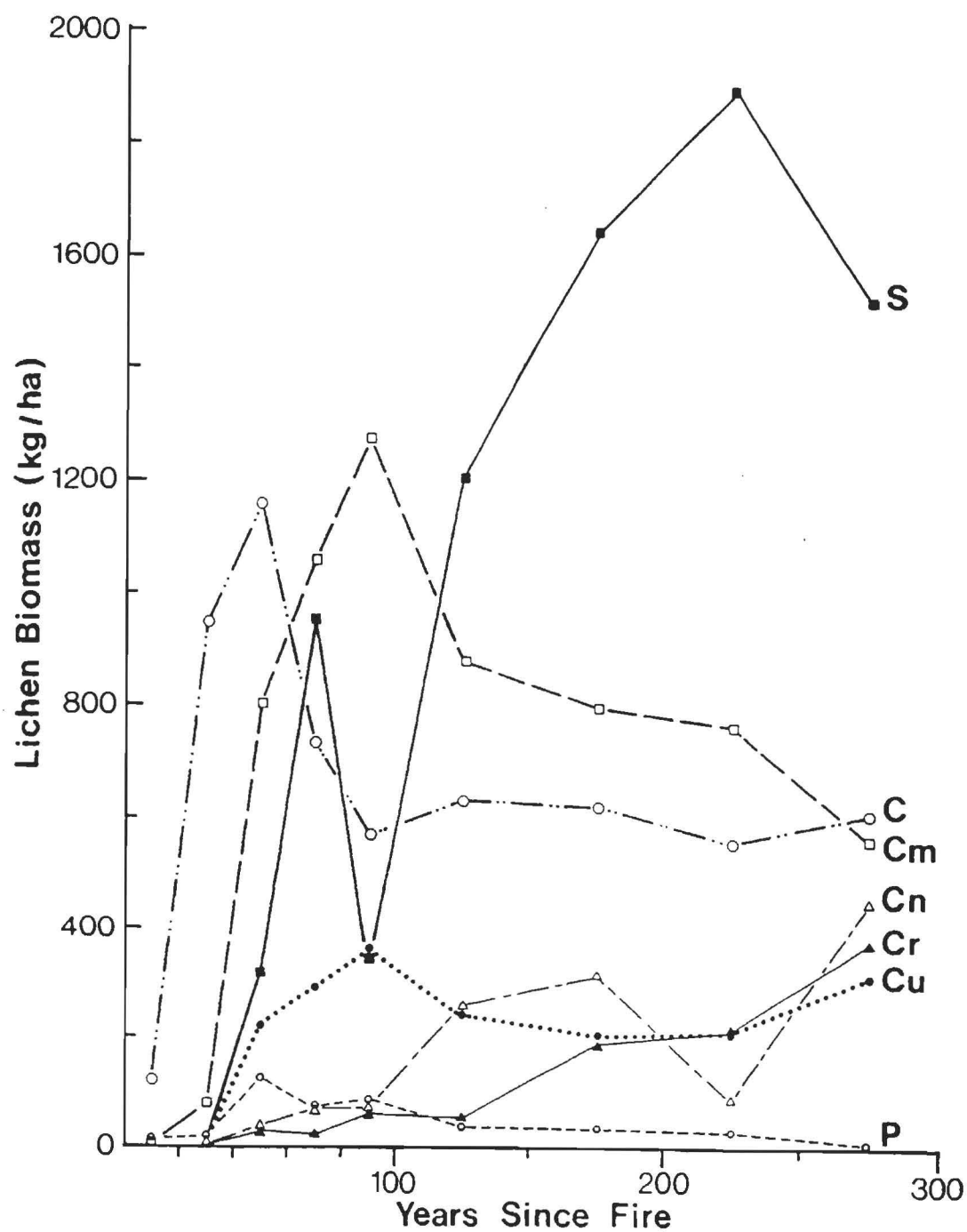


Figure 15. Biomass of *Stereocaulon* spp. (S), *Cladonia* spp. (C), *Cladina mitis* (Cm), *Cetraria nivalis* (Cn), *Cladina rangiferina* (Cr), *Cladonia uncialis* (Cu), and *Peltigera* spp. (P) on upland sites at 20-year (to 100 years) and 50-year intervals after fire on winter range of the Beverly herd.

Conclusion 7. Biomass of lichens preferred by caribou remained about constant from the 61-80 year class to the oldest forests in age class 251-300 years.

Productivity (rate of growth) of lichens preferred by caribou, in particular *Cladina mitis* appeared to be highest in forests 75-125 years old. Shorter growth forms in some sites older than 125 years, a consequence of forest thinning and drier conditions, was associated with a more-continuous mat of lichens.

Data. Biomass of grouped "caribou lichens" (*C. mitis*, *C. stellaris*, *C. rangiferina*, and *Cet. nivalis*) peaked in the 81-100 year class (Fig. 14), as did individual species *C. mitis* and *Cl. uncialis* (Fig. 15). Biomass of *Cet. nivalis*, *C. rangiferina*, and *Stereocaulon* spp. peaked in the oldest age class (251-300 years). *Stereocaulon* spp. and *Cetraria* spp. were the dominant lichen species as early as 51-70 years after fire in the Abitau-Dunvegan lakes area where drumlinoid ridges are the major topographic feature (Kershaw and Rouse 1976). Those species of lichens appear to be less preferred by caribou than *Cladina* spp. (Des Meulles and Heyland 1969) and pure mats of *Stereocaulon* spp. usually are not grazed.

Remarks. Relatively constant biomass of lichens favored by caribou at ages older than about 60 years suggests that a zero fire rate would produce maximum amounts of usable range and highest total biomass of lichens on a range-wide basis.

Complete control of fires, were it possible, would result in old forests of unknown vegetative characteristics. Presumably it would result in spruce forests with multi-aged trees and lichen mats dominated by *Stereocaulon* spp. with patches of

Cet. nivalis and *C. rangiferina* and low biomass of *Cladonia* spp. and *C. mitis*. Some sites would be characterized by large circular clumps of spruce, that regenerated through layering, interspersed with openings. Layering is asexual reproduction where low branches take root and result in a ring of "daughter" trees. Much of the diversity in lichen species caused by successional changes would be lost. Pine and other fire-dependent species would all but disappear in the absence of fire. This discussion refers to upland sites and greater diversity may occur in lowland sites.

Creation of vegetation diversity by fire results in a much denser moose population than would occur in mature and old forests. This alternative prey for wolves can be detrimental to caribou through incidental yet significant predation on caribou in some areas of southern Canada. Barren-ground caribou and wolves are essentially a one prey-one predator system in most of northern Canada and predation on relatively sparse moose population is incidental to a wolf-caribou system.

Recommendation 7. *Even if a goal of caribou managers is to produce optimum sustained yield of caribou in the Beverly herd and fire could be controlled, fire managers should allow for a low incidence of fire, which creates diversity in fire-dependent ecosystems.*

Conclusion 8. There is a time lag between re-establishment after fire of lichen species preferred by caribou and their extensive use by caribou.

Data. The main basis for this conclusion are comparisons of data for lichen biomass (Fig. 14) and pellet-group densities (Fig. 13) for forests in various age classes and aerial observations of use. Biomass of lichens preferred by caribou ("caribou lichens") and all lichens adjusted for apparent relative use by caribou ("weighted lichens") was about constant in forests older than 60 years. Pellet densities, indicative of relative degree of past use of forests, were highest in forests 151-200 and 201-250 years post fire. Extensive forests 51-60 years old located west and southwest of Hill Island Lake were little used by caribou although they traveled through the area several times. Similarly, extensive forests 51-70 years old in the Lady Grey Lake area were little used by caribou though they often traveled and wintered in older forests to the east around Thekulthili and Sparks lakes.

Remarks. Factors other than forage biomass that could affect use by caribou include distribution of forage (clumped versus uniform), shallower and softer snow under large, tall trees, differences in crusting and icy layers, visibility of predators, and differences in thermal cover. These factors relate to canopy characteristics, tree species composition, tree sizes and distribution, and shrub cover. Traditional use patterns could also be a major factor.

Recommendation 8. *Calculation of optimum winter range cannot be based solely on the recovery of forages preferred by caribou but must also be based on caribou use preferences for forests of various ages and composition.*

Conclusion 9. Fire over the past 50 years and in particular the historically high rate since 1970 has reduced, to a considerable degree, the capacity of historic winter range to support caribou.

Data. Average annual burn rates greater than about 0.5% certainly will reduce carrying capacity of winter range (Table 1). Burn rates exceed 0.5% in over half of former "usual" winter range of the Beverly herd in the primary study region (Fig. 1). Burn rates change very quickly from low to high over a distance of only about 50 km. Average annual burn rates since 1967 vary greatly from area to area (each area covered by 1:250 000 map sheets); e.g., from about 0.3% on the Abitau and McCann lakes map sheets to 3-4% on Hill Island Lake, Taltson River, and Fort Smith map sheets (Table 2). In northern Saskatchewan, range south of Lake Athabasca and the Fond-du-Lac River system is almost all (>90%) known or estimated to be younger than 50 years. Over 50% of range in the first 80 km (50 miles) north of Lake Athabasca has burned in the past 50 years.

Remarks. More winter range may be needed if, for example, the caribou herd was allowed to increase at a rate equal to the growth rate of the human population in user communities, i.e., a doubling about every 20-25 years.

Recommendation 9. *If more winter range is required for a much larger population of caribou than currently exists or winter range around settlements is to be safeguarded, at least 50% of forests within the usual range of the herd must be maintained at ages older than 50 years west of 108°W in the NWT and up to 75% in the same state east of 108°W.*

Conclusion 10. Overuse of winter range by caribou will be difficult to assess by evaluation of caribou forages. Range condition is best monitored by periodic assessment of nutritional status of a herd in conjunction with snow conditions.

Data: Localized overuse of range was observed at a few favored locations along lake shores that are used every time caribou are in an area. But a short distance away there was no use of habitats with good cover and biomass of lichens favored by caribou. In fact, most habitats removed from regular travel routes indicated little or no use by caribou. Such areas are only used when caribou remain in one area for several weeks and gradually extend their feeding areas out from favored ones near lakes, rivers, streams, and meadows.

Remarks: The nature of range overuse by caribou is not known for continental ranges in North America. If caribou cannot detect overused range under snow, they may waste energy cratering for sparse lichens in their usual foraging areas even though good range may occur off main travel routes. Barren-ground caribou do not appear to test snow for odors of forage by pushing their muzzle into snow, unlike woodland caribou (*R. t. caribou*). With localized overuse of range, caribou could lose sufficient energy reserves over a series of winters causing pregnancy rates to decline and mortality of young age classes to increase. Such changes could go undetected, with lower recruitment being attributed to predation. Range would be overused in certain locations but not in others. There is thus a buffer system against widespread overuse of winter range. One is behavioral and expressed through range selection. The other is a consequence of variable snow conditions and characteristics including

decreased range availability once snow is disturbed by caribou. Such negative feedback mechanisms indicate the possibility of a density-dependent regulatory system (DDRS). As a population increases in size, the environment becomes less favorable for caribou. Fecundity (pregnancy rates) declines and mortality of caribou, particularly calves, increases. Skogland (1986) reported that a DDRS was operating in Norwegian reindeer herds. Messier et al. (1988) proposed a DDRS to explain decline in fecundity and increased mortality in the George River herd of caribou in Quebec-Labrador. That herd grew rapidly (to 11%/year) to about 1984 and has since stabilized or decreased (Couturier et al. 1990). The supposed necessity to expand into distant and marginal habitats is a major component of Messier et al.'s (1988) hypothesis. DDRS are difficult to prove because factors such as weather variability are known to influence fecundity and mortality with little or no density effect.

Recommendation 10. *Assessment of winter range overuse probably is best attempted by monitoring changes in muscle and fat reserves in samples of caribou obtained at the beginning and end of the occupation of forested winter range, i.e., November/December and March/April. Assessment based on forage cover and biomass are difficult for many reasons and only semi-quantitative because of variable accessibility caused by snow and ice.*

Conclusion 11. Snow appears to influence movements and distribution of caribou in at least three ways: (1) by use of deep snow zones early in the winter before forage accessibility is affected; (2) by avoidance of snow deeper than 60-70 cm; and (3) avoidance of areas with hard snow or icy layers on lichen mats.

Data. Snow measurements, 1980-87. Snow depths at weather stations.

Observations of caribou movements. Analysis of caribou movements in relation to snow characteristics (Thomas 1991a).

Remarks. Ground lichens in eastern portions of forested winter range in the primary study area (east of 106° W) within 80 km of tree line are poorly accessible in late winter of most years because of deep snow and drifted snow among short trees that occur in that area.

The best adaption for a caribou herd in order to even out or maximize use of the entire winter range, based on the above observations, would be utilization of eastern portions of forested range in early winter when snow is shallow and then move to western portions of the range in late winter where they usually would encounter easier feeding. That utilization pattern was observed in early winters of 1982-83, 1983-84, and 1984-85.

Average snow depths, as indexed by water equivalents data, were greater than average after 1980-81 (Fig. 16). Eastern range could be used extensively in winters of below average water equivalents of snow.

Recommendation 11. *Priorities for fire management on caribou winter range in the NWT should take into account the influence of snow on movements and distribution of the Beverly herd.*

Figure 16.

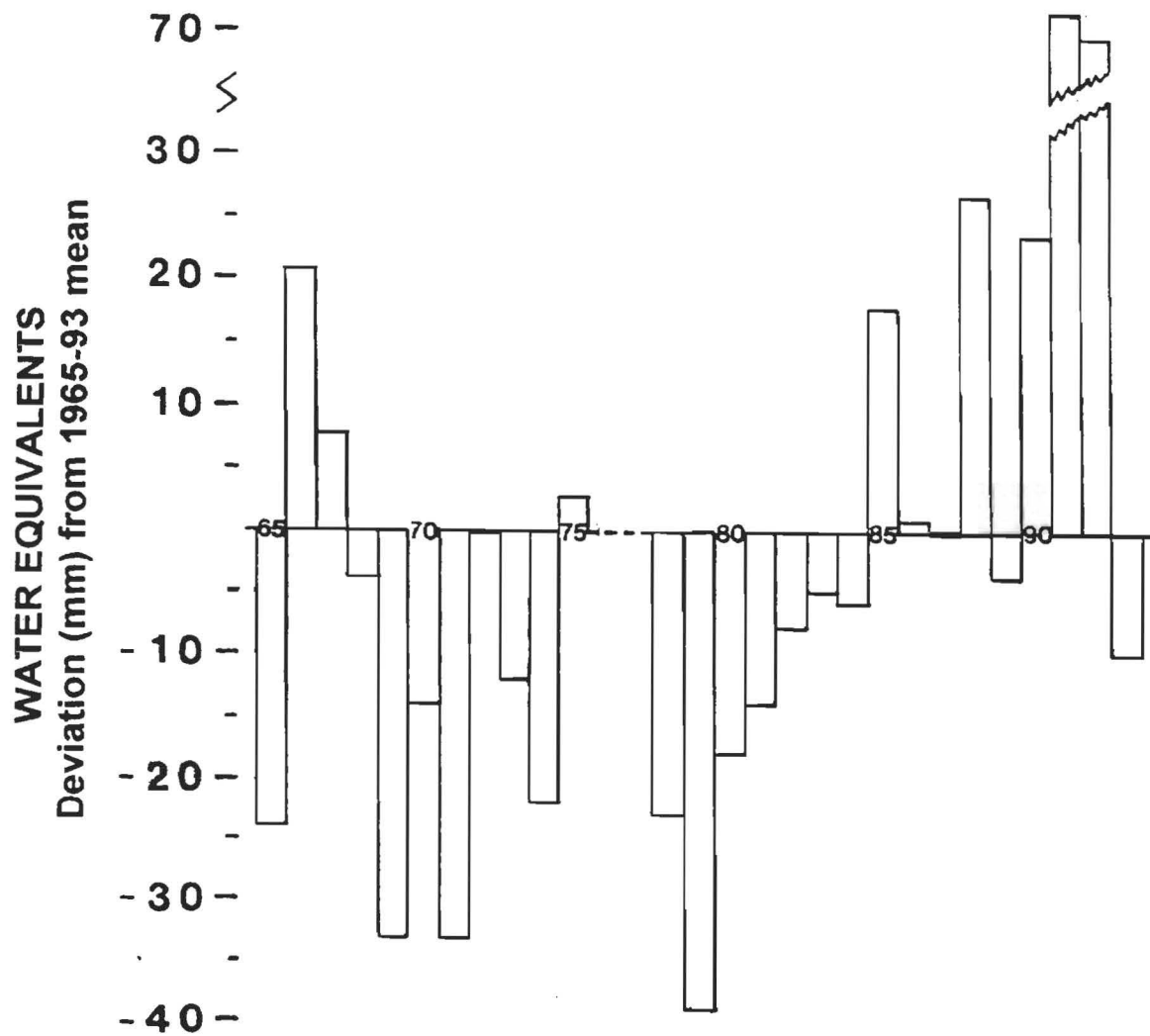


Figure 16. Deviations of water equivalents (mm) from sample means for all other winters in snow cores for individual winters, 1965-66 through 1992-93. Data from Water Survey of Canada for 11 stations on winter range of the Beverly herd of caribou.

Conclusion 12. The Beverly herd usually uses eastern range early in winter and western range later, possibly an adaptation to greater average snowfall in the east (Table 6).

Data. Movement patterns of the main herd, 1983 through 1987, and data in Table 6.

Table 6. Average depths (cm) of snow in the study area in March each year from 1980 through 1988.

Year	Range wide	West of 107°30'	East of 107°30'	Brazen Lake	Porter Lake	Beauvais Lake	Fort Smith
1980	53 ¹			45			
1981	31			36	31		
1982	54	52	58	52	54		37
1983	54	52	60	45 ²	46	61	55
1984	54	50	58	50	58	57	40
1985	57	57	58	58	52	61	58
1986	66	61 ³	79	71 ⁴	68	79	58
1987	55	52	63	63	52	59	62
1988	70	67	75	59			
Ave.	58 ⁵	56	64	53	52	63	52

¹ Estimated.

² Measurement on February 10. Nearest measurement in March was 51 cm.

³ At Flett Lake.

⁴ At Dunvegan Lake.

⁵ Omitting 1981 because only four sites were measured.

Remarks. The rut usually occurs in the eastern half of winter range, which may dictate observed temporal use. Alternatively, use of eastern range in early winter of most years could simply relate to recent summer migration patterns. There is evidence of a circular movement pattern in summer. If the migration route from calving grounds to the vicinity of tree line is western, the caribou travel to eastern parts of the range in August and September and vice versa. Use of western migration routes was common in the late 1970s and 1980s (A. Hall pers. comm.).

Movements of the Beverly herd from August through October are poorly known. During August 1981, components of the Beverly herd traveled from tree line to Beverly Lake and may have crossed the Thelon and Dubawnt rivers. They retraced the spring migration route.

Recommendation 12. *All winter range used by the Beverly herd must be considered important to future welfare of the herd. Managers should be discouraged from ranking relative importance of winter ranges and sacrificing supposedly poorer range to other resource use. For example, in recent years, while western range was more important to the main concentrations of caribou in late winter than eastern range (east of 107°30'W), the eastern range is still important as large groups usually move through it in early winter and small groups traditionally occupy southern portions (border region and in Saskatchewan) of eastern range every winter. An option should be maintained for the herd to use all parts of its historic "usual" winter range and perhaps its historic maximum range.*

Conclusion 13. An increase in herd numbers will not necessarily result in expansion of forested winter range occupied by the Beverly herd because some areas formerly occupied by the herd contain little suitable range as a result of fire.

Data. Burn maps for NWT and Saskatchewan, LANDSAT images, and burns mapped on survey flights. There is a scarcity of large blocks of suitable range in the NWT in a sector west of 109° W and south of 62° N. The same applies in Saskatchewan south of Lake Athabasca and the Fond-du-Lac River and west of Wollaston Lake (the Athabasca Plain). There are also high burn rates up to 64 km (40 miles) north of Lake Athabasca, the Fond-du-Lac River, and Black Lake. The best (least burned) range in Saskatchewan is in the 60° N border area east of 107° W and in the northeast corner of the province (the Phelps Lake 1:250 000 map sheet and to a lesser extent, the Wollaston Lake map sheets). In addition to burns that were mapped in Saskatchewan, there are many large areas where forests are believed to be too young to produce good winter range for caribou.

Remarks. Caribou populations may tend to expand their range as they increase in numbers but there are exceptions. Range expansion of the growing George River herd was pronounced.

Recommendation 13. *Fire management to reduce burn rates and, perhaps, an increase in herd size will be necessary to restore caribou to areas that apparently are burned every 50-100 years. There is doubt whether fire can be controlled in such areas characterized by few natural barriers to the spread of fire and rapid drying of surface vegetation over sand or bedrock.*

Conclusion 14. Lichens are more important to the Beverly herd in forested habitats than indicated by composition of plants in rumens and feces.

Data. Some items such as dead conifer leaves and mosses are ingested incidentally and these tend to lower proportions of lichens. Adjustment of data for these incidental components and unidentified material increases proportions of lichens in data sets to 72%, 95%, 75%, and 91-94% (Scotter 1967b, Thompson and McCourt 1981, Thomas and Hervieux 1986, Thomas and Barry 1991). The histological techniques used by Scotter (1967a) and by Thomas and Hervieux (1986) probably leads to underestimations of proportions of lichens because fine material is lost through washing sieves (Gaare et al. 1977). Relatively high (**Table 7**) and rapid digestion of lichens compared with other elements in the diet (Thomas and Kroeger 1981, Thomas et al. 1984) also would result in an underestimation of proportion of lichens ingested by caribou.

Remarks. A mixture of lichen species, both long and short forms, was adequate for reindeer in Alaska, whereas a diet of only fruticose forms was sub-minimal (Palmer 1944). Potential reasons included low protein content (2-4%) of *Cladina* spp. and differences in vitamins and ash. For example, protein content of *Peltigera* spp. and *Stereocaulon* spp. are in the range 16-18% and 6-8%, respectively. Palatability of those species is low (Palmer 1944, Courtright 1959) but ingestion of even small proportions may facilitate digestion of "reindeer lichens" and improve nutrition. A listing of long and short forms of lichens and nutrient analyzes are in Table 1 of Courtright (1959).

Recommendation 14. *Assessments of relative value of parts of forested winter ranges can be based largely on lichens in terms of forage although other habitat factors are also important.*

Table 7. Apparent digestibilities (dry matter disappearance) of major plant species eaten by caribou as estimated in several *in vitro* trials using test tubes and flasks, with and without urea.

Plant species	Dry matter disappearance (%) ¹		
	Flasks + urea	Flasks	Test tubes
<i>Cladina mitis</i>	77	66	56, 53, 48, 44, 43
<i>C. rangiferina</i>	49	52	45, 37, 35
<i>Cladonia</i> spp. ²	76, 74, 67	62, 54, 48	55, 47, 44, 44, 41, 41, 39, 36, 30
<i>Cetraria nivalis</i>	91	87	55, 38, 34, 20
<i>Stereocaulon</i> spp.	66	67	48, 47, 45, 30, 24
<i>Peltigera</i> spp.			44, 38, 33, 32
Arboreal lichens ³	94, 89	72, 67, 65	76, 65, 59, 52, 52, 47, 43, 42, 42, 39, 32
<i>Ledum</i> spp.			31, 31, 19
<i>Empetrum</i> sp.			54, 30
<i>Vac. vitis-idaea</i>			43, 33, 25
<i>Carex rostrata</i> ⁴			67, 63, 57
Moss species			30, 29, 29, 26, 25, 24, 24, 22, 19, 18, 17, 16, 16, 15 14, 12, 7

¹ Data from Thomas et al. 1984.

² *C. uncialis*, *Cl. amaurocraea*, *Cl. cornuta*, and several grouped species.

³ *Usnea hirta*, *Evernia mesomorpha*, *Alectoria americana*, and *Hypogymnia physodes*.

⁴ Winter-green leaves.

Conclusion 15. Some terrestrial lichen species are preferred over others by caribou and certain lichen growth forms permit easier foraging under snow than others. Any conclusions about optimum ages of forests for caribou winter range must consider preference, palatability, nutritional, and accessibility factors.

Data. Field observations in summer of winter feeding sites and comparisons of rumen contents with observations of relative abundance of lichen species, suggest that *Stereocaulon* and perhaps *Peltigera* spp. are not selected, whereas *Cladina* and *Cetraria* spp. are selected. The selection or avoidance of *Cladonia* spp. is difficult to assess, as selection or avoidance is likely to be species specific. Caribou were never noted to seek out the "rooted" forms of *Cladonia* spp. that are abundant and robust in young forests. *Cladina mitis* appears to be selected by caribou but assessments are difficult because lichens seldom occur in pure mats by species.

A mixture of lichens is eaten at almost every feeding crater and site. Some data on preferences of caribou for lichen species is available from studies in Quebec (Des Meulles and Heyland 1969) and Alaska (**Table 8**). Studies have not been done on possible toxic effects of consuming too much of certain lichen species. It was necessary to estimate relative selectivity of lichen species by caribou and weight biomass values accordingly in order to assess optimum forest ages for caribou range and thereby optimum burn rates. Weight of *Stereocaulon* spp. was reduced arbitrarily by 75%; weight of *Cladonia uncialis* and "other *Cladonia* spp." by 50%.

Table 8. Order of preference of caribou for lichen species in tests conducted in Quebec and Alaska.

Preference order	Location of test	
	Quebec ¹	Alaska ²
1	<i>Cladina</i> spp. ³	<i>Cladina alpestris</i>
2	<i>Cladina rangiferina</i>	<i>Cladina rangiferina</i>
3	Arboreal ⁴	<i>Stereocaulon paschale</i>
4	<i>Cetraria islandica</i>	<i>Cetraria richardsonii</i>
5	<i>Stereocaulon</i> spp.	<i>Peltigera aphthosa</i>

¹ Des Meulles and Heyland 1969.² Holleman and Luick 1977.³ *C. mitis*, *C. alpestris*, and *C. uncialis*.⁴ *Usnea* spp., *Evernia mesomorpha*, and *Alectoria* spp.

Remarks. Obtaining data on forage preferences is exceedingly difficult. Examination of a large number of craters provides qualitative data on what appears to be eaten and what is left. Tame caribou can be used but there is always doubt that their preferences are the same as for wild caribou. For example, dietary needs may influence diet of wild caribou.

Recommendation 15. *More data are needed on caribou forage preferences and relative palatability and digestive qualities of lichen species. More information than could be obtained in this study is needed on species composition, productivity, and biomass of lichens in old forests (>250 years post-fire) of various types and on caribou forage preferences and nutritional aspects before accurate estimates of optimum burn rates on caribou winter ranges can be made.*

Conclusion 16. Tree lichens proportionally are insignificant in diets of caribou in most winters but they become an emergency food supply in winters of exceptionally deep snow or when ice layers or hard snow on lichen mats severely restrict access to terrestrial lichens.

Data. Rumen analyzes (Scotter 1967a, Miller 1976a, Thomas and Hervieux 1986). Field observations in several winters (1957, 1958, 1980 to 1987). Observations of others (Kelsall 1968; Miller 1976a, 1976b).

Arboreal lichens at 0-2 m above ground level increased with age of forest until age class 81-100 years and thereafter remained about constant (**Table 9**). They were subjectively rated as absent, rare, sparse, and light, respectively, in the first four 20-year age classes. Scotter (1967b) found little difference in arboreal lichen abundance between stands 51-100 years old and older ones. The lower dead branches of old spruce trees usually have good growths of lichens on them.

Management aimed at protecting terrestrial lichens will also protect arboreal lichens. Arboreal lichens may be a critical food supply in winters such as 1961-62 when exceptionally deep crusted snow or ice layers restrict use of terrestrial lichens. Some use of arboreal lichens was noted in March 1984 when a icy layer of snow 8 cm thick covered lichen mats in openings between trees over much of the forested winter range of the Beverly herd. Arboreal lichens were used extensively in March 1985 when snow depths ranged from 50 to 60 cm and hard crusts of snow occurred just above the ground at some locations. A shortage of arboreal lichens is unlikely to become a problem unless the herd becomes much larger than the present number and availability of ground lichens is restricted for several winters in succession.

Table 9. Average ordinal rating of arboreal lichen abundance in forests in 13 age classes at 176 sites on winter range of the Beverly herd of caribou.

Age class (yr)	Sample size	Arboreal lichen abundance		
		Mean ¹	Standard deviation	Standard error
1 - 20	12	0.0		
21 - 40	13	0.1	0.27	0.08
41 - 60	30	1.2	0.69	0.13
61 - 80	24	2.0	0.76	0.16
81 - 100	6	2.8	0.37	0.17
101 - 120	6	2.2	0.90	0.40
121 - 140	15	2.5	0.96	0.26
141 - 160	12	2.3	0.83	0.25
161 - 180	17	2.6	0.97	0.24
181 - 200	8	2.6	0.48	0.18
201 - 220	15	3.0	0.63	0.17
221 - 240	15	2.7	0.85	0.23
241 - 260	3	2.7	0.47	0.33

¹ Scale: 0 = nil; 1 = sparse; 2 = light; 3 = moderate; and 4 = abundant.

Remarks. For unknown reasons, caribou seem to use some arboreal lichens in March whether snow is deep or not. Use seems to be correlated with warm weather when the temperature is around freezing. The lichens then may be moist and pliable. Greatest use of arboreal lichens was noted in March 1985 where snow depths within the caribou distribution averaged 59 cm. Greater use of arboreal lichens in late winter could be associated with greater access to minerals in seepage areas and creeks that overflow.

Recommendation 16. *No special consideration must be given to arboreal lichens in management plans for caribou and fire.*

Conclusion 17. The late-winter period (February-April) is the most critical time for caribou on forested winter range because forage accessibility decreases and travel becomes more difficult as winter progresses.

Data. Snow measurements indicate that depths increase from January through March and surface crusts form in late March and April. There was a gradient in snow depths from west to east in the southern half of the primary study region in most winters with least snowfall in the west, particularly the southwest.

Remarks. Caribou begin to migrate from winter range from as early as February to as late as May. April formerly was the most frequent month for spring migration to begin and tundra was not reached until late April-early May (Kelsall 1968). In the 1980s, spring migration usually began about mid March and tree line was reached in the last 2 weeks of March. The exception was a subherd that wintered along tree line in 1983-84 and began to leave the forest in late February. In winters of deep snow, migration is delayed and forage accessibility may be poorest in April and May when crusts form on the surface of snow at night and when cold spells follow warm days.

Recommendation 17. *Fire management practices should give highest priority to safeguard winter ranges that are frequently used in late winter (February-April).*

Nonacho, Thekulthili, Alcantara, Manchester, and Porter lakes comprise such an area where forage is most accessible in February, March, and April because of relatively low average snowfall.

Conclusion 18. The optimum areal rate of burning to produce range with highest carrying capacity for caribou probably ranges between 0.25% and 0.5% annually, considering a need for diversity caused by fire, and proportion of land that is productive for caribou at various burn rates.

Data. At a burn rate of 1% and assuming equal flammability with time, only 61% of the range is productive for caribou (Table 1). Obviously the optimum burn rate is greater than zero or diversity would be lost. It probably is less than 0.5% because too much of the range is too young for growth of lichens preferred by caribou at higher burn rates.

Maintenance of pine and mixed pine/spruce forests on the western half of the range requires a higher average annual burn rate than in eastern parts of the range where pine is not common. Pine does not occur within about 50 km of the tundra east of about 107°W.

Remarks. No preference or avoidance by caribou for pine, mixed pine/spruce, or spruce forests was evident in this study. The advantage to caribou of a park-like open under-story in pine forests about 81-150 years post fire may be offset by ingestion of pine needles that litter the forest floor. An open under-story is a result of lower branches dying and in many cases breaking off. The open forests are conducive to lichen growth in an almost continuous mat. Barren-ground caribou seem to prefer to feed in such open forests where lichen forage is abundant and predators are easily detected.

Recommendation 18. *If numbers of caribou are to be optimized, then a long-term goal subject to cost-benefit analysis should be to maintain at least 75% of the usual range of the Beverly herd in forests older than 50 years.*

Conclusion 19. Assuming fire management is necessary, there should be varying geographic goals for percentage of range that is maintained at ages suitable for grazing by caribou. The ecoregions and ecodistricts of Bradley et al. (1982) are probably the most appropriate management units.

Data. Ecoregions and ecodistricts are in Figure 12. Ecodistricts may be subdivided into smaller units as more information becomes available.

Remarks. Any fire suppression goals should be based on priority zones in this report and adjusted according to caribou management goals, by logistical and cost factors, and by other fire management considerations.

Recommendation 19. *Assuming that caribou managers adopt measures that will increase size of the Beverly herd, percentage of caribou winter range that should be maintained in ages older than 50 years in ecodistricts is as follows: Mid Boreal 50%; High Boreal (HB) 2, 50%; HB 1, 60%; Low Subarctic (LS) 1, 60%; LS 2, 70%; LS 3, 70%; LS 4, 50%, and High Subarctic 5, 80%. Ecodistrict LS 2 probably should be subdivided into LS 2a southeast of a straight line through Doran and Manchester lakes and LS 2b northwest of that line. Fire management goals are 75% and 60%, respectively in zones LS 2a and LS 2b. These goals presume a larger herd than present but management to produce a maximum sustained yield is not recommended.*

Conclusion 20. Fire management decisions cannot be made in isolation; they must be matched to management plans for the Beverly and other caribou herds, management plans for other wildlife species, and, preferably, integrated resource management plans. There must be an ecosystem approach rather than a single-species approach to caribou winter ranges.

Data. "Long Term Management Plan for the Beverly and Kaminuriak Herds of Barren-Ground Caribou." (Beverly and Kaminuriak Caribou Management Board, October 1986). There is no evidence that present fire rates and resultant burn mosaics are now limiting the population of caribou.

Moose make greatest use of forests 21-40 years after fire (**Fig. 17**) (Thomas 1991b). Should there be zones where fire management is aimed at producing relatively dense moose populations with a provision for occasional use by caribou? A productive ratio might be 25% old growth, 25% mature, and 50% in young forests but those proportions are not sustainable without prescribed fire. The ideal mosaic of forest ages and their distribution for moose in the study area is not known. A mix of 10-30 year burns with old growth should produce the highest density of moose. Such mosaics are rare and temporal (fleeting).

Remarks. Some key questions respecting management of caribou are: (1) Will the Beverly herd be managed in future and, if so, at what population level? (2) Is it a management goal to attempt in the long-term to re-establish caribou on regions of winter range little used in the past 15 years where high burn rates prevailed?

Ideally, the herd should be managed at a level necessary to provide sufficient

Figure 17.

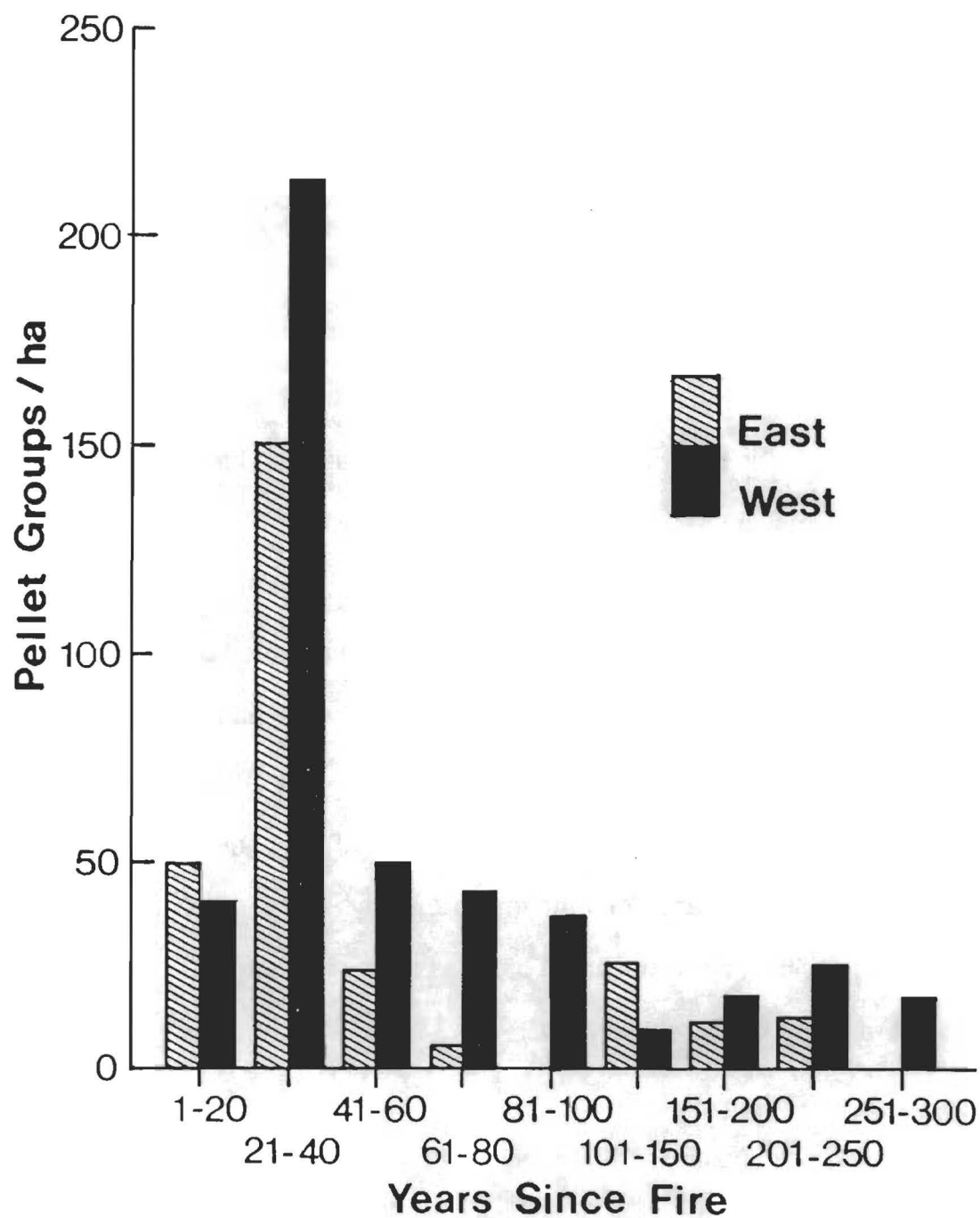


Figure 17. Densities of moose pellet groups at 20-year (to 100 years) and 50-year intervals after fire in taiga west and east of $107^{\circ}30'W$.

caribou to meet needs of all users. Experience has shown that about 5% of caribou over 1 year of age can be harvested annually from barren-ground caribou herds that use tundra and forest range in North America. Therefore, about 200 000 adult caribou are needed to supply 10 000 caribou presently needed annually by people in the range of the Beverly herd. But what of the future? Will settlements continue to grow at the current annual rate of about 3-4%, which results in a doubling of population every 18-24 years? Will a larger user population still require caribou as a main meat source or will other foods be substituted? If user populations continue to grow at the present rate and caribou continues to be the main meat source, then 400 000 caribou will be needed in 15-20 years and 800 000 caribou in 30-40 years. Estimates of caribou numbers are grossly low and all these estimates must be increased. Perhaps no one can answer these questions but caribou managers and advisors should be aware of them and prepare for not only a need to manage caribou but a need to manage caribou intensively.

Several constraints preclude management of caribou now: (1) caribou population estimates, on which management should be based, are of unknown accuracy and confidence limits are usually 40-60% of the population estimate; (2) harvest data are too inaccurate for effective caribou management; (3) addition of 1-year-old caribou to the Beverly population is measured almost annually but with no sampling design to account for non-random distribution and with unknown precision; (4) mortality of caribou from natural causes such as wolf predation, parasites and diseases, and accidents is not known and can only be estimated; and (5) herd users are not as yet prepared to accept management options such as quotas, restrictions on sex of caribou that may be killed, or restricted harvest seasons.

There are few management options: (1) harvest reductions; (2) predator (mostly wolf) control; and (3) habitat protection. Hunters want harvest controls to be a last resort after all other measures are tried. Wolf defenders want wolf control to be a last resort and then only to save an endangered species.

A second question of herd distribution can be considered almost in isolation of caribou management because size of the Beverly herd may influence distribution to some unknown extent. Realistically, desired distributions should not be larger than the historic "usual" winter range of the herd.

Management plans are needed for other wildlife species and then a fire management plan can be based on an integration of plans for various wildlife species, and other factors (costs, logistics, manpower, etc.), and variability in occurrence of natural fire.

Recommendation 20. *Fire management plans as they relate to caribou must be based on caribou management plans that contain clear goals concerning population size and trend and desired winter distributions of caribou herds. The Beverly and Kaminuriak Caribou Management Plan should be revised to reflect such goals.*

Conclusion 21. If fire management is deemed necessary to satisfy caribou management goals, there is need for priorities on where to control fires and priorities regarding intensity of control measures.

Data. Conclusions 1-20 and supporting data. Previous studies of caribou and effects of fire on them and their range.

Remarks. Priorities will range from nil (where suppression is not required) to areas where all fires should be fought. If several fires break out in one storm, fire managers need to know which ones have greatest priority for their limited crews. There follows a series of conclusions and recommendations regarding priorities for fire control based largely on caribou and user considerations. No consideration is given to fire fighting logistics, settlement protection, and little consideration to other animal species. Those aspects, although important, are not considered because they are beyond the scope of this study or there are inadequate data.

Recommendation 21. *Priorities for fire management should be based in part on: (1) herd security and conservation based on past use of range by caribou, including migration routes, and frequency of use; (2) ensuring or facilitating access to wintering caribou by subsistence users; (3) variations in burn rate across the range; (4) present age and size distributions of forest stands; (5) forest cover types; (6) bedrock and terrain characteristics; (7) long-term variations in snow depths; and (8) fire suppression efficiencies and costs.*

Conclusion 22. To ensure future conservation of the Beverly herd, a core area of the herd's winter distribution should be managed such that at least 50% of that area is in successional stages older than 50 years. Of course, a higher proportion must be maintained in ages >50 years if a management goal is optimum sustained yield of caribou.

Data. "Core winter range" is defined as portions of range that are occupied at some stage of winter almost every year and receive heavy use in most winters. Core range has shrunk progressively from the 1940s through the 1980s (**Fig. 18**). This area is based on knowledge about usual winter distribution of the herd since about 1948. Based on distributional data to about 1960, core range of caribou herds included a large area of northern Saskatchewan south to about 58°N and range further to the west in Alberta and NWT than is presently described.

Under certain assumptions, 61% productive range (older than 50 years) corresponds to an average annual burn rate of 1% and a fire cycle of 100 years (Table 1). In practical terms, within a defined area, it is easier to track proportion of forest younger than 50 years and attempt to maintain its proportion at less than 50%.

Remarks. This conclusion relates to a bad case scenario that could result if fires continue to burn 15-25% of range each decade or the herd declines through a combination of hunting, predation, disease, and global pollution. The theory is that as a population decreases in size it contracts its range into a core area. This may or may not happen with a migratory species such as barren-ground caribou.

Recommendation 22. *To safeguard the Beverly herd of caribou, high priority should be given to maintaining at least 50% of forests in the core caribou winter range, as defined in Figure 18, in age classes older than 50 years.*

Figure 18.

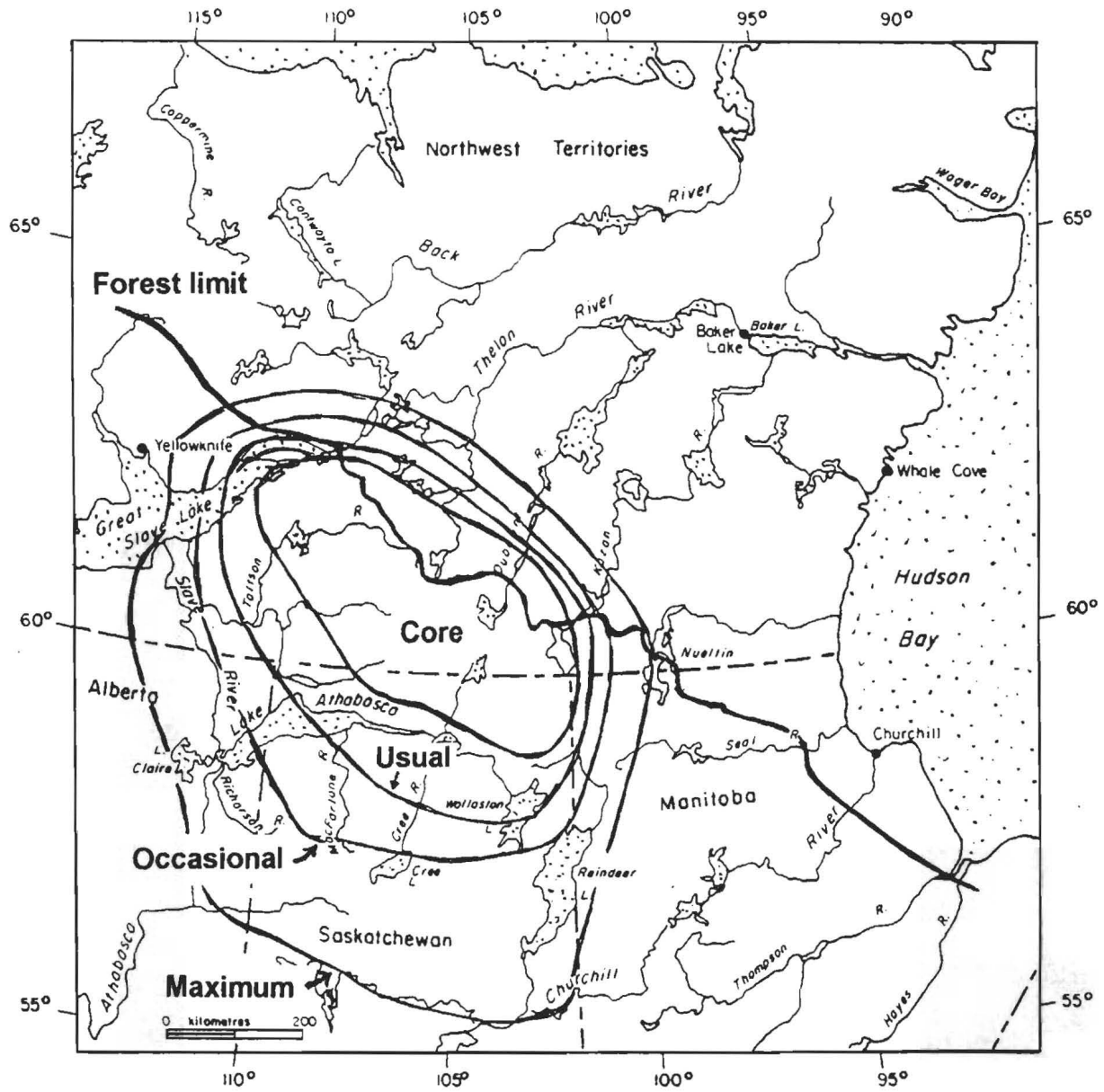


Figure 18. Categories of use by caribou on forested winter range of the Beverly herd since about 1940. Only core range in Saskatchewan was used from 1982-83 to 1986-87.

Conclusion 23. Retraction in the south and west of the maximum, usual, and core winter range dictates that fire management will be necessary in those areas if caribou managers want to restore caribou to their former range.

Data. Maximum and "usual" forested winter range of the Beverly herd decreased in size in the 1980s compared with the previous four decades (Fig. 18). Loss of range to fire was the most apparent cause. However, greater hunting mortality in segments that traditionally wintered south of the communities of Uranium City, Fond-du-Lac, Stony Rapids, and Black Lake in Saskatchewan may have been a contributing factor. If combined hunting and natural mortality is greater than addition of calves to a herd segment, that sub-population will gradually disappear. Other segments may increase in size at the same time. There is little suitable range for caribou south of Lake Athabasca and the Fond-du-Lac River because of a high burn rate in the past 40 years. There appears to be little suitable range south of the Athabasca Plain in Saskatchewan. Energetic costs of migrating that far south and the added hunting mortality that occurs (e.g., the large kill in 1979-80) may contribute to caribou not using such range.

The usual range in the 1980s corresponds closely to the Transitional Forest Zone (Rowe 1972) except for western portions of that zone between Athabasca and Great Slave lakes. It also corresponds closely to the Taiga Shield Ecozone (Fig. 1) (Environment Canada 1986), ignoring its northern boundary. The northern limit of Taiga should be the limit of continuous forest, perhaps defined as areas where trees >3 m in height cover >50% of land surface. The northern limit of taiga as mapped, corresponds approximately to the "limit of trees." This limit usually bounds isolated patches of scrubby white spruce in favorable growth areas such as in the lee of

eskers and in river and stream valleys. The Shield appears to be better caribou winter range than non-shield areas to the south. There are many possible reasons including: (1) higher frequency of lakes on the Shield (caribou prefer to travel, rest, and avoid predators on lakes); (2) shorter migration distances (there are energy costs to migration); (3) few settlements on the Shield in northern Saskatchewan (most are on the periphery of the Taiga Shield); and (4) higher burn rates and larger blocks of range too young to produce lichen mats used by caribou.

Remarks. Data on range use before 1982 are sporadic and incomplete. They do not permit an objective comparison between use in the 1980s and in earlier years. There is no reason to believe that herd size has changed significantly in the past 35 years, except for minor fluctuations. Various counts from 1948 to the present are subject to large errors and large confidence limits. This point is raised because some biologists believe that large herds will occupy large ranges and as a herd declines in size the usual range occupied by it will shrink. The theory may have some validity but several exceptions could be listed if space permitted. For example, size of the Beverly herd in the 1980s (listed at 164 000, 264 000, and 190 000 in 1982, 1984, and 1988, respectively) may have been larger than in the 1940s and 1950s when the herd ranged as far south as the Churchill River in Saskatchewan and it crossed the Slave River (Banfield 1954, Kelsall 1968).

Recommendation 23. *Protection of remaining forests over 50 years of age may be necessary to hasten return of caribou to former ranges in northern Saskatchewan and western NWT. Otherwise it will be 2020 at the earliest and more likely 2030 before caribou use areas burned since 1970. Whether fire management can be effective in such areas must be assessed by fire managers in view of their resources and priorities throughout their jurisdiction.*

Conclusion 24. The Athabasca Plain, a Precambrian sandstone area of northern Saskatchewan, should be viewed as potentially excellent caribou winter range but undependable because of its short fire return interval.

Data. The Athabasca Formation occupies an area of 100 000 km² in Saskatchewan (Schreiner et al. 1981) and it extends into Alberta. A short average fire return interval of about 40-50 years on range on the Athabasca Sandstone region (Carroll and Bliss 1982) south of Lake Athabasca and the Fond-du-Lac River (**Fig. 19**) reflects severe burning in several years since 1969. The sand dunes region south of Lake Athabasca was intensively studied in the 1970s including vegetation mapping.

Remarks. The Athabasca Plain is not secure caribou winter range and its frequent use in the 1940s and 1950s and perhaps in the first half of this century may have been due to favorable weather that permitted large blocks of forests to grow older than 40-60 years and become good caribou feeding areas.

Recommendation 24. *In Saskatchewan, higher priority for fire management should be given to range on the Taiga Shield than to the Athabasca Plain (Athabasca Sandstone Formation). There has been consistently greater use by caribou of the Shield and an extremely short fire return interval in predominantly pine forests growing on the Athabasca Plain preclude effective fire control. Protection should be extended to the Athabasca Plain if caribou management goals change towards optimum sustained yield and fire managers develop techniques to control fire where there are few natural barriers to fire except earlier burns. Within the Taiga Shield, highest priority should be extended to blocks north of each of the major communities and centered on major traditional travel routes to the NWT.*

Conclusion 25. Slave River Lowlands south and west of the Taiga Shield (Precambrian Shield) and a Transitional Zone (**Fig. 20**) along the periphery of the Shield should be managed for moose, bison, and furbearers rather than for caribou.

Data. Lowlands habitat within the primary study area is more suitable for moose and bison than caribou. Wet areas with good production of coarse sedges and shrubs dominate the landscape. Dry upland sites suitable for lichen production occupy a small proportion of the area. Moose numbers are relatively high in the region; use by caribou is low and infrequent. According to J. Schaefer (pers. comm.) much of this lowland region burned about 1950. There are stands of pine and spruce in alluvium beside the Slave River but lichen growth is sparse. The lowland area is extensively hunted by NWT General Hunting Licence Holders in Fort Smith. There are several productive trap lines in the area.

A transition zone between Precambrian Shield and Cambrian bedrock is characterized by a high burn rate, abundant deciduous tree species on uplands, excellent moose and beaver habitat, and poor caribou habitat. The region is productive for furbearers and several trap lines occur in the zone. Production of browse used by moose is high in regenerating forests 5 to 30 years after fire. Moose also require some old forests for cover, thermal, and escape habitat.

Recommendation 25. *Fire management in the Slave River Lowlands and an adjacent transitional zone (Fig. 20) should be directed towards production of moose and furbearers and not caribou. A high burn rate (1-2% annually) and small burns may be the best management objective in that region.*

Figure 20.

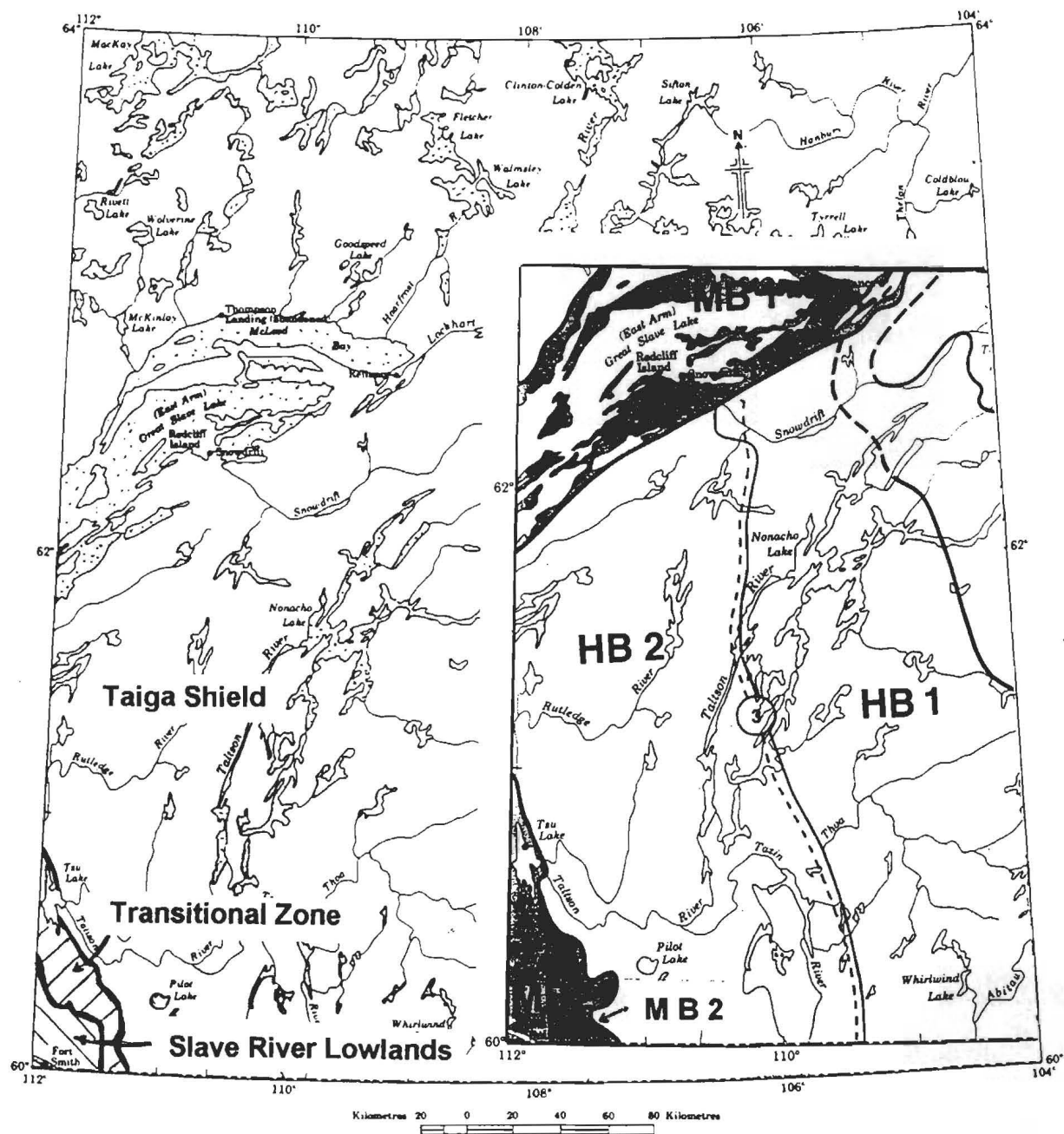


Figure 20. Slave River Lowlands and a transitional zone between the lowlands and Taiga Shield where fire management should not focus on caribou. This zone is similar to Mid Boreal Zone 2 (Bradley et al. 1982).

Conclusion 26. Until more information on fire-caribou relationships is obtained, fires should not be controlled in regions where less than 12.5% of winter range has burned in the last 50 years, that is, the average annual fire rate is below 0.25% annually.

Data. Fire maps and data from aerial transects.

Remarks. Mapping of burn rate zones in **Figure 21** is provisional because boundaries are based on a subjective evaluation of burns in the region and on preliminary data from aerial transects of habitat types and ages. The area with a low fire rate is characterized by relatively thick till, elongated drumlinoid ridges, spruce dominated forests, and numerous lowlands and bogs that serve as natural fire breaks. Flammability of such forests appear to be low and fire spread rates must be low. Therefore most fires in that area remain small. Contributing factors are poor drainage, higher than average snowfalls, and a shorter snow free season than west of 108°W.

A cautious note. Much of the area involved apparently was burned about the 1750s and a fire could sweep the zone again with extremely dry weather conditions and a low water "table." The only fire breaks are lakes, the few recent burns, and lowland wet areas between the upland "islands." Lowland areas will burn if they become sufficiently dry. When such conditions occur, the likelihood of controlling fire in large expanses of old forest is low or none.

Recommendation 26. *Fires should not be controlled in regions where the average annual burn rate is low (less than 0.25%). The zone so indicated (Fig. 21) is provisional and can be defined quickly with a geographic information system (GIS).*

Figure 21.

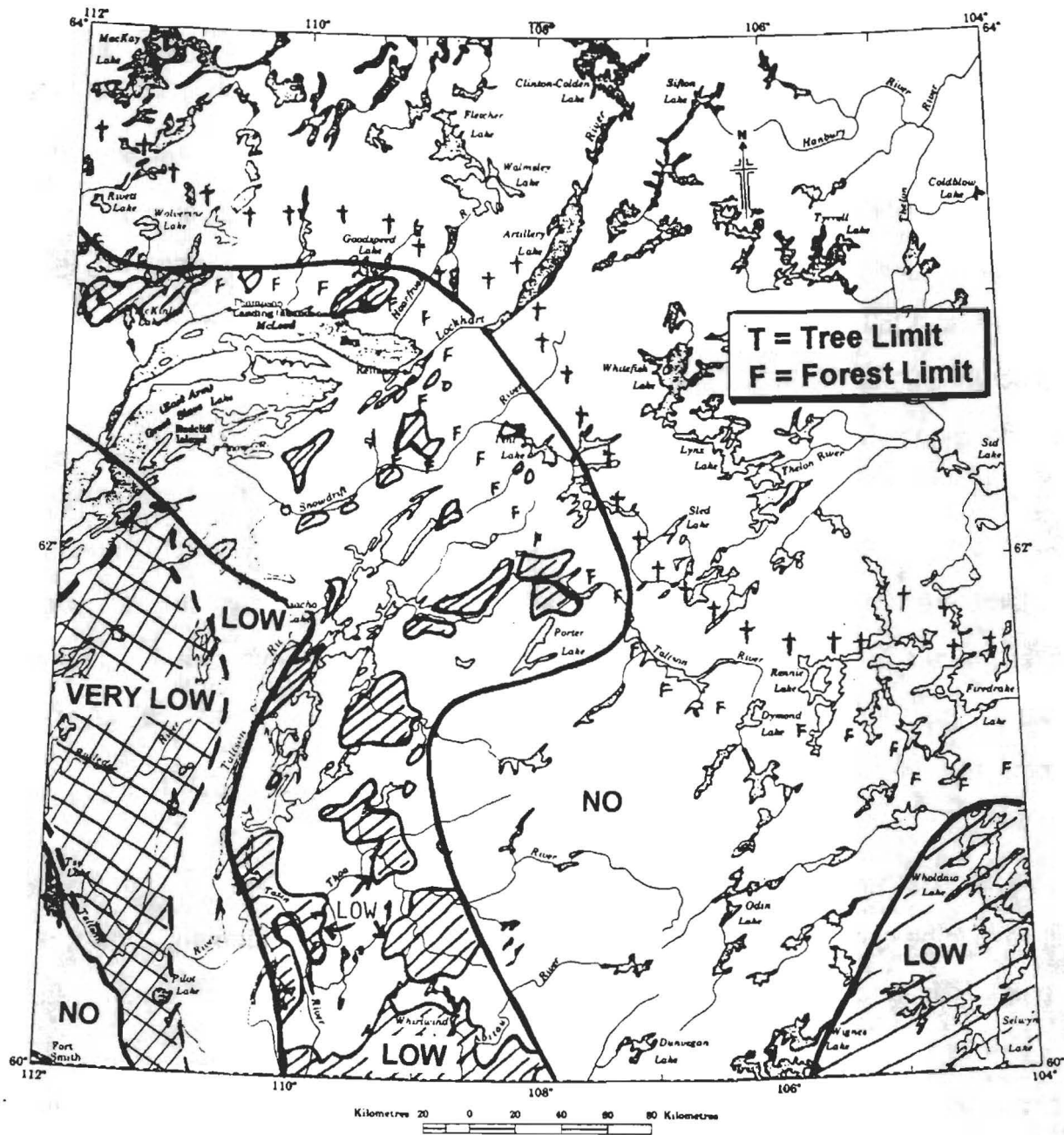


Figure 21. Regions of no, very low (cross hatched), and low (hatched) priority for fire suppression based on multiple factors listed in recommendations 1-32.

Conclusion 27. The cause of high and very high fire rates has more to do with size of burns than frequency of burns. Burns tend to be largest in regions with high burn rates and smallest in regions with low burn rates. Control of fire will be difficult when burns are large.

Data. Burn maps and observations. Previous work, e.g., Johnson and Rowe (1975) found that number, size, and frequency of fires decreased towards tree line. Areas with high and very high burn rates experienced enormous burns from 1905 to 1935 and 1970 to 1980. Large burns occurred southwest of the primary study area in 1981 and southeast of it in 1973. There appears to be a progression of large fires to the east starting in 1979. In 1980, 1984, and 1989, large fires occurred east of 108° W where few had occurred for at least 50 years. Checks of forest ages between 104° W and 108° W indicated a large number in the range 225-235 years. It appears that large areas burned in the 1750s. If this happens again in the next 30 years, the Beverly herd could be severely affected. Forest age estimates beyond 300 years are crude because the oldest trees have died and are rotting on the ground. Duff layer depths and soil characteristics help to identify ancient forests.

Remarks. No consideration is given in this report to costs of fire-fighting although it will have to be considered when formulating priorities for fire management. For example, it is far cheaper to suppress fires close to communities than in distant area.

Recommendation 27. *Assuming that priorities must be placed on fire management and that efficiency of control will decrease from regions with low burn rates to regions with high burn rates, then zones of priority can be established that are based on burn rates. Highest priority should be placed on regions with moderate burn rates and lowest in region with very high burn rates (Fig. 22).*

Figure 22.

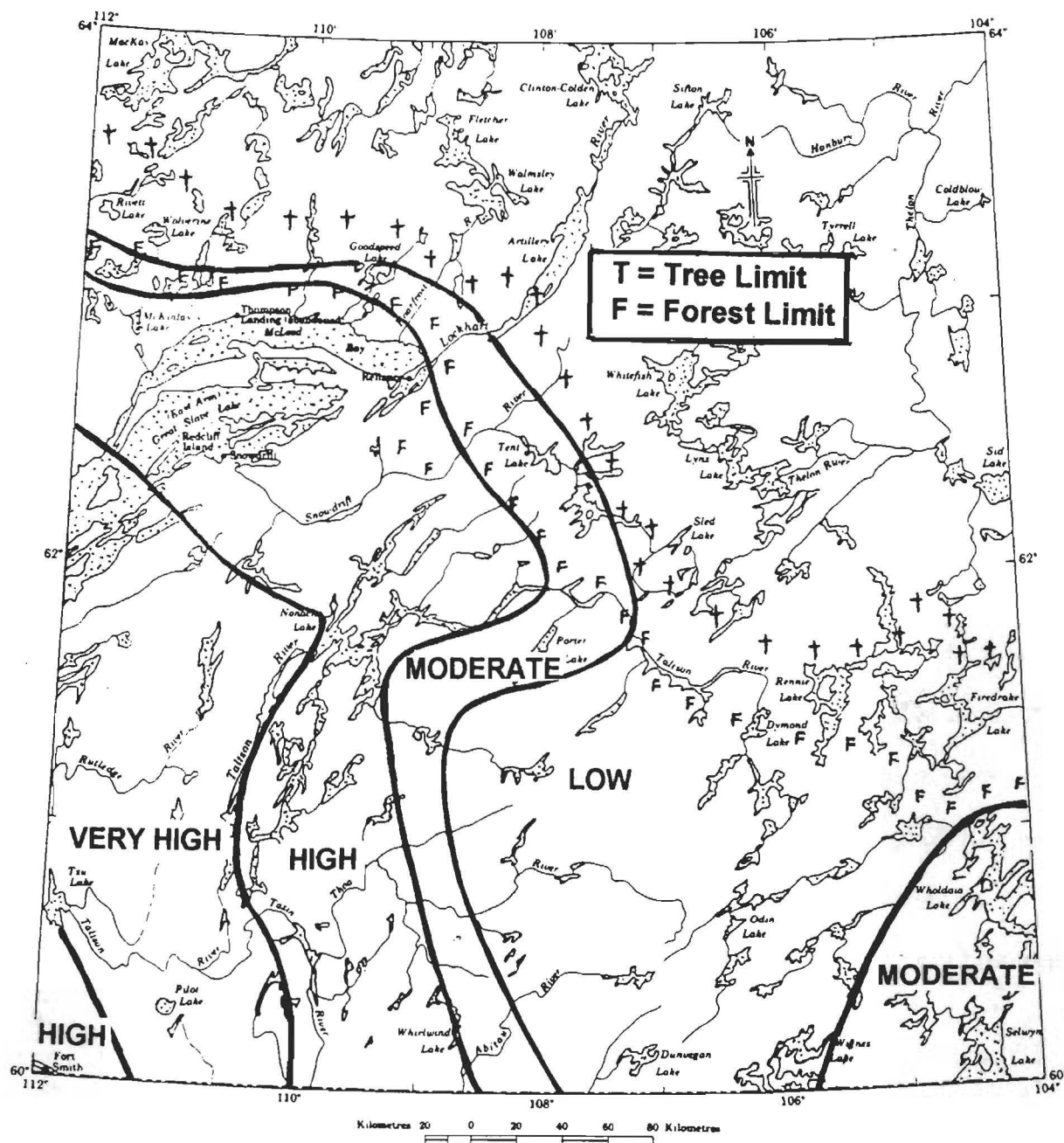


Figure 22. Subjective evaluation of average annual burn rate categories based on burn maps and forest age distributions: low = <0.5%, moderate = 0.5-1%, high = 1-5%, and very high = >5%.

Conclusion 28. Use of forested winter ranges in the NWT appears to be influenced directly or indirectly by surface materials in that caribou seem to prefer regions covered with till or alluvium over regions with exposed bedrock.

Data. Field work in summers 1983 through 1986 in the Nonacho Lake region. Aerial observations made in winters 1982-83 through 1986-87. **Figure 23** is a map that attempts to further define till and drift thicknesses somewhat differently than that mapped by Bradley et al. (1982).

Remarks. Trees are stunted on tops of hills where bedrock is exposed. Fruticose lichen mats usually are patchy on exposed bedrock. Lichens quickly dry unless there is some soil or moss cover. Sparse cover over bedrock permits drifting of snow and formation of hard layers in snow. Cover usually is too open for best production of *Cladina* spp. Travel by caribou over rough exposed bedrock is more difficult and hazardous compared with smooth till. Thus, areas covered by till are better winter range than areas of exposed bedrock and several factors contribute to that difference. Fruticose lichens preferred by caribou grow best in uniform, open forests on nutrient-poor sandy soils. Caribou select habitat at several scales: regional, forest type, and feeding site. Surface materials and soils influence habitat at all three scales.

Recommendation 28. *Any prioritization of fire management should give lower priority to regions with high proportions of exposed bedrock and shallow drift than regions with moderate and thick surface till or drift. Lower priority should be given to control of fire on bedrock than on till (Fig. 23).*

Conclusion 29. Barren-ground caribou is basically a tundra species and when it ranges into forests, it prefers open spaces and open forests.

Data. Under long term average conditions, use of forested winter ranges is beneficial to caribou. When in the forest, it spends much of the time in open spaces (lakes, streams, and meadows) and in open forest types. The major advantages are increased range size, more-favorable feeding conditions in forests in some winters, and protection from cold winds. A preference for open forests (Low Subarctic) over more-closed Boreal Forest probably relates to lichen growth differences, visibility of predators, shorter migration routes, and differences in hunting pressure. Some barren-ground caribou remain on tundra year round, but none remain in forests in summer. The most-commonly used winter ranges are within 200 km of forest limits, and periodic excursions onto tundra in winter are more common than was previously recorded.

Remarks. The Taiga Shield ("Transitional Lichen Forest") is used in all years, even in the occasional winter when the Boreal Forest zone is used as winter range. Of course it must be traveled through to reach the Boreal Forest.

Recommendation 29. *Management of fire in the taiga (Low Subarctic and High Boreal Ecoregion of Bradley et al. 1982) should be given priority over management of historic ranges in the Mid Boreal Forest Ecoregion and higher priority be given in Zone 1 than in Zone 2 of the High Boreal Region mapped by Bradley et al. (1982).*

Conclusion 30. Forest stands younger than 50 years are (1) little used by caribou at any season and especially in late winter, and (2) their ignition index and flammability is low compared with older stands.

Data. Field observations and Figure 13. Young pine forests usually have a high density of trees and passage through them is difficult. Visibility is poor. There are few openings where lichens can flourish. Rowe et al. (1975) and Johnson (1979) noted that fire hazard increased with age of stands. Field observations suggest this observation certainly is valid in the study region east of 110°W. Most fires appear to start in old forests. Many old forests with dark tone in satellite images of the 1970s have burned subsequently.

Remarks. Protection should be placed on forest blocks beginning at age 50 years post-fire because susceptibility to fire appears to be low in stands younger than 50 years. Fires often burn out soon after they encounter stands younger than 50-60 years of age, except in extreme fire conditions (dry and windy) as encountered in the summer of 1979 northeast of Fort Smith. Fire will burn short distances into burns 10-30 years old in the study region mainly because many trees killed in the last fire burn readily after falling and forming a criss-cross pattern.

Recommendation 30. *Low priority for fire management should be given to stands younger than 50 years (Fig. 24). However, fire history maps must be updated periodically to reassess priorities.*

Figure 24.

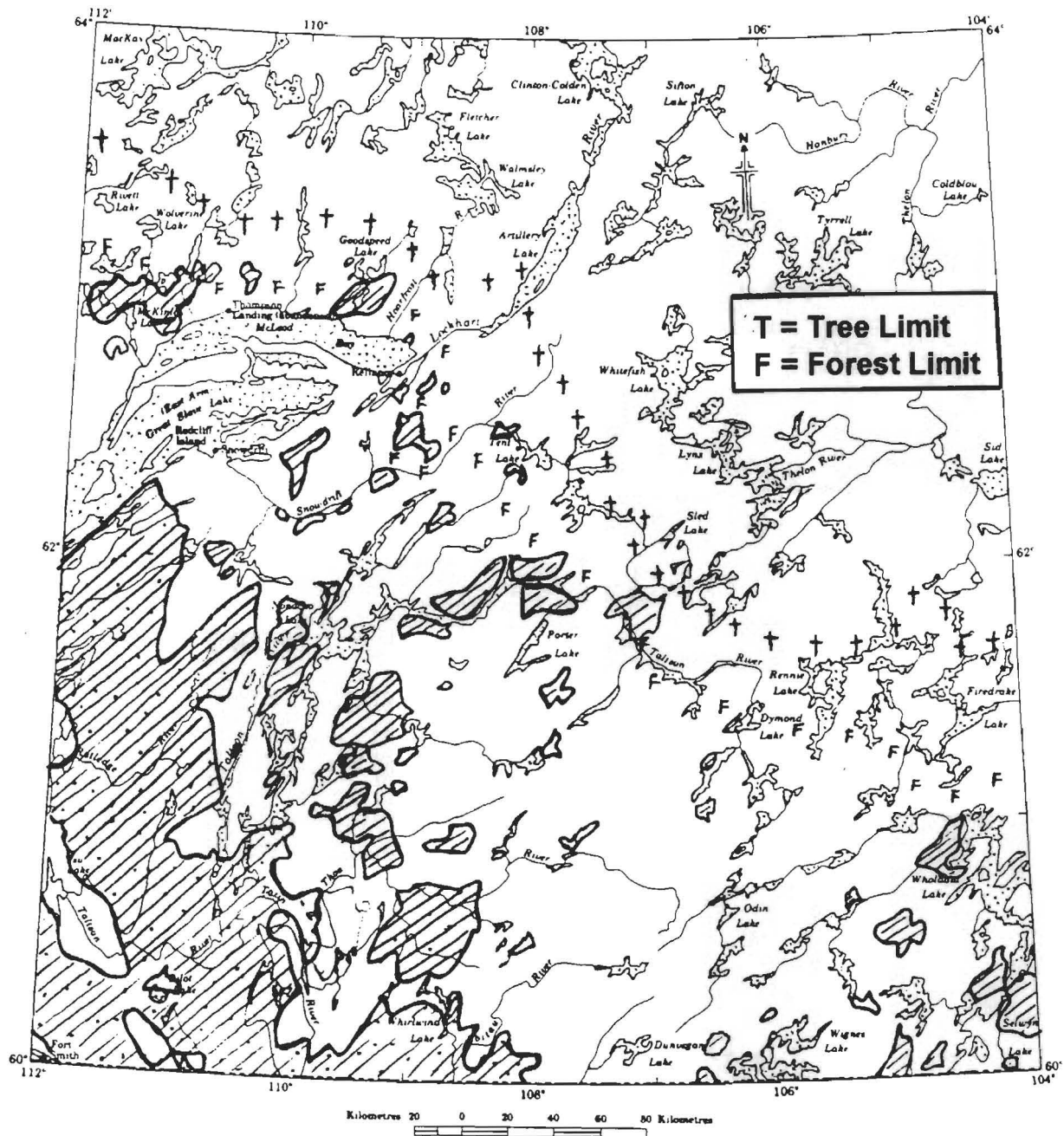


Figure 24. Areas of the winter range of the Beverly herd that were burned between about 1940 and 1987.

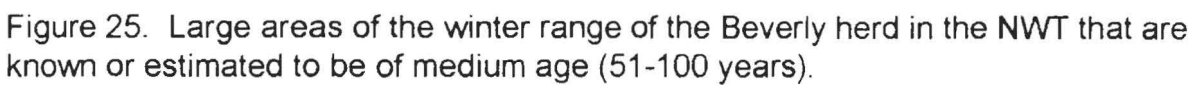
Conclusion 31. Fires should be more easily controlled in forests 51-100 years old than in older ones. Forests that are now 51-100 years old will be valuable to caribou in the next 51-100 years.

Data. Ages of stands where fires started and burned out. Fire maps. Fire fuels appear to increase with time after fire. The main fire fuels near the ground in older forests are lichens. Cover and biomass of low shrubs was about constant with time (Thomas and Kiliaan 1998c). Forests 51-150 years old are valuable to caribou even though use of forests was highest 151-250 years after fire. Productivity of caribou lichens was about constant in forests older than about 60 years. Lichen species favored by caribou such as *Cladina mitis* became shorter in old forests as canopies opened and conditions became drier.

Remarks. Forest ages determined from spot checks on the ground were mapped with aid of LANDSAT imagery, aerial photography, and habitat transects that provided estimated ages of forest stands at about 8 km to 16 km intervals throughout forested winter range in the primary study area. They may be grouped by decade for management purposes.

Recommendation 31. *When other factors are equal and decisions must be made about fighting fires in various-aged stands, priority should be given to fires in forests 51-100 years old (medium aged) versus fires in old and ancient forests. Some medium-aged stands mapped to date are in **Figure 25**.*

Figure 25.



Conclusion 32. Large tracts of forests older than 50 years in regions with high burn rates may become important winter foraging areas in the next few years and their continuance as potential winter range provides for maximum winter distribution of caribou under the present burn mosaic. Such areas tend to provide corridors to pockets of productive winter range and they will be "stepping stones" to regions that will return to productive status in the next 10-50 years.

Data. Burn maps and observations. Cover and biomass of lichens in relation to forest age.

Remarks. Large tracts of forests over 50 years old in areas with very high burn rates are, in theory, an unlikely occurrence. They should receive lower priority because fire control is likely to be much more difficult and caribou are less likely to use those areas. Areas with very high burn rates are located in the southern and western periphery of the "usual" range of the herd since the 1960s, except perhaps just south of Great Slave Lake.

Recommendation 32. *Any program of fire management should give high priority to large unburned forests in regions with high or moderate burn rates within the historic "usual" winter range of the Beverly herd. Such areas are mapped in **Figure 26**.*

Figure 26.

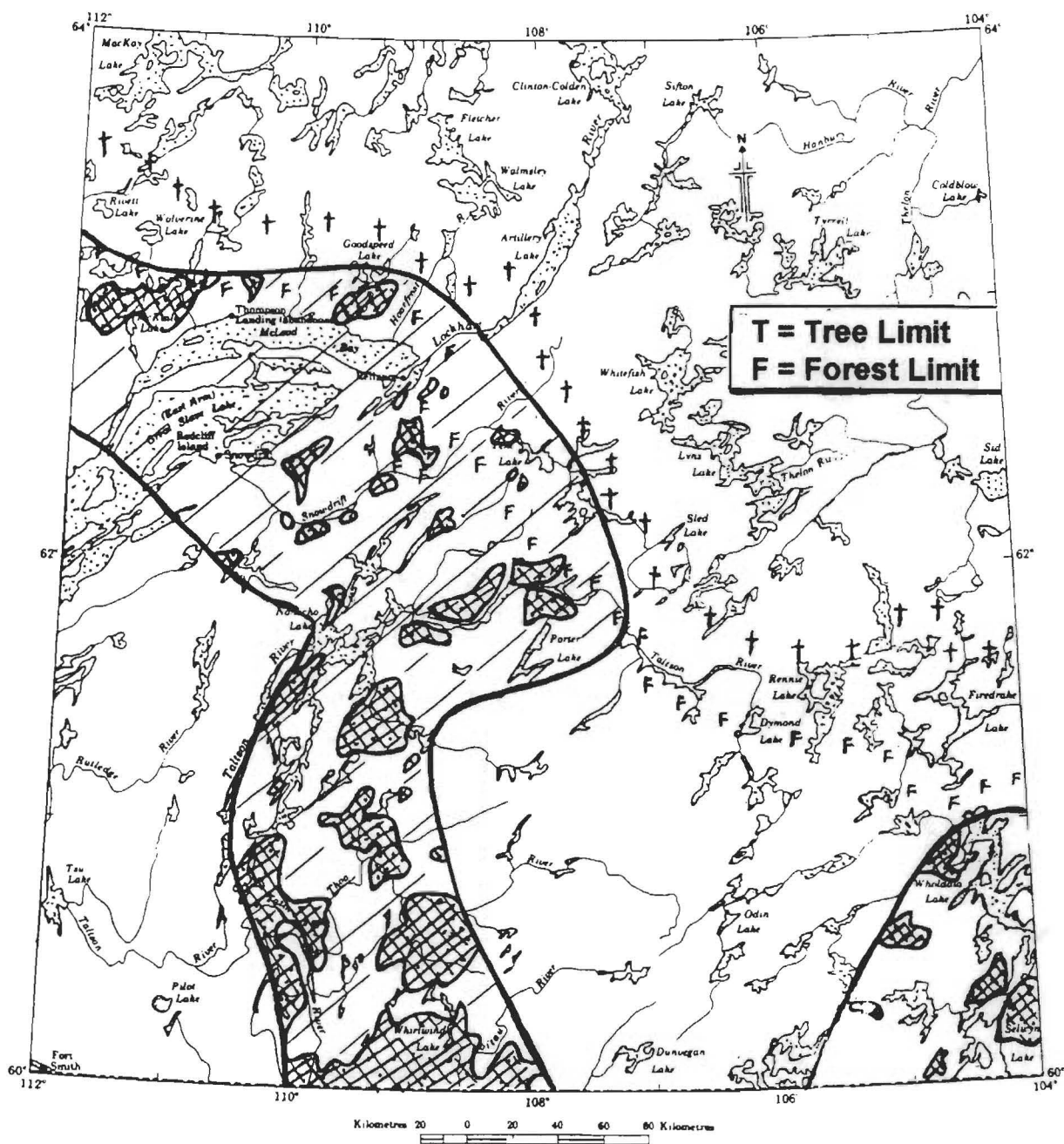


Figure 26. Forests not burned in the last 50 years (hatched), with the exception of recent burns (cross hatched) in a zone of moderate or high burn rates (Fig. 22).

Conclusion 33. Collation of conclusions and recommendations 21 to 32 is a basis for setting priorities on where fires should be controlled on winter range of the Beverly herd in the NWT, provided that future caribou managers deem it is necessary.

Data. The weight that each factor is given in setting priorities is somewhat arbitrary with present knowledge. Weighting of factors is based almost entirely on biological considerations and logistical/economic factors will have to be added by others.

Remarks. An objective system for establishing priority zones could be developed by giving points to various map units (e.g., ecodistricts) for each factor, weighting factors, and producing an overall rating system. For example, on a scale of 0-10, the "core" use area could be given 10 points, the "usual" use area 6 points, the "occasional" use area 4 points, the "historic maximum" use area 2 points, and other areas 0 points. The same would be done for e.g. snow depths, fire frequency, and many other factors. Then each factor could be weighted. For example, traditional use of range might be given a weighting factor of 5, snow depths a factor of 3, etc. Thus, core winter range would contribute 50 points towards a final relative rating of zones. This technique was not used because of technical difficulties, insufficient scale of biophysical mapping, and inadequate data for relative ratings within and among factors. The priority rating system therefore is based on a subjective collation of identified factors.

Recommendation 33. *Assuming that fire management is expanded on caribou winter range of the Beverly herd, priority should be based on ratings mapped in Figures 27, 28, and 29.*

Addendum: Priorities here are based on caribou range in isolation from hunters and are dependent on future recommendations of caribou managers.

Subsequently, fire suppression priorities based on local priorities, fire history, and goals for proportions of forests older than 50 years were adopted (Beverly & Qamanirjuaq Caribou Management Board 1994a, 1994b, Thomas & the Board 1996).

Figure 27.

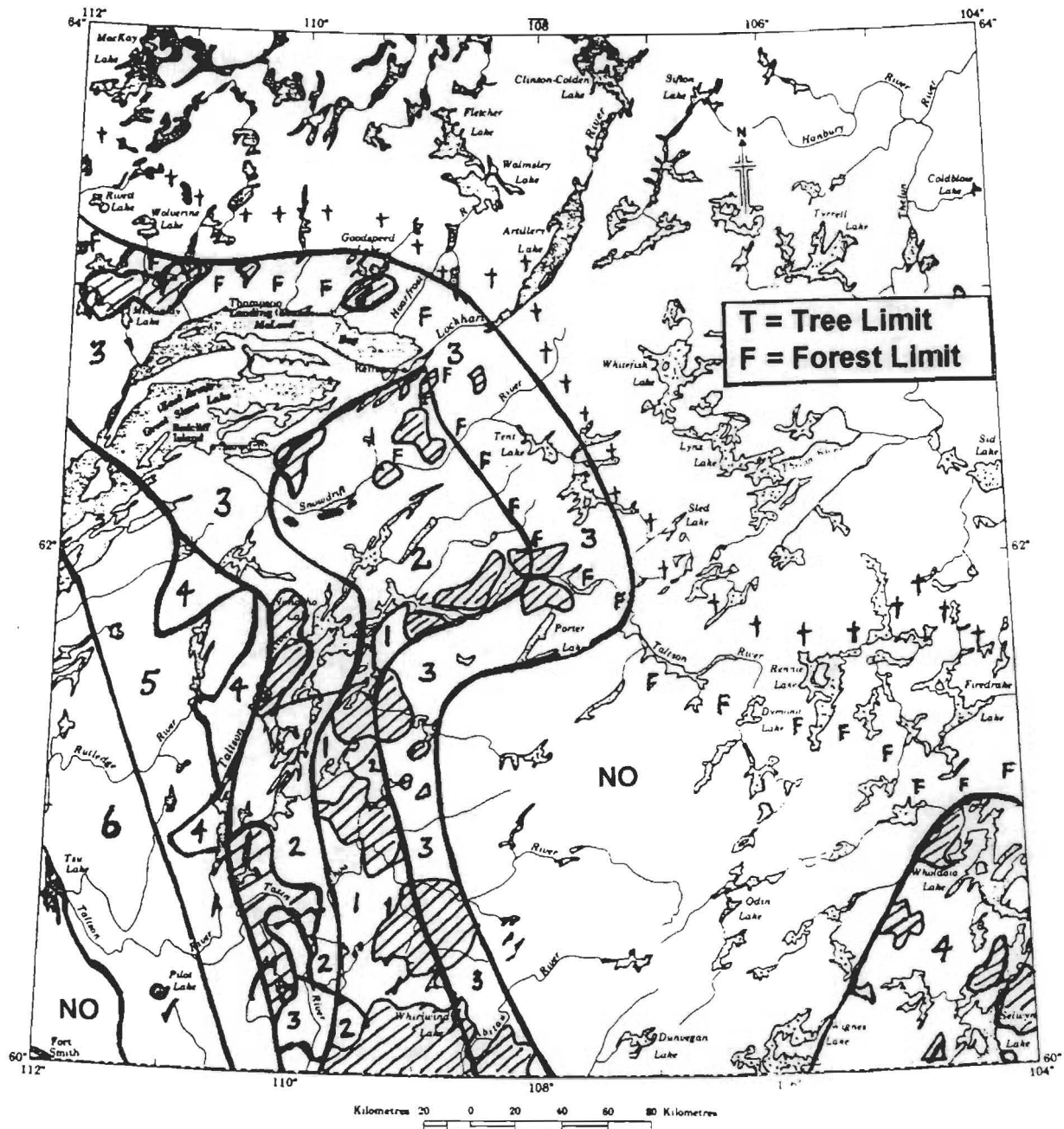


Figure 27. Priority ratings (# 1 highest) for fire suppression in the next few years with the present burn pattern based on conclusions 1-32.

Figure 28.

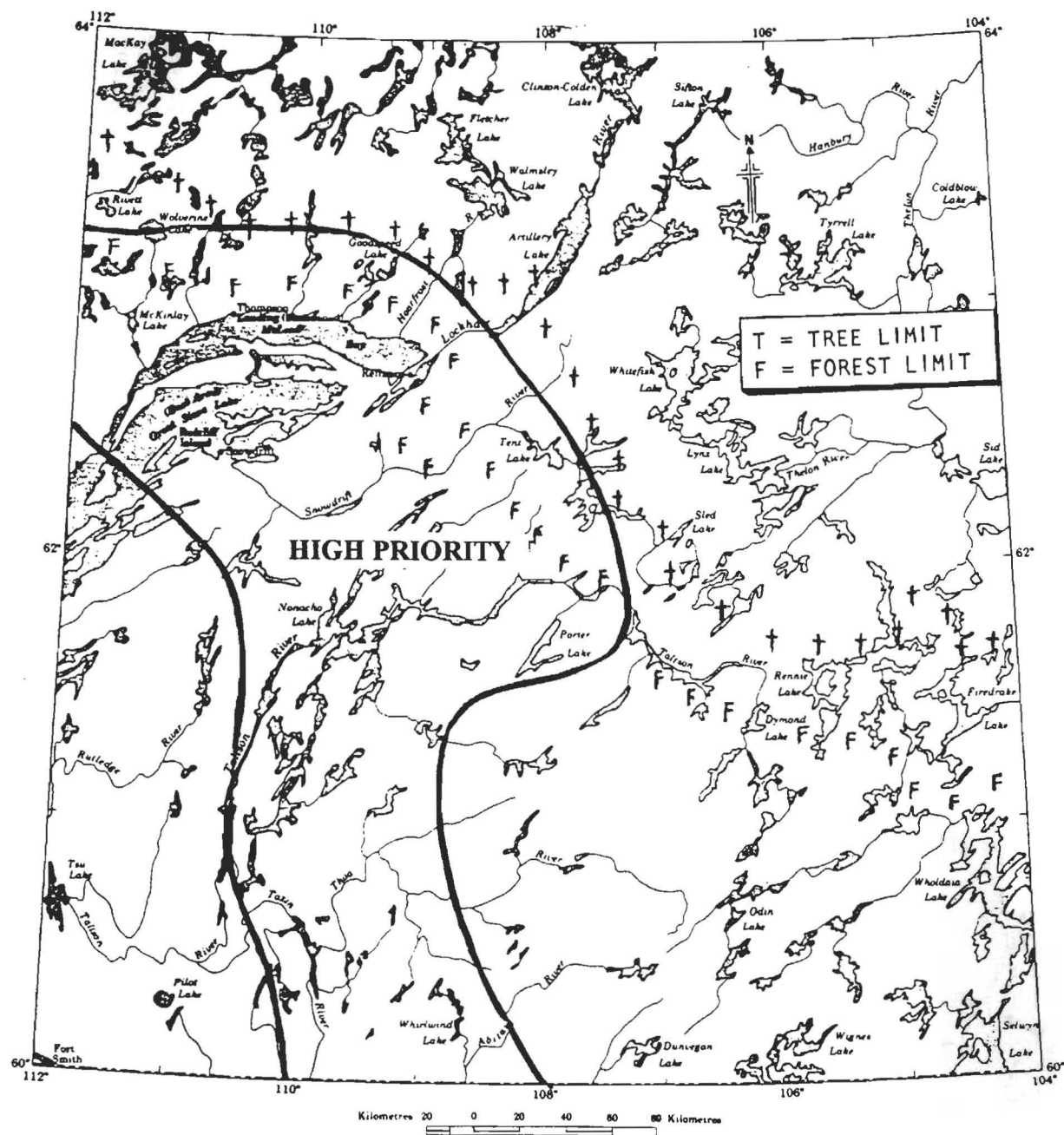


Figure 28. Generalized high priority areas for fire suppression if it is deemed necessary by caribou managers in future. Enclosed within the area are low priority areas (Fig. 27).

Conclusion 34. More data are needed on fire behavior in the primary study region, such as fire susceptibility and flammability of stands of various ages and cover types, ignition points, lightning frequencies, fire intensities and useful indices of intensities, burn directions, and spread rates in various habitat types and under various weather conditions, burn completeness, causes of extinguishment, and long-term effects of suppressing fires.

Data. Many fires were noted to burn out in young and medium-aged stands. Therefore, effective fire control over vast areas, if possible, could lead to extensive areas of old forests where control would be difficult in severe fire years such as 1979 and 1989 in the study area.

Remarks. The distribution, sizes and proportion of unburned "islands" within burns is a clue to fire intensities. Density of standing dead trees is another indicator. Crown fires under high wind condition is indicated by lines of live and dead trees indicating differential burning intensities along the front of a fire. Direction of a burn is indicated by the fire "lines" created under windy conditions and unburned patches in the lee of lakes. Fires in 1970 were particularly intense, leaving signatures in satellite imagery that were comparable to younger burns.

Recommendation 34. Studies of behavior of natural fires are needed, including those that will provide indices of burn intensity and burn completeness that can be used to map burns for caribou management purposes.

Conclusion 35. There is need for detailed studies of plant ecology in the study area to learn more about relationships among fires, habitat type, terrain, weather, and other factors and their effects on plant succession, cover, productivity, and biomass. Emphasis should be placed on ecology of *Cladina mitis*.

Data. Scotter (1971b), Rowe et al. (1975), Johnson (1979, 1981a, 1981b); Black and Bliss 1978). Kershaw's studies (e.g. Kershaw and Rouse 1971 & 1976) on one habitat type in the Carleton Lake area provided only cover data. Our results from studies in summers 1983 to 1986 only provide field cover and biomass data for upland sites. *Cladina mitis* is the most important forage species for caribou in pine and pine/spruce forests in the NWT, Alberta, and British Columbia. For example, cover of *C. mitis* should be related to sunlight exposure, moisture condition, canopy characteristics, shrub characteristics, surface vegetation, and soil characteristics including pH. A multi-variate analysis may reveal relative importance of those and other variables in the ecology of *C. mitis*. In the humid climate of eastern Canada, *C. stellaris* replaces *C. mitis* as the dominant species used by caribou.

Remarks. Cover and biomass data from this study will provide some insight into successional stages after fire but detailed studies of plant ecology would be valuable.

Recommendation 35. Any studies of plant succession after fire, where cover, biomass, and productivity are evaluated, should be supported and facilitated because such information is needed to define an optimum burn rate that will produce optimum winter range for caribou.

Conclusion 36. There is a need to annually map all burns over 1000 ha (1 km²) on winter range (historical maximum in Fig. 9) and a further need for more data on each fire including ignition point, direction of spread, proportion not burned, and their cover types and topographic class (upland or lowland).

Data. Data needs include a stratification of burns relative to proportions of unburned inclusions. These might include for example, classes "A" (no inclusion), "B" (1-5% unburned), "C" (5-10% unburned), and "D" (11-20% unburned), etc. A further subdivision into upland and lowland inclusions would be useful.

Remarks. A minimum requirement is annual mapping of burns visually, photographically, or using GPS technology. Verification of boundaries and mapping of inclusions by satellite imagery is strongly recommended.

Recommendation 36. *Mapping of all burns larger than 1 km² must continue in order to monitor status of winter range and set priorities for fire management. Burn maps should contain coded data on proportions of unburned inclusions, burn intensities, ages of forests burned, direction of spread, and other useful information such as age of stands where fire burned out.*

Conclusion 37. This study is concerned with fire-caribou relationships. However, any fire management plan should look at effects of fire on a multi-species basis and there is little information on how other species including moose and furbearers respond to various successional stages and mosaics of stands in various successional stages in the study area.

Data. Scotter (1964, 1965, 1971a, 1971b); Miller (1976a, 1976b); Kelsall et al. (1977); Viereck and Schandelmeier (1980); this study. Moose use forest age classes 10 years to 30 years more than others for foraging in taiga. A fire management strategy to produce high densities of moose differs greatly from that for caribou.

Remarks. Moose may become an important alternative meat source in areas of high fire frequency and marginal caribou habitat. However the nutrient-poor sandy and gravelly soils that produce the best conditions for lichen production (e.g., the Athabasca Plain) are poor producers of willows and other shrubs used by moose.

Recommendation 37. *Long-term studies are needed to show relationships between fire-induced successional stages and species other than caribou, specifically moose and fur bearers.*

Conclusion 38. Fat reserves, body weights, and skeletal size of caribou in the Beverly herd should be monitored periodically to assess range quality. Health of the herd in terms of parasites and diseases should be monitored every few years through special organized sampling.

Data. The nutritional status of individuals in the herd can be estimated by measuring body weights and fat deposits on the back, kidneys, or in marrow of leg bones or mandibles. Results for individuals or class groups then would be compared to data in report 1 (Thomas and Kiliaan 1998a). Fat reserves indicate nutritional conditions of caribou in months and even years leading up to sampling. The mandible is easily collected and it yields information on age, sex, skeletal size, and condition. In the mid 1970s, it was found to produce reliable indices of condition in Peary caribou (*R. t. pearyi*) (Thomas et al. 1977) and subsequently it was used as a condition indicator in Alaskan caribou (Davis et al. 1987).

Remarks. Data on weights, fat reserves, and even antler weights can be used to estimate fecundity using relationships established in this study .

Recommendation 38. *Fat reserves of the Beverly herd should be monitored annually through collection of mandibles of caribou killed by hunters and more comprehensive information on weights, fat reserves, skeletal size, pregnancy rates, and health of the herd should be monitored every 5 years through special organized sampling.*

Conclusion 39. If the Beverly herd is to be managed or intensively managed at a high sustainable level, there is need to improve data collection techniques through use of conventional and satellite collars and other modern technology.

Data. Conventional collars have been used successfully in a large number of studies and satellite collars are past experimental stages and fully operational. Global positioning system collars are being developed. Radio collars can provide several types of essential information: (1) definition of seasonal ranges and relative degree of use of specific range areas and habitats; (2) occurrence of herd and subherd emigration/immigration and mixing; (3) rates of natural mortality; (4) causes and timing of mortality; (5) possible reasons for differences in condition, fecundity, and recruitment among herds and subherds (i.e., information on the ecology of caribou); (6) location of aggregations, subherds, and herds for photography of numbers and composition data; (7) behavior in relation to snow, insects, large burns, and other natural features; and to human activities of many types.

Remarks. Management of the Beverly herd is hindered by a perceived inability to use modern techniques of wildlife research. Many advances in knowledge of caribou ecology in the past 10 years have come through use of radio collars.

Recommendation 39. *If the Beverly herd is to be managed in future and particularly if a goal of management is to increase sustainable harvest, then management boards and management agencies must use all available techniques to obtain sound data at reasonable cost.*

LITERATURE CITED (additional references are in Appendix 2).

Banfield, A.W.F. 1954. Preliminary investigation of the barren-ground caribou, Can. Wildl. Serv. Wildl. Manage. Bull. Ser. 1. No. 10A and 10B.

Bradley, S.W., J.S. Rowe, and G. Tarnocai. 1982. An ecological land survey of the Lockhart River map area, Northwest Territories. Ecol. Land Classif. Ser., No. 16., Lands Directorate, Environment Canada, Ottawa. 152pp.

Beverly and Kaminuriak Caribou Management Board. 1986. Executive summary of the long-term management plan for the Beverly and Kaminuriak herds. The Secretariat, BQCMB, 3565 Revelstoke Dr., Ottawa, ON K1V 7B9. 64pp.

Beverly and Qamanirjuaq Caribou Management Board. 1994a. A review of fire management on forested range of the Beverly and Qamanirjuaq herds of caribou. The Secretariat, BQCMB, 3565 Revelstoke Dr., Ottawa, ON K1V 7B9. 64pp.

Beverly and Qamanirjuaq Caribou Management Board. 1994b. Fire management recommendations for forested range of the Beverly and Qamanirjuaq herds of caribou. The BQCMB, 3565 Revelstoke Dr., Ottawa, ON K1V 7B9. 12pp + maps.

Black, R.A. and L.C. Bliss. 1978. Recovery sequence of *Picea mariana* - *Vaccinium uliginosum* forests after burning near Inuvik, Northwest Territories, Canada. Can. J. Bot. 56:2020-2030.

Carroll, S.B. and L.C. Bliss. 1982. Jack pine-lichen woodland on sandy soils in northern Saskatchewan and northeastern Alberta. Can. J. Bot. 60:2270-2282.

Clarke, C.H.D. 1940. A biological investigation of the Thelon Game Sanctuary. Nat. Mus. Can. Bull. 96, Biol. Ser. No. 25.

Courtright, A.M. 1959. Range management and the genus *Rangifer*: a review of selected literature. MSc thesis, Univ. Alaska, Fairbanks. 172pp.

Couturier, S., J. Brunelle, D. Vandal, and G. St-Martin. 1990. Changes in the population dynamics of the George River Herd, 1976-87. Arctic 43:9-20.

Dauphiné, T.C. Jr. 1976. Biology of the Kaminuriak Population of barren-ground caribou. Part 4: Growth, reproduction, and energy reserves. Can. Wildl. Serv. Rep. Ser. No. 38. 69pp.

Davis, J., P. Valkenburg, and D.J. Reed. 1987. Correlations and depletion patterns of marrow fat in caribou bones. J. Wildl. Manage. 51:365-371.

Des Meulles, P. and J. Heyland. 1969. Contribution to the study of the food habits of caribou. Part 1. Lichen preferences. Nat. Can. 96: 317-331.

Environment Canada. 1986. Canada's environment: an overview. Lands Directorate, Environment Canada, Ottawa.

Ferguson, R.S. 1983. Fire history of the Beverly caribou winter range, NWT. Rep. to Caribou Manage. Bd., March 1983. Wildl. Serv., Dep. Renew. Res., Yellowknife, NWT. 21 pp.

Gaare, E., A. Sorenson, and R.G. White. 1977. Are rumen samples representative of the diet? *Oikos* 29:390-395.

Harper, F. 1932. Mammals of the Athabasca and Great Slave Lake region. *J. Mammal.* 13:19-36.

Heard, D.C. 1983. Hunting patterns and the distribution of the Beverly, Bathurst, and Kaminuriak caribou herds based on tag returns. *Acta Zool. Fennica* 175:145-147.

Holleman, D.F. and J.R. Luick. 1977. Lichen species preference by reindeer. *Can. J. Zool.* 55:1368-1369.

Johnson, E.A. 1979. Fire recurrence in the subarctic and its implications for vegetation composition. *Can. J. Bot.* 57:1374-1379.

Johnson, E.A. 1981a. Vegetation organization and dynamics of lichen woodland communities in the N.W.T., Canada. *Ecology* 62:200-215.

Johnson, E.A. 1981b. Fire recurrence and vegetation in the lichen woodlands the Northwest Territories Canada. Pp. 110-114 in *Proc. Fire History Workshop, 1980*. Gen. Tech. Rep. M-81, Rocky Mount. For. and Exp. Res. Stat., U.S. For. Serv.

Johnson, E.A. and J.S. Rowe. 1973. Fire in the subarctic wintering ground of the Beverly caribou herd. *Am. Midland Nat.* 94:1-14.

Johnson, E.A. and J.S. Rowe. 1975. Studies on vegetation and fire in the wintering ground of the Beverly caribou herd. Rep. to Can. Wildl. Serv. 103pp.

Kelsall, J.P. 1960. Co-operative studies of barren-ground caribou, 1957-58. *Can. Wildl. Serv. Manage. Bull. Ser. 1, No. 15*.

Kelsall, J.P. 1968. The migratory barren-ground caribou of Canada. *Can. Wildl. Serv. Monogr. No. 3*. Queen's Printer, Ottawa.

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. Wildl. Serv. Occas. Pap. No. 32*. 56pp.

Kershaw, K.A. and W.R. Rouse. 1971. Studies on lichen-dominated systems. II. The growth pattern of *Cladonia alpestris* and *Cladonia rangiferina*. Can. J. Bot. 49:1401-1410.

Kershaw, K.A. and W.R. Rouse. 1976. The impact of fire on forest and tundra ecosystems. Final Report 1975. ALUR 75-76-63. Arctic Land Use Res. Program. Dept. Indian and Northern Affairs, Ottawa. 54pp.

MacAuley, A.J. 1983. Fire history of the barren-ground caribou winter range, Saskatchewan. Rep. to Caribou Manage, Bd., March 1983. Dep. Tourism and Renew. Resources, Prince Albert, Saskatchewan. 8pp.

Makinow, E. and K.A. Kershaw. 1976. Studies on lichen dominated systems: xix The postfire recovery sequence of black spruce-lichen woodland in the Abitau Lake region, N.W.T. Can. J. Bot. 54:2679-2689.

Manitoba Wildlife Branch. 1983. Incidence of forest fires on the barren-ground caribou winter range in northern Manitoba, 1977 to 1981. Rep. to Caribou Manage. Bd., March 1983. Dep. Nat. Resources, Winnipeg, MB.

Messier, F., J. Huot, D. Le Henaff, and S. Luttich. 1988. Demography of the George River caribou herd: evidence of population regulation by forage exploitation and range expansion. Arctic 41:279-287.

Miller, D.R. 1976a. Biology of the Kaminuriak population of barren-ground caribou. Part 3: Taiga winter range relationships and diet. Can. Wildl. Serv. Rep. Ser. 36.

Miller, D.R. 1976b. Wildfire and caribou on the taiga ecosystem of north-central Canada. Ph.D. Thesis, University of Idaho, Moscow, Idaho. 125pp.

Miller, D.R. 1980. Wildfire effects on barren-ground caribou wintering on the taiga of north-central Canada: a reassessment. In Reimers, E., Garre, E. and Skjenneberg, S. (eds). Proc. 2nd Int. Reindeer/Caribou Symp. 1979. Direktoret for vilt og ferskvannsfisk, Trondheim, Norway.

Murphy, P.J., S.R. Hughes, and J.S. Mactavish. 1980. Forest fires in the Northwest Territories: a review of 1979 forest fire operations and forest fire management policy. Northern Affairs Program, Dep. Indian Affairs and Northern Dev., Ottawa. 164pp.

Mychasiw, L. 1983. Comparison of forest fire mapping results from aerial reconnaissance and from LANDSAT imagery. Unpubl. Rep. N.W.T. Wildl. Serv., Yellowknife. 25pp.

- Palmer, L.J.** 1944. Food requirements of some Alaskan game animals. *J. Mammal.* 25:49-54.
- Schreiner, B.T., D.F. Acton, and P.P. David.** 1981. Geology. Ch. 11 in Athabasca Sand Dunes in Saskatchewan. Mackenzie River basin Study Rep. Suppl. 7. Mackenzie River Basin Committee.
- Skogland, T.** 1986. Density dependent food limitation and maximal production in wild reindeer herds. *J. Wildl. Manage.* 50:314-319.
- Scotter, G.W.** 1964. Effects of forest fires on the winter range of barren-ground caribou in northern Saskatchewan. *Can. Wildl. Serv. Prog. Rep. No. 3.* 81pp.
- Scotter, G.W.** 1965. Study of the winter range of barren-ground caribou with special reference to the effects of forest fires. *Can. Wildl. Serv. Prog. Rep. No. 3.* 81pp.
- Scotter, G.W.** 1967a. The winter diet of barren-ground caribou in northern Canada. *Can. Field-Nat.* 81:33-39.
- Scotter, G.W.** 1967b. Effects of fire on barren-ground caribou and their forest habitat in northern Canada. *North Am. Wildl. Conf.* 32:246-259.
- Scotter, G.W.** 1971a. Wild fires in relation to the habitat of barren-ground caribou in the taiga of northern Canada. *Ann. Proc. Tall Timbers Fire Ecol. Conf.* 10:85-106.
- Scotter, G.W.** 1971b. Fire, vegetation, soil, and barren-ground caribou relations in northern Canada. Page 209 - 230 in C.W. Slaughter, R.J. Barney and G.M. Hansen eds. *Fire in the northern environment - a symposium.* Pacific Northwest Forest and Range Experimental Station, Portland, Oregon.
- Thomas, D.C., R.H. Russell, E. Broughton, E.J. Edmonds, and A. Gunn.** 1977. Further studies of two populations of Peary caribou in the Canadian Arctic. *Can. Wildl. Serv. Prog. Rep. No. 80.* 14pp.
- Thomas, D.C.** See Appendix 2 for reports and publications related to this study.
- Thompson, D.C. and K.H. McCourt.** 1981. Seasonal diets of the Porcupine caribou herd. *Am. Midl. Nat.* 105:70-77.
- Viereck, L.A. and L.A. Schandelmeier.** 1980. Effects of fire in Alaska and adjacent Canada -- a literature review. *Tech. Rep. 6, Bur. Land Manage., U.S. Dep. of the Interior.* 124pp.

Appendix 1. Objectives from "Winter Range Relationships of the Beverly herd: a Research Proposal", May 1982 (Revised January 1983).

The general objective of this study is to improve our understanding of the role of fire in the winter ecology of barren-ground caribou so that recommendations can be made about fire management. Specific **major objectives** are as follows:

1. To evaluate the adequacy of the present winter range for the present population of caribou and to speculate on how many caribou the winter range could support at various burning rates and average snow conditions.
2. To determine the winter range requirements of the herd, with emphasis on forage requirements as inferred from rumen samples, fragments in fecal pellets, examination of feeding craters, digestibility values, and energetics.
3. To assess the influence of burns of various ages, sizes, and degrees on the behavior of caribou, with emphasis on caribou movements, general use of ranges, and feeding locations.
4. To obtain data on the regeneration of flora after fire with emphasis on tree cover and ground lichens.
5. To obtain data for winter ranges in the NWT on the relative frequencies of physiographic regions, ecoregions, cover types, other appropriate units as yet undecided, and all major burns since about 1930.
6. To obtain data on fire rates and fire intervals in various parts of winter range.
7. To assess the effects of snow on caribou movements, distributions, and forage availability, with emphasis on differences related to time since fire.
8. To obtain sufficient quantitative and qualitative data to be in a position to recommend if, where, and when fire management should be exercised on winter range of the Beverly herd, to the betterment of caribou and caribou users.
9. To involve user groups and concerned agencies with all phases of the study and to relay the results promptly by informal and formal means.

SUB-OBJECTIVES (numerically relate to major objectives)

- 1.1 To measure changes in body weight, composition, and fat reserves from November to March and to compare the results with baseline data from the Kaminuriak herd and others.
- 1.2 To determine age-specific pregnancy rates in relation to condition of females in November and March.

- 1.3 To determine relationships between condition indices and calf survival (with F.L. Miller and Anne Gunn).
- 1.4 To obtain data on parasites and diseases and relate them to condition, the level of wolf predation, and other environmental variables.
- 1.5 To relate changes in conditions and pregnancy rates to climatic variables, movements patterns, and inferences on the levels of insect harassment.
- 2.1 To determine the degree and type of use of the range in relation to range types and interval since fire.
- 2.2 To obtain data on the seasonal diets of caribou from analyzes of rumen samples and fecal pellets.
- 2.3 To obtain information on forage preferences by examining feeding sites.
- 3.1 To assess the degree to which burns of various sizes, types, degrees, and configurations form barriers to caribou movements during migration and during range shifts in the winter.
- 3.2 To relate relative general use of specific regions to age of stands and successional stage.
- 3.3 To obtain data on the relative frequency that caribou use various-aged stands for foraging.
- 4.1 To measure the regeneration post-fire of trees, lichen genera, and other key species, with due consideration to fire severity, geology, soils, topography, and climate.
- 5.1 With NWT Wildlife Service and Department of Indian Affairs Northern Development, to map the winter range of the Beverly herd in the NWT at least in terms of broad physiographic units, broad cover types (trees and surface), and major burns since about 1930.
- 5.2 To seek co-operation of Saskatchewan to extend mapping to their ranges.
- 5.3 To obtain data on burn rates and fire intervals and use that information to estimate fire recurrence and minimum interval to the next burn.
- 6.1 To examine the need for fire management on a range-wide basis at the present population level and at various higher levels.
- 6.2 To evaluate the need for fire management from the viewpoint of each community within historical limits of caribou winter range.

Appendix 2. Reports and publications arising from this study of Beverly herd caribou and their winter range, 1980 through 1987.

PROGRESS REPORTS

1. **Thomas, D.C.** 1982. The winter ecology of barren-ground caribou in north-central Canada: a short review of current knowledge. Can. Wildl. Serv. Rep. 19pp.
2. **Thomas, D.C. and H.P.L. Kiliaan.** 1982. A brief report on the March 1982 sample of barren-ground caribou from the Beverly herd. Can. Wildl. Serv. Rep. 15pp.
3. **Thomas, D.C.** 1983. Preliminary results of the March 1983 sample of barren-ground caribou from the Beverly herd. Can. Wildl. Serv. Rep. 16pp.
4. **Thomas, D.C. and H.P.L. Kiliaan.** 1983. Movements of the Beverly herd of barren-ground caribou, October-December 1982. Can. Wildl. Serv. Rep. 17pp.
5. **Thomas, D.C., H.P.L. Kiliaan, and E. Broughton.** 1983. A preliminary report on the November 1982 sample of barren-ground caribou from the Beverly herd. Can. Wildl. Serv. Rep. 10pp.
6. **Thomas, D.C. and H.P.L. Kiliaan.** 1984. Distribution and physical status of the Beverly herd of barren-ground caribou in early winter, 1983-84. Can. Wildl. Serv. Rep. 17pp.
7. **Thomas, D.C. and H.P.L. Kiliaan.** 1984. Physical condition of the Beverly herd of caribou in March 1984. Can. Wildl. Serv. Rep. 29pp.
8. **Thomas, D.C.** 1985. Fire management of the winter range of the Beverly herd in the Northwest Territories: Tentative conclusions and recommendations. Can. Wildl. Serv. Rep. 57pp.
9. **Thomas, D.C. and H.P.L. Kiliaan.** 1985. Physical condition of the Beverly herd of barren-ground caribou in March 1985. Can. Wildl. Serv. Rep. 34pp.
10. **Thomas, D.C. and H.P.L. Kiliaan.** 1985. A simple technique for preparing dental sections for mammalian age determination. Can. Wildl. Serv. Rep. 7pp.
11. **Thomas, D.C. and H.P.L. Kiliaan.** 1985. Movements and physical condition of the Beverly herd of caribou in early winter 1984-85. Can. Wildl. Serv. Rep. 22pp.

12. **Thomas, D.C., H.P.L. Kiliaan, and C. Dong.** 1986. Physical status of the Beverly herd of barren-ground caribou in December 1985. Can. Wildl. Serv. Rep. 27pp.
13. **Thomas, D.C. and H.P.L. Kiliaan.** 1986. Distribution and physical characteristics of the Beverly herd of caribou in February and March 1986. Can. Wildl. Serv. Rep. 31pp.
14. **Thomas, D.C.** 1989. A brief guide to monitoring the physical condition of caribou. Can. Wildl. Serv. Rep. prep. for Beverly and Kaminuriak Caribou Manage. Bd. 9pp.
15. **Thomas, D.C. and H.P.L. Kiliaan.** 1998a. Fire-caribou relationships: (I) Physical characteristics of the Beverly herd, 1980-87. Tech. Rep. Series No. 309. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 178pp.
16. **Thomas, D.C. and H.P.L. Kiliaan.** 1998b. Fire-caribou relationships: (II) Fecundity and physical condition of the Beverly herd. Tech. Rep. Series No. 310. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 96pp.
17. **Thomas, D.C., H.P.L. Kiliaan, and T.W.P. Trottier.** 1998. Fire-caribou relationships: (III) Movement patterns of the Beverly herd in relation to burns and snow. Tech. Rep. Series No. 311. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 176pp.
18. **Thomas, D.C. and H.P.L. Kiliaan.** 1998c. Fire-caribou relationships: (IV) Recovery of habitat after fire on winter range of the Beverly herd. Tech. Rep. Series No. 312. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 115pp.
19. **Thomas, D.C.** 1998a. Fire-caribou relationships: (V) Winter diet of the Beverly herd in northern Canada, 1980-87. Tech. Rep. Series No. 313. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 43pp.
20. **Thomas, D.C. and H.J. Armbruster.** 1998. Fire-caribou relationships: (VI) Fire history of winter range of the Beverly herd. Tech. Rep. Series No. 314. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 94pp.
21. **Thomas, D.C.** 1998b. Fire-caribou relationships: (VII) Fire management on winter range of the Beverly herd: final conclusions and recommendations. Tech. Rep. Series No. 315. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 100pp.
22. **Thomas, D.C.** 1998c. Fire-caribou relationships: (VIII) Background information. Tech. Rep. Series No. 316. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 104pp.

PUBLICATIONS (related to fire-caribou relationships)

1. **Thomas, D.C. and P. Kroeger.** 1981. Digestibility of plants in ruminal fluids of barren-ground caribou. *Arctic* 34:321-324.
2. **Thomas, D.C., P. Kroeger, and D. Hervieux.** 1984. *In vitro* digestibilities of plants utilized by barren-ground caribou. *Arctic* 37:31-36.
3. **Thomas, D.C. and D.P. Hervieux.** 1986. The late winter diets of barren-ground caribou in north-central Canada. *Rangifer*, Spec. Issue 1:305-310.
4. **Thomas, D.C., S.J. Barry, and H.P. Kiliaan.** 1989. Fetal sex ratios in caribou: maternal age and condition effects. *J. Wildl. Manage.* 53:885-889.
5. **Thomas, D.C. and S.J. Barry.** 1990a. Age-specific fecundity of the Beverly herd of barren-ground caribou. *Rangifer Spec. Issue No. 3*:257-263.
6. **Thomas, D.C. and S.J. Barry.** 1990b. A life table for female barren-ground caribou in north-central Canada. *Rangifer Spec. Issue No. 3*:177-184.
7. **Thomas, D.C. and H.P.L. Kiliaan.** 1990. Warble infestations in some Canadian caribou and their significance. *Rangifer Spec. Issue No. 3*:409-417.
8. **Roed, K.H. and D.C. Thomas.** 1990. Transferrin variation and evolution of Canadian barren-ground caribou. *Rangifer Spec. Issue No 3*:385-389.
9. **Thomas, D.C.** 1991a. Adaptations of barren-ground caribou to snow and burns. Pp. 482-500 *in* Butler, C.E. and Mahoney, S.P. (eds.). *Proc. 4th North American Caribou Workshop*, St. John's, Newfoundland.
10. **Thomas, D.C.** 1991b. Moose diet and use of successional forests in the Canadian Taiga. *Alces* 26:24-29.
11. **Thomas, D.C. and S.J. Barry.** 1991. Microhistological analyzes of caribou diet: fecal versus rumen samples and other variables. Pp. 516-529 *in* Butler, C.E. and Mahoney, S.P. (eds.). *Proc. 4th North American Caribou Workshop*, St. John's, Newfoundland.
12. **Thomas, D.C. and J. Schaefer.** 1991. Co-management defined: the Beverly and Kaminuriak Caribou Management Board. *Rangifer Spec. Issue No. 7*:73-89.
13. **Beverly and Qamanirjuaq Caribou Management Board.** 1994a. A review of fire management on forested range of the Beverly and Qamanirjuaq herds of caribou. The Secretariat, BQCMB, 3565 Revelstoke Dr., Ottawa, ON K1V 7B9. 64 pp. (Drafted by **D.C. Thomas**).

14. **Beverly and Qamanirjuaq Caribou Management Board.** 1994b. Fire management recommendations for forested range of the Beverly and Qamanirjuaq herds of caribou. The Secretariat, BQCMB, 3565 Revelstoke Dr., Ottawa, ON K1V 7B9. 12 pp + maps (drafted by D.C. Thomas).
15. **Thomas, D.C.** 1995. A review of wolf-caribou relationships and conservation implications in Canada. IV8:pp 1-15 *in*: Ecology and Conservation of Wolves in a Changing World. L.N. Carbyn, S.H. Fritts, and D.R. Seip. (eds.). Can. Circumpolar Inst., Univ. of Alberta, Edmonton.
16. **Thomas, D.C.** 1996. Prevalence of *Echinococcus granulosus* and *Taenia hydatigena* in caribou in north-central Canada. Rangifer Spec. Issue No. 9:331-336.
17. **Thomas, D.C. and the Beverly and Qamanirjuaq Caribou Management Board.** 1996. A fire suppression model for forested range of the Beverly and Qamanirjuaq herds of caribou. Rangifer Spec. Issue. No. 9:343-349.
18. **Thomas, D.C., S.J. Barry, and G. Alaie.** 1996. Fire-caribou-winter range relationships in northern Canada. Rangifer 16 (2):57-67.