SIMULATION ANALYSIS OF COMPONENTS OF ONTARIO'S MOOSE HABITAT GUIDELINES

by

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ABSTRACT

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Key Words: moose (*Alces alces*), moose habitat guidelines, Habitat Supply Analysis (HSA), simulation modelling, Geographic Information System (GIS)

The intent of Ontario's "Timber Management Guidelines for the Provision of Moose Habitat" is to use timber management to maintain or improve the moose habitat potential of a forest. In the boreal forests of Ontario, timber management without consideration of these guidelines has followed a pattern of progressive clearcutting. Economics was the most important factor in determining harvest patterns. Timber management following the guidelines requires that moose habitat play a prominent role in the design of timber harvest patterns. The guidelines are part of an overall objective to double the size of the moose population in the province by the year 2000.

The objective of this study was to test the efficacy of components of the guidelines by comparing two timber management scenarios, one following the guidelines, the other not. A habitat supply model served as the assessment tool. The study area was the Aulneau Peninsula on Lake of the Woods in northwestern Ontario.

M-HSAM (moose habitat supply analysis model) was developed to forecast future moose habitat potentials for the forest. M-HSAM is a GIS-based simulation model which forecasts moose carrying capacity of the landscape for each of three seasons: summer, early winter, and late winter. The model requires data that describe the vegetative development of stands in terms of summer food, early winter food and early winter cover available for moose. A GIS is used for proximity analysis that accounts for the "edge effect" between moose cover and moose food during the early winter period, to limit travel distances between early-winter habitat and late-winter habitat, and to evaluate moose habitat at a scale similar to the size of the average home range of moose.

Generally, the results demonstrate that timber management following the guidelines provides better moose habitat than the non-guidelines approach for early winter and late winter. In both of these seasons, cover was a key factor in the determination of moose habitat potential as it is in reality. Summer habitat values for the two approaches were similar.

The carrying capacity numbers produced in the M-HSAM simulations are higher than the actual moose population levels on the Aulneau Peninsula. Since other factors (e.g. predation, disease, hunting) serve to limit moose populations the carrying capacities are reasonable. However, for M-HSAM to gain credibility the model must be invalidated. Despite this, M-HSAM represents a useful tool for assessing the impacts of timber management strategies on moose habitat potential.

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The crux of this study was the development of a habitat supply analysis for moose, a project which entailed assembling expert opinion in several areas of moose ecology. Special thanks to those who gave willingly of their time to guide me through this stage. For the development of the seasonal curve sets and identification of season start and end dates thanks to John McNicol, Al Bisset, Tim Timmermann, Art Rodgers, Ken Abraham, Rob Rempel, and Rick Gollat, all of the Ontario Ministry of Natural Resources, and to Peter Jordan of the University of Minnesota in St. Paul.

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CHAPTER 1

INTRODUCTION

The moose (*Alces alces*) is a featured wildlife species in Ontario. The range of moose lies largely within the Boreal Forest Region, extending somewhat into the Great Lakes - St. Lawrence Forest Region (Cumming, 1972), as shown in Figure 1. Historically, moose management policies in Ontario have focused on regulatory directives governing moose hunting, with the objective of maintaining a healthy moose population in the province (Cumming, 1974). These policies were established in direct response to the generally accepted theory that sport hunting was the primary factor limiting Ontario's moose population.

In the mid 1970s, questions regarding the health of the provincial moose population prompted an analysis of moose census data over a period of several years. When results of this analysis indicated sharp declines in the moose population - 35% over a period of about 15 years (Euler, 1983) - it became clear that standard provincial moose management strategies were inadequate. The sharp moose population declines were attributed to poaching, predation, and habitat loss as well as hunting.

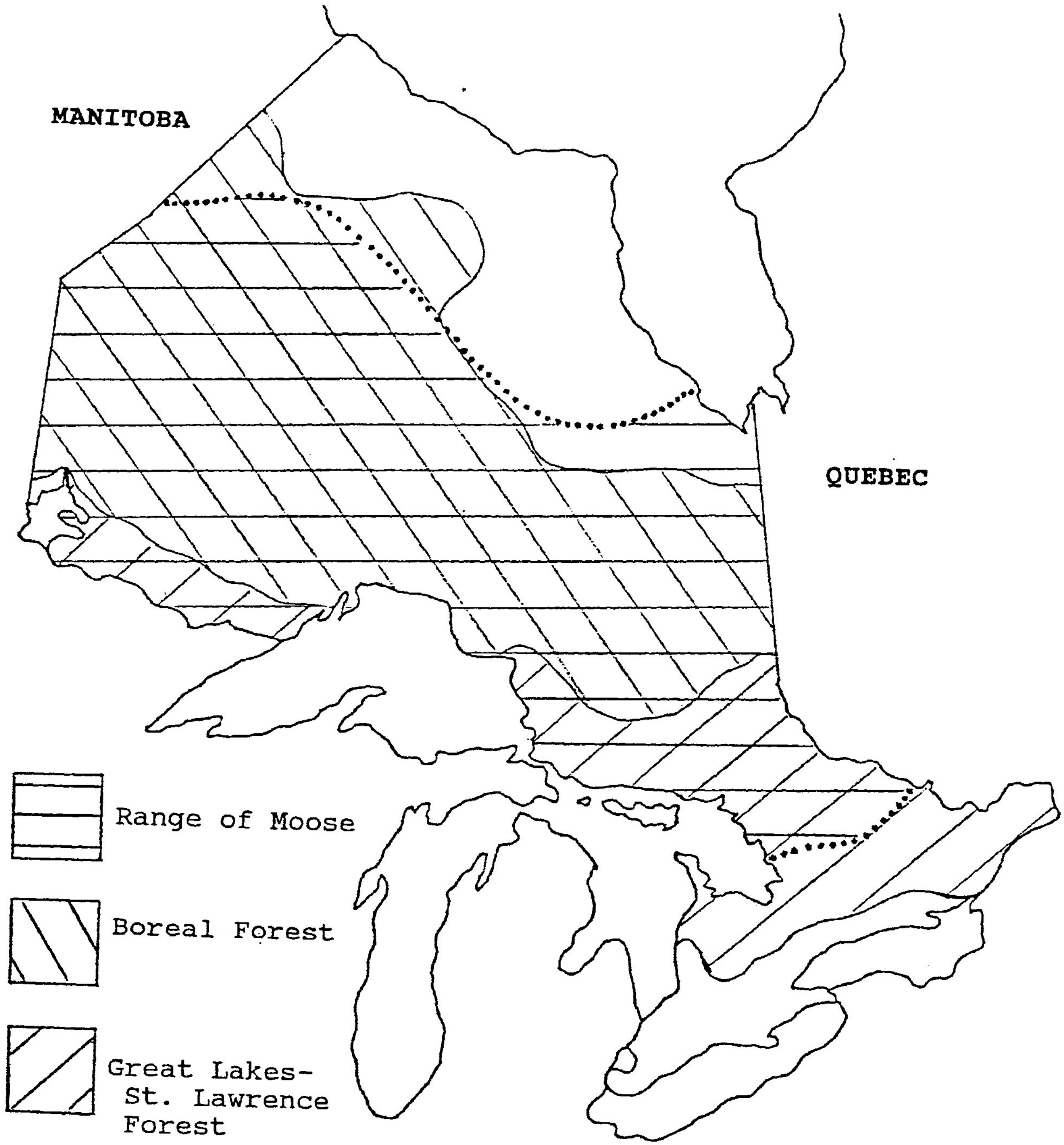

Figure 1. Map of Ontario showing the range of moose (*Alces alces*) with respect to the Boreal and Great Lakes - St. Lawrence Forest Regions.

In 1979, the OMNR (Ontario Ministry of Natural Resources) undertook a series of public open houses to discover new ways to improve moose management in Ontario. During these open houses, 92 percent of the participants expressed a need to improve timber harvest practices as a means of improving moose habitat (OMNR, 1980a). The public perception was obvious. If moose population levels were to increase, management strategies could not continue to focus solely on hunting. Initiatives directed at moose habitat management were also required.

In 1980, the OMNR introduced new moose hunting regulations requiring two persons per moose tag rather than one person per tag (Timmermann and Gollat, 1984). This change was not well-received by moose hunters, leaving further changes to moose hunting regulations only remotely possible. Habitat management became an integral part of the new focus for moose management in Ontario.

That same year, the Wildlife Branch of the OMNR issued a provincial Moose Management Policy statement (OMNR, 1980b). This document not only outlined objectives of the moose management strategies and targets for moose populations, but also provided basic management policy to control hunting and manage moose habitat. The broad objective was "to protect and enhance the moose resource and to provide opportunities for recreation from moose for the continuous social and economic benefit of the people of Ontario..." (OMNR, 1980a). The policy for moose habitat management sought to "...maintain or enhance moose habitat directly in the forest management process...", while also providing assurance that quality moose habitat would not be sacrificed for timber production (OMNR, 1980a). The framework to develop more specific moose habitat management guidelines was then in place.

The "Guidelines for Moose Habitat Management in Ontario" (OMNR, 1984) was the first attempt at aligning forest management activities with moose habitat management "...in order to produce good moose habitat with a minimum loss of wood fibre." In 1988 the OMNR furthered this effort with the publication of "Timber Management Guidelines for the Provision of Moose Habitat" (OMNR, 1988). These moose-habitat guidelines recognized timber harvest operations as a major habitat-altering process which, if properly planned and implemented, could be used to change the forest structure for the benefit of moose populations.

The moose-habitat guidelines were compiled as the result of a series of workshops. Pooled expert opinion, together with limited and localized field research, thus became the basis for development of the moose-habitat guidelines.

Implementation of the guidelines in the timber-management planning process was undertaken in a somewhat piecemeal fashion.

The guidelines serve the specific purpose of providing for moose habitat while permitting a desired level of timber extraction. The moose-guidelines document outlines that, in the long term, imposition of the moose-habitat guidelines should not remove stands from timber harvest unless specified areas of concern have been identified (e.g. moose calving sites, aquatic feeding areas) and withdrawn from timber harvest eligibility. Such areas of concern are given priority in the Timber Management Planning Manual (OMNR, 1986). Moose values, as well as those of other non-timber interests, are identified during the timber-management planning process and applied as stand-level constraints on harvest allocations in the Timber Management Plan (TMP). Habitat-altering provisions from the moose-habitat guidelines are imposed after the extent of the areas eligible for timber harvest have been determined. The guidelines are then applied at the stand level, usually by OMNR foresters and wildlife biologists, often in conjunction with a forest-products company forester. Additional timber harvesting costs caused by the application of the moose-habitat guidelines are born by the timber interests. The flexible nature of the guidelines has led to differences in application across OMNR's administrative jurisdictions that have similar forest types (J. McNicol, 1989, pers. comm.). Differences of this nature have caused concern, and the objectives of the guidelines have been challenged.

Where moose are the featured species, application of the moose-habitat guidelines is mandatory in the timber-management planning process, and it is generally accepted that they form the basis for the sustainability or improvement of moose habitat. However, the fact remains that no explicit evidence has yet been produced to demonstrate the value of the moose-habitat guidelines. Will imposition of the moose-habitat guidelines result in improved moose habitat and therefore contribute to increased moose populations over (a) large areas (e.g. 10^4 to 10^6 ha), and (b) time (e.g. 10 to 100 years)?

The timber-management planning process provides for establishment of timber objectives at the forest-management unit level. Stand-level options are orchestrated to meet forest-level objectives over time. Timber and moose outputs are indirectly linked in reality, yet no moose targets exist for specific forest-management units in Ontario. Population targets for moose do exist for Wildlife Management Units (WMU), but WMU boundaries rarely coincide with forest-management unit boundaries.

The basic assumption behind application of the guidelines in any forest-management unit in Ontario is that their implementation will maintain or improve moose carrying capacity of the habitat in that area. The intention of this study is to investigate this assumption using a simulation approach to habitat-supply analysis. Therefore, the objective of this research is:

> To forecast quantitatively the extent to which application of the "Timber Management Guidelines for the Provision of Moose Habitat" in a forest-management unit in northwestern Ontario could benefit components of moose habitat.

Presently the relationships between moose and habitat at the scale of moose populations in Ontario are not quantified. Thompson and Euler (1987) advocated examining habitat at this larger scale as "...the needs of a population must be considered." Because habitat can be a limiting factor for moose populations, these relationships need to be explicated before the role of habitat change (i.e. spatial and temporal patterns) in moose population dynamics can be understood. Addressing the objective above requires a first step in quantifying these relationships.

Presently there exists a discrepancy between the procedures, knowledge and tools applied in developing options for reaching timber goals, and those applied towards wildlife goals. The importance of this discrepancy cannot be understated because significant additional timber harvest costs or loss of merchantable timber may be incurred by application of the moose-habitat guidelines without any quantified indication of the potential benefits to moose populations. A quantitative indication of the improvements to the habitat carrying capacity for moose through application of the moose-habitat guidelines is needed to demonstrate the actual worth of the guidelines, an important step for acceptance of the guidelines by timber managers. This study will yield a generalizable habitat-responsive moose carrying capacity forecasting model linked to a Forest Resource Inventory (FRI) database. The model can be updated for use in the TMP process for most forest management units in Ontario. It will permit evaluation of timber harvest patterns and silviculture prescriptions in terms of moose habitat supply.

This report describes the procedure used to address the objective and the results of the analyses, and presents a discussion of the findings. A description of the study area is given in Chapter 2. Chapter 3 is a précis of the moose-habitat guidelines. Chapter 4 presents the case for using a GIS (Geographic Information System)-based habitat supply analysis simulation model as a tool for assessing future supplies of moose habitat in a forest. A detailed description of the moose habitat supply analysis model developed and used for this study, and a description of the scenarios implemented for the test are provided in Chapter 5. Chapter 6 presents the results of the model tests for: (a) the entire study area; and (b) a selected area within the study forest. Chapter 7 outlines the conclusions of the work, and discusses further work which might be undertaken to improve the model as a general moose habitat supply analysis model.

CHAPTER 2

STUDY AREA

The Aulneau Peninsula (hereafter referred to as the Aulneau) was selected as the study area for the project. A digital GIS-based FRI database for the Aulneau was made available by the Kenora District Office of OMNR.

The Aulneau is situated in the Lake of the Woods Plains Ecoregion in Northwestern Ontario (Wickware and Rubec, 1989). The Aulneau is thoroughly described by Eckersley (1978). The following descriptions of location, physiography and climate are synopses of Eckersley's (1978) report.

LOCATION

The Aulneau lies some 30 km east of the Manitoba border (see Figure 2) between the latitudes of 49° 15′ North and 49° 30′ North and the longitudes of 94° 15′ West and 94° 45′ West. At one time connected to the mainland by a 60 m isthmus of land, the Aulneau was severed from the mainland by a channel built in 1963, thereby rendering it an island. It is the largest single landmass in Lake of the Woods and is surrounded by numerous smaller islands.

PHYSIOGRAPHY

The Aulneau is approximately 100,000 ha. More than 25% of the area is lake and waterway, leaving some 73,500 ha of land area. The shoreline exceeds 400 km in length and is characterized by several deep inlets extending into the Peninsula. In its interior the Aulneau encompasses only two larger waterbodies, Obabikon Lake (2,200 ha) and Arrow Lake (1,056 ha). The remainder of the area covered by water is made up of a large number of smaller lakes. The broken topography is further typified by muskeg areas and marshes.

The Aulneau is situated entirely within the Precambrian Shield. The surficial geology, topography and soil types are the product of successive glacial advances and retreats during the glacial epochs. The topography is rugged and moderately broken with small and intricate variations in relief. Elevations on the Aulneau range from 325 m above sea level around its perimeter to 385 m in parts of the interior.

The soils on the Aulneau are generally thin, coarse textured and scattered in distribution. Approximately 30% of the Peninsula is dominated by bare bedrock with small pockets of till and clay in the low-lying areas. A shallow strip of loam less than 2 km wide stretches across the northern edge of the Peninsula, covering some 10% of its area. The remaining 60% of the Peninsula's surface area is comprised of glacial till with bedrock outcrops and small, isolated pockets of clay.

CLIMATE

The Aulneau Peninsula is primarily influenced by the continental (Prairie) climate and moderated by the Great Lakes marine climate. The area averages 180 frost-free days and a 170-day growing season. Mean January temperatures are -17°C while mean July temperatures are 22°C. Average annual precipitation is 66 cm with total annual snowfall averaging 150 cm.

FORESTS

The Aulneau Peninsula lies along the northern boundary of the Great Lakes - St. Lawrence Forest Region, within the Quetico Section (Rowe, 1972). Logging and forest fires have resulted in the establishment of a boreal-like forest (Eckersley, 1978), a common occurrence in this area (Rowe, 1972; Wickware and Rubec, 1989). The tree species which make up the forests of the Aulneau are shown in Table 1.

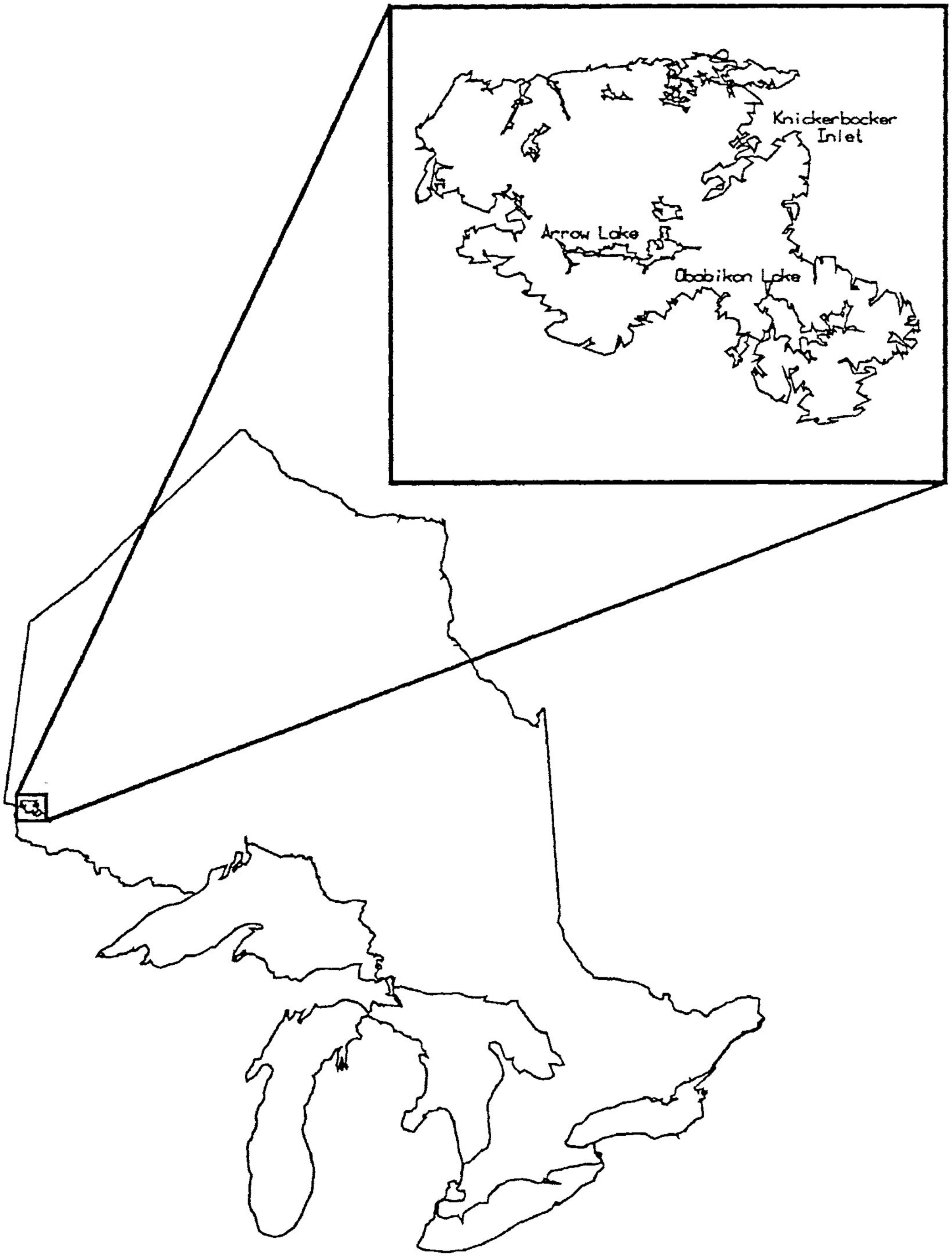

Figure 2. Location and form of the Aulneau Peninsula.

Table 1. Tree species of the Aulneau Peninsula.

COMMON NAME	SCIENTIFIC NAME	ABBREVIATION
Balsam Fir	*Abies balsamea* [L.]Mill.	Bf
White Birch	*Betula papyrifera* Marsh.	Bw
Black Ash	*Fraxinus nigra* Marsh.	As
Tamarack	*Larix laricina* (Du Roi) K. Koch	Ll
White Spruce	*Picea glauca* [Moench] Voss	Sw
Black Spruce	*Picea mariana* [Mill] B.S.P.	Sb
Jack Pine	*Pinus banksiana* Lamb.	Pj
Red Pine	*Pinus resinosa* Ait.	Pr
White Pine	*Pinus strobus* L.	Pw
Poplar	*Populus tremuloides* Michx. and/or *Populus balsamifera* L.	Po
Bur Oak	*Quercus macrocarpa* Michx.	Oa
Cedar	*Thuja occidentalis* L.	Ce

Boreal tree species dominate the forests of the Aulneau including pure or mixed stands of jack pine, trembling aspen, white birch, balsam fir and, white and black spruce, while remnant stands of eastern white pine and red pine also occur (G.M. Wickware and Associates, 1989). These patterns are reflected in the actual FRI information for the Aulneau, as summarized in Table 2. The jack pine and poplar working groups combine for a total of 84.5% of the productive forest area of the Aulneau (49.6% and 34.9% each respectively). A graphical representation of the age-class composition of these two working groups in comparison to the overall age-class distribution is provided in Figure 3.

Table 2. Age-class distribution by working group for the forest of the Aulneau Peninsula (ha).

	20-YEAR AGE CLASSES[1]							
Working Group	I	II	III	IV	V	V	VII	TOTAL
Pj	2142	29	12988	9837	2339	534	18	27887
Po	625	738	3529	10256	4272	228	0	19648
Sp[2]	431	11	181	1338	708	27	590	3286
Bf	32	201	2270	748	0	0	0	3251
Pr	67	37	31	442	104	36	41	758
Pw	25	0	22	145	108	32	78	410
Bw	8	11	59	222	81	0	0	381
Oc[3]	31	0	0	55	128	7	94	315
Oh[4]	0	0	0	196	78	11	5	290

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1 20-Year Age Classes are defined as:

I	stands between 1 and 20 years old;
II	stands between 21 and 40 years old;
III	stands between 41 and 60 years old;
IV	stands between 61 and 80 years old;
V	stands between 81 and 100 years old;
VI	stands between 101 and 120 years old; and,
VII	stands older than 120 years.

Spruce working group includes all spruce stand types.

Other Conifer working group includes coniferous stand types other than Pw, Pr, Pj, Sp or Bf.

Other Hardwood working group includes deciduous stand types other than Bw or Po.

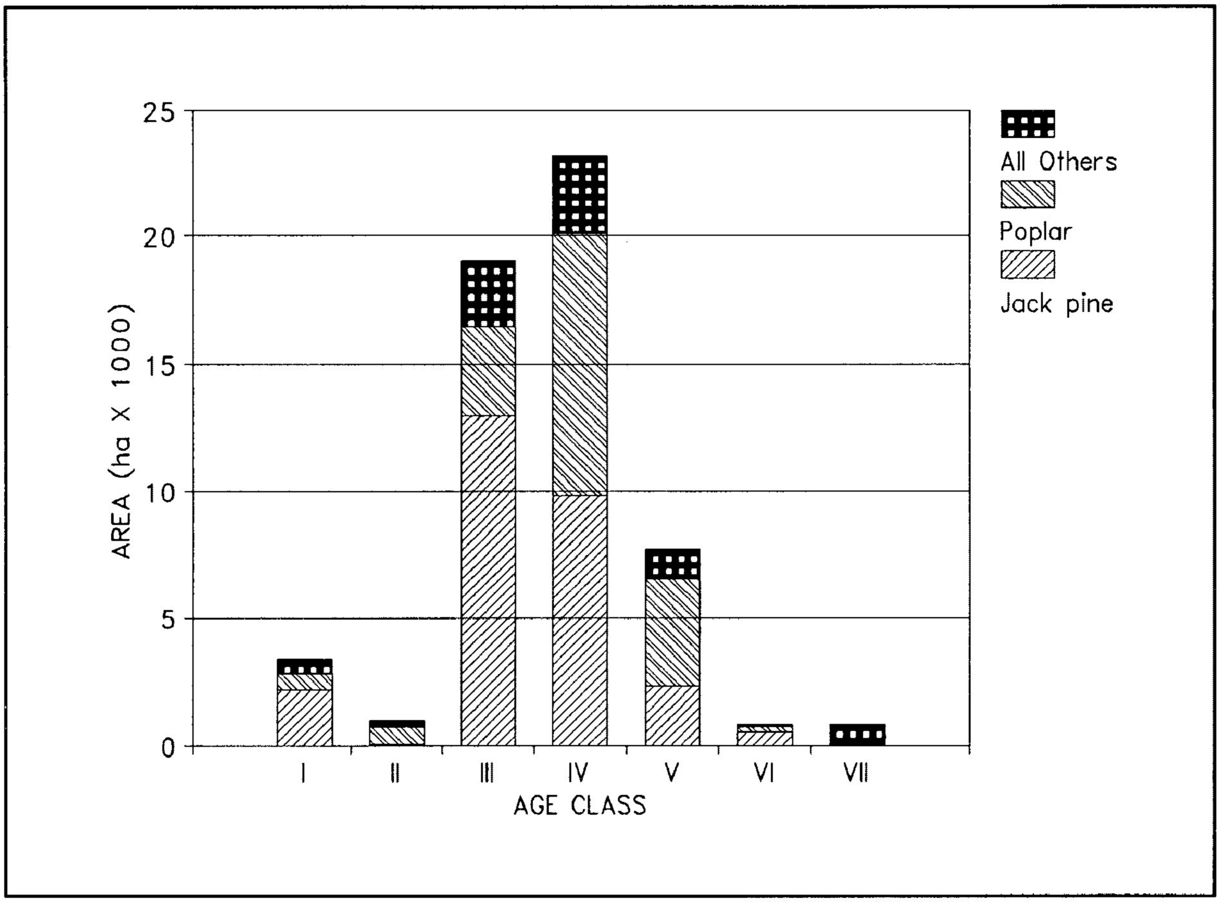


Figure 3. Age-class distribution of the jack pine, poplar and all other working groups.

CHAPTER 3

SUMMARY OF THE MOOSE-HABITAT GUIDELINES

The "Timber Management Guidelines for the Provision of Moose Habitat" (OMNR, 1988) assent to the concept that "...timber management is wildlife management..." (Thomas, 1979). Baskerville (1992) elaborated: "...the essence of habitat management is the design of actions to regulate the temporal and spatial availability of forest habitat." To be effective, wildlife-habitat management must be integrated with forest management (Gilbert and Dodds, 1987). The purpose of the guidelines is "... to assist resource managers in maintaining or creating through timber management the diversity of age classes and species of vegetation that provide habitat for moose..." (OMNR, 1988). The guidelines represent an attempt to "...address general needs for moose habitat that acknowledges the fact the moose range over the whole forest and require various habitat components throughout the area..." (OMNR, 1988). It is acknowledged in the guidelines that timber management can have a positive influence on moose habitat.

The guidelines address the life requisites of moose by ensuring that seasonal moose habitat requirements are identified and maintained, or, if possible, enhanced to achieve improved moose habitat mosaic while permitting a maximum sustainable level of timber harvest. Key moose-habitat features (e.g. calving sites, aquatic feeding areas, mineral licks) are protected from timber harvest activities. Additional measures that ensure continued use of these areas by moose are described.

The guidelines have been divided into two major sections describing provisions for moose habitat in timber management for the two principal forest regions of Ontario - the Boreal and the Great Lakes - St. Lawrence. Each of these sections is further divided to deal with: (a) forest access; (b) timber harvest operations; (c) site preparation; (d) forest regeneration; and (e) maintenance. The primary difference in the guidelines for each forest region is in the timber harvest operations. Guidelines pertaining to the other four sections are similar for the two regions. The guidelines under review in this study are those for the Boreal Forest Region since the Aulneau Peninsula is composed primarily of boreal forest types and is managed as a boreal forest.

The components of the guidelines specifically assessed in this work relate to timber harvest operations, specifically the size and management of clearcuts. It was assumed that protection of the important areas (calving sites, aquatic feeding areas, mineral licks) are measures which would be undertaken regardless of the clearcut size limitations imposed by the guidelines. The clearcut size component of the guidelines represents a substantial deviation from the continuous clearcutting practices undertaken in the boreal forest prior to consideration of moose habitat in timber management. At that time the large clearcuts were assumed to be a significant habitat management problem (Thompson and Euler, 1987). The components of the moose-habitat guidelines tested in this study are:

a. maximum size of clearcuts of 80-130 ha with buffer areas (of residual forest) between cuts; and

b. clearcuts greater than 100 ha should have scattered patches of residual forest within cutover area.

A copy of the guidelines is provided in Appendix I.

CHAPTER 4

SIMULATION AND GIS IN HABITAT STUDIES

This work focused on determining whether adherence to the moose-habitat guidelines might result in improved moose habitat in the study forest when compared to non-guidelines approaches to forest management. A simulation approach featuring a response-forecasting model was used.

A monitoring approach would also be appropriate for this objective. It would involve designing an experiment in a forested landscape which would permit comparative analysis between treatment and control alternatives. Forest management without consideration of the guidelines might be the control side of the experiment, while forest management according to the guidelines would be the treatment side. A sufficiently large forest would be required to plan and implement forest management for each of these alternatives. Periodic and frequent field measurements related to moose habitat carrying capacities would be necessary to compare treatment and control results. This type of field experiment would require considerable commitment in terms of time and financing, as well as a forest and associated forest management planning dedicated to such a study. A field study approach was considered well beyond the scope of this project.

The degree to which the modelling approach yields results approximating those of the monitoring approach depends on how well the assumptions built into the model mimic the actual situation, and whether the outputs produced in the model could be reliably measured in the monitoring approach with similar frequency and periodicity. Assumptions implemented in the model represent, to the extent possible, averages of actual situations. Measurements in a monitoring approach must represent a wide enough sample to accurately produce a similar average.

MODELS

Models are representations or abstractions of real-world situations (Holister, 1984; Starfield and Bleloch, 1986; Morrison *et al.*, 1992; Patton, 1992) that help to describe reality for the model builder (Duinker, 1985). Numerous authors have suggested that models can help to identify possible consequences of management actions before they are implemented (e.g. Holling, 1978; Ward, 1978; Walters, 1986; Starfield and Bleloch, 1986; Page, 1987). Karns (1987) wrote that modelling is "...one way to put all our knowledge into a single working statement, and if nothing else, can serve as a means of technology transfer."

Starfield and Bleloch (1986) contended that models are intellectual tools which "...help us to (1) define our problems, (2) organize our thoughts, (3) understand our data, (4) communicate and test that understanding, and (5) make predictions."

The following four points show how modelling fits into the process for progress in science and natural resource management.

1. Unlike traditional research which is usually directed at gaining an understanding about systems on a component by component basis, models permit one to research the entire system. In other words, one can study what happens when all of the components of the system are assembled (Walters, 1986; Antonovsky and Korzuhkin, 1986).

2. Models which assemble components of systems are necessary to make progress in the field of ecology (Jeffers, 1988).

3. Duinker (1986a) stated that "...natural resource management relies on the science of ecology and related disciplines to generate part of the supporting information base."

4. Nyberg (1990) suggested that, using monitoring and adapting models and management techniques accordingly, one could probably improve timber-wildlife integration five times faster than waiting for researchers to conduct experiments on every practice.

Thus, models which link key components of ecological systems are helpful to make progress in natural resource management. Models, then, are learning tools which can help determine the impacts of any external perturbation on the entire system.

HABITAT MODELS

"A habitat model is a tool for assessing an area's ability to support a wildlife species..." (Fish and Wildlife Branch, New Brunswick Department of Natural Resources, 1989). In a landmark document aimed at incorporating wildlife-habitat considerations into forest planning, Thomas (1979) set the stage for the use of models as tools to assess quality and quantity of wildlife habitat. Since then, wildlife-habitat models have evolved through Habitat Suitability Index models in the early 1980s (e.g. Allen, 1982; Allen, 1983; Short, 1984) which provided "snapshot" assessments of wildlife habitat in an area, to Habitat Supply Analysis (HSA) "...in which measures of the quantity and quality of habitat features to be produced by a management prescription are used to project future habitat quality for wildlife..." (Greig *et al.*, 1991). Naylor *et al.* (1992) described HSA as a useful tool for integrating timber and habitat in the timber management planning process in Ontario.

HSA combined with simulation models of forest succession yield Habitat Supply Models (HSM) which provide wildlife managers with the capability of planning for future habitat supply (Greig *et al.*, 1991). HSMs forecast the habitat-producing capability of an area (e.g. Seagle *et al.*, 1987; Schuerholz *et al.*, 1988), thereby incorporating the temporal dimension. Greig *et al.* (1991)

defined HSM as "...dynamic simulation of habitat values for wildlife species in response to forest-management regimes".

Wildlife-habitat models have often been developed to estimate the effects of timber management directly on wildlife habitat (e.g. Patch, 1987) and indirectly on wildlife populations (e.g. Duinker, 1986b; Schuerholz *et al.*, 1988). Morrison *et al.* (1992) explained that "...the goals of modelling wildlife-habitat relationships are usually associated with prediction".

SIMULATION

Although many kinds of mathematical models exist (Holling, 1978; Morrison *et al.*, 1992) simulation was chosen as the modelling technique for this study, for the following reasons:

1. Simulation permits replication of system dynamics over time. This study attempted to track changes in the moose-habitat characteristics of the forest for two alternative forest-management regimes over time. The time period must be long enough to permit forest stand development and forest succession to influence moose habitat in the alternative forest-management regimes, and long enough to permit the alternative strategies to be theoretically implemented for at least the duration of a TMP term (20 years). Thus,

perturbations (timber harvest) would be permitted to influence moose habitat continuously as in the real-world system.

2. Simulation models are most useful when the problem involves parameters whose values vary or are not well known (Morrison *et al.*, 1992). Many of the parameters which determine moose habitat have not yet been properly quantified, yet they require consideration when modelling for moose-habitat values. An example is the contribution of certain forest stand types to early winter cover for moose.
3. Simulation modelling permitted a forest the size of the Aulneau Peninsula to be analyzed without aggregating forest stands into larger units and thereby sacrificing spatial resolution. The spatial integrity of each stand could remain intact using simulation.
4. Simulation models "...have flexibility to program a wide variety of functions and relationships and thus make full use of the knowledge we do have..." (Holling, 1978).
5. Ward (1978) suggested that simulation models are valuable in environmental impact studies as they are "...well suited to handling large numbers of realistic assumptions." This study was in fact an environmental impact study in which the impacts of alternative forest-management regimes were assessed in terms of moose habitat.
6. Simulation models permit forecasting of the impacts of management interventions to a system. The focus of this

study is to determine which management interventions will best suit moose-habitat supply over time.

7. Nyberg (1990) suggested that simulation could deal with long-term habitat trends, precisely the subject of this study.

Goodall (1989) advocated that simulation modelling was often the "...most appropriate way..." to predict "...what changes will occur to natural systems, either if left undisturbed or (more often) if they are subject to certain perturbations...".

GIS IN MODELLING

Norton and Nix (1991) described GIS as a "... computer-based system designed specifically to facilitate the digital storage, retrieval and analysis of spatially-referenced environmental data...". Johnson (1990) added that manipulation of spatially-distributed data is an important element of GIS. These systems have been used for numerous natural resource and environmental applications (e.g. ESRI, 1991a; ESRI, 1991b).

Baskerville (1988) described GIS as a means of making new types of decisions, not just a way to make old forms of decisions better. Johnson (1990) explained that "...in ecological studies the recent emphasis on larger study areas over longer time spans has coincided with the development of geographical information systems...".

GIS was determined to be an important component of this study for several reasons, all linked to the spatial components of the study. First, GIS could permit a systematic sampling of the entire forest area in a manner similar to that used by Duinker (1986b). Secondly, important components of moose ecology could be addressed in the model. These components include distance-dependent moose-habitat relationships which could not be addressed for the entire forest without GIS capabilities. Third, the spatial integrity of the stands could be maintained, not only in terms of size but also of spatial location and proximity to other stands, and in terms of shape. These spatial characteristics contribute to one of the most widely endorsed theories of wildlife-habitat management, the edge effect or interspersion (Dasmann, 1964). "Adequate representation of spatial interspersion is possible only by processing habitat data while retaining its spatial integrity. This is only feasible through computerized map analysis..." (Eng *et al.*, 1990). Fourth, the essence of this study was assessment of two distinct spatial patterns of timber management in terms of moose habitat. GIS was vital for such analysis. GIS provides a means to address issues of spatial and temporal heterogeneity, an impossible task prior to the development of this technology (Johnson, 1990).

In short, "...the most realistic models require ... the spatial capabilities of a geographic information system..." (Naylor *et al.*, 1992).

SUMMARY

In summary, I chose to test the guidelines using a GIS-based habitat supply analysis simulation model. The important features governing this choice were:

1. consideration of the temporal dimension;
2. utilization of both available data <u>and</u> knowledge;
3. impact assessment of timber-management regimes in terms of future moose habitat;
4. maintenance of spatial integrity of the stands; and
5. capability of evaluation over an entire forest management unit.

Greig *et al.* (1991) provided a classification scheme which presented a conceptual framework of how wildlife modelling would fit with the treatment of space (see Figure 4). Clearly the model for this study required the complexity of at least Level 3 - spatial-pattern projection of habitat values for a wildlife species.

	TREATMENT OF SPACE	
ENTITIES DYNAMICALLY MODELLED	STAND LOCATIONS IGNORED	STAND LOCATIONS ACCOUNTED FOR
WILDLIFE HABITAT	Non-spatial projection of habitat values for a wildlife species (Level 1)	Spatial-pattern projection of habitat values for a wildlife species (Level 3)
WILDLIFE POPULATION	Non-spatial projection of dynamic occupancy of a wildlife species in a dynamic habitat (Level 2)	Spatial-pattern projection of dynamic occupancy of a wildlife species in a dynamic habitat (Level 4)

Figure 4. A classification scheme for Habitat Supply Models in forest planning (modified from Greig *et al.* (1991)).

CHAPTER 5

METHODS

MOOSE HABITAT SUPPLY ANALYSIS MODEL

The moose habitat supply analysis model (M-HSAM) addressed both the temporal and spatial dimensions of moose habitat through the use of simulation techniques in a GIS environment. As M-HSAM is a simulation model, it does not provide optimal solutions. Rather, M-HSAM could aid in selecting a forest management strategy that provides sufficient moose habitat. Quantitative predictions of future moose habitat resulting from alternative forest management strategies can be compared to demonstrate the best option. The user depicts harvest patterns in time and space, and stipulates silviculture regimes as inputs to the model. M-HSAM is then invoked to interpret forest response to each management strategy in terms of moose habitat.

The basis for M-HSAM was the "Habitat Suitability Index Models: Moose, Lake Superior Region" (Allen *et al.*, 1987). Allen *et al.* (1987) presented two HSI models as tools to aid wildlife managers in measuring moose habitat. The moose HSI models were modified for this study to reflect spatial and temporal variations of moose habitat. The modifications were introduced after consultations with several moose-habitat experts. Simulation techniques which depicted forest development and forest succession were introduced to permit forecasting of future moose habitat supply. GIS techniques were included to permit spatial-temporal interfacing, address edge effect, and permit landscape-scale calculations of habitat supply while retaining representation of landscape pattern.

The calculations performed by M-HSAM represent a systematic sampling of the landscape for its capability to supply moose habitat. Although Allen *et al.* (1987) characterized moose habitat using two seasons (growing season and dormant season) using Model I, habitat assessments in M-HSAM further divided the dormant season into early winter and late winter, as advocated by several authors including Thompson and Euler (1987), Timmermann and McNicol (1988) and Jackson *et al.* (1991). In M-HSAM, calculations of Moose Carrying Capacity (MCC) of the landscape were made for three seasons: summer, early winter and late winter, based on habitat preferences shown by moose (Table 3). Specifications for start and end dates of the three seasons (Table 3) were derived after consultation with moose experts.

Table 3. Start and end dates, duration and habitat components of the three seasons in M-HSAM.

SEASON	START DATE	END DATE	DURATION	HABITAT COMPONENTS
Summer	Apr. 16	Sept.30	170 days	Food
Early Winter	Oct. 1	Jan. 15	105 days	Food and Cover
Late Winter	Jan. 16	Apr. 15	90 days	Cover

M-HSAM progresses through a series of steps, involving GIS spatial data manipulation techniques and simulation techniques, towards the ultimate carrying capacity calculations. These steps are:

1. Grid point overlay (GIS technique);
2. Habitat window (GIS technique);
3. Classification of stands (simulation technique); and
4. Habitat window MCC calculations (simulation technique).

Grid Point Overlay

The basis of the MCC calculations involves the implementation of the GIS pseudo-raster technique (Koppikar *et al.*, 1990). A grid of points is spatially overlain with the FRI polygon coverage. The points gain access to the attributes of the underlying forest stand polygons. Thus, a vector-based polygon coverage of the study area is converted to a pseudo-raster-based coverage by using a simple sampling technique (Koppikar *et al.*, 1990). Burrough (1986) suggested that a disadvantage of vector data is the difficulty of interfacing it with simulation techniques. The conversion from vector data to raster data permitted interfacing the GIS component of the model with the simulation component, thereby overcoming this disadvantage. A brief description of rastor and vector GIS is provided in Appendix II.

Various authors have expressed concern about spatial scaling in ecology (Wiens, 1989; Turner, 1990; Schulz and Joyce, 1992). Turner (1990) explained that "...the spatial scale of ecological data encompasses both grain and extent." Whereas extent refers to the overall size of the study area (the Aulneau Peninsula in this study), grain refers to area represented by each data unit or the resolution of the data (Turner, 1990; Wiens, 1989). Wiens (1989) suggested that extent and grain were "...analogous to the overall size of a sieve and its mesh size, respectively." Grain then refers to the area represented by each grid point in this study, and is a function of the distance between the points or the size of the grid.

The use of GIS diminishes the problems of insufficient extent (Schulz and Joyce, 1992). In fact, extent problems for this study have been eliminated since the entire management unit was used as the study area, a feature enabled by data availability and GIS capability. Wiens (1989) suggested that expanding the extent of a study area usually means enlargening the grain. This logistical limitation was not encountered in this study due to the storage capacity and computational power of the GIS. The maximum extent was selected without constraining the choice of grain size. Thus, grain remained the important spatial scaling factor yet to be determined.

Grain must capture the landscape pattern (variations in size, shape and arrangement of forest stands) and essential processes of moose habitat requirements related to the landscape pattern. Large grain (low resolution) effectively reduces the amount of spatial detail represented in the data. Small grain (high resolution) causes inefficiencies in the data compilation and computing phases of spatial modelling. The latter problem was less important since: (a) data compilation had already been completed (data were provided by Kenora District Office, OMNR) in a vector-based GIS, thereby capturing all of the curvilinear polygon boundaries from the FRI maps of the Aulneau Peninsula; and (b) computing power and storage capabilities used for the study were far in excess of the requirements of the study area database. Emphasis then shifted to selection of a resolution which would favour fineness, so spatial detail would not be sacrificed.

In a study which analyzed spatial scaling in marten (*Martes americana*) habitat modelling, Schulz and Joyce (1992) found that grain sizes which were less than 1% of the species home range did not "... change the prediction of the number of suitable home ranges regardless of habitat quality." Schulz and Joyce (1992) reviewed other studies in which fine resolutions were used to err on the side of conservatism with respect to spatial applications in wildlife habitat ecology.

A grain size of 4 ha was selected for M-HSAM. Since a point grid was used as the data unit, the distance between points was 200 m (with a 200 m X 200 m point grid, each point represents 4 ha of the study area). The choice of 200 m as the distance was important for the following reasons:

1. Home ranges for moose vary from 20 to 40 km^2 (Timmermann and McNicol, 1988). The 4-ha grain selected for this study is less than 1% of these home range values, thereby conforming to the recommendations of Schulz and Joyce (1992).

2. Hamilton *et al.* (1980) found that 95% of moose browsing occurred within 80 m of residual cover in severe winters. The work of Allen *et al.* (1987), which was based on the results of a workshop of moose experts, used 100 m as the distance from cover that moose would travel for browse. The 200-m point grid used in M-HSAM would yield average proximity calculations between habitats of 100 m, which coincided with the work of these authors.

3. The minimum size of a forest stand delineated on the Ontario FRI maps is approximately 4 ha. It was therefore assumed that almost all forest stands would be represented in the pseudo-raster overlay. M-HSAM forecasts MCC's for an entire forested landscape, so small stands not accounted for in the point-on-polygon overlay would therefore not appreciably influence the MCC values for a large area.

Habitat Windows

Another GIS procedure employed in M-HSAM is a "roving window technique" similar to that used by Duinker (1986b). As Duinker (1986b) explained, the roving window technique allows the capture of spatial dynamics involved when a mobile animal reacts to changes due to location-specific forest operations. In essence, the window technique involves calculating the habitat supply within a specific area, and then moving the window 50% and redoing the calculation. The technique consists of overlaying a 2304 ha (4800 m X 4800 m) sampling unit or window on the 200 m grid points. Seasonal MCC's are calculated for each window. Seasonal MCC's of the window consider the attributes of all 576 grid points within that window. The seasonal MCC's of the habitat in each 2304 ha window are assigned to the centre point of each habitat window. A 50% overlap of windows in both the X and Y directions permits each 200 m grid point to contribute to the MCC value of 4 habitat windows. The window centre points were 2400 m apart in both the X and Y axes. If 50% or more of the 200 m grid points in a habitat window (at least 288 of the 576 grid points within each habitat window) overlaid land polygons, the calculations of carrying capacity were completed. The remainder of the 200 m points would overlay water polygons. MCC values of zero were assigned to those habitat windows in which less than 50% of the 200 m grid points overlaid land polygons.

The window-by-window habitat assessment continues until the entire study area is complete (Figure 5). Home range sizes for moose vary greatly, not only by season but also by sex of the animal and geographic location (Timmermann and McNicol, 1988). A window size of 2304 ha (4800 m X 4800 m) was selected because it:

(a) matched the home ranges values (20 - 40 km^2). It was felt important to have a habitat window of this general magnitude; and
(b) was a geometric correlation to the 200 m window. Using the point grid distance of 200 m X 200 m and the 50% overlap, the 2304 ha window was the smallest window greater than 20 km^2 (refer to Appendix III for an explanation).

From the standpoint of analyzing model outputs, the windows provide an intermediate level of information between the grain and the extent. At the 200 m grid point level, excessive information would be provided, resulting in too much detail with no indication of habitat supply at the scale of moose home range. On the other hand, amassing the information for the entire study area entails excessive averaging and loss of spatial variability of moose habitat. The windows provide an intermediate level of resolution in which habitat variability is captured while excessive noise is avoided.

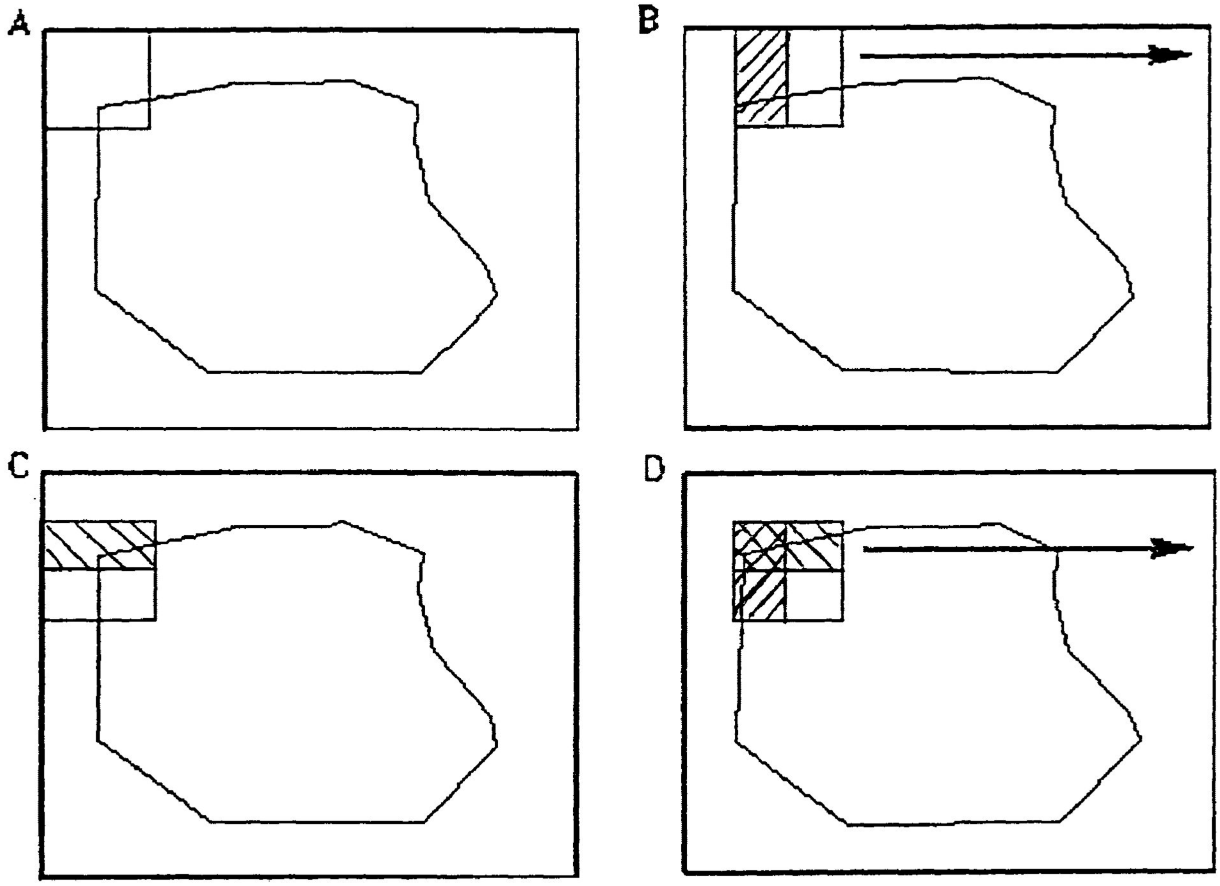


Figure 5. A diagram showing the 50% horizontal and vertical overlap of the "roving window technique". The process is completed on a row by row basis until the entire study area is systematically sampled.

Classification of Stand Types

A stand-type classification scheme was developed to permit the designation of each stand in the forest into a stand type, based on characteristics of producing food or providing cover for moose. Based on information in the FRI and a general knowledge of forest tree species in this area, thirteen stand types were defined for the forests of the Aulneau Peninsula (Table 4).

Table 4. Stand types used in M-HSAM for the Aulneau Peninsula.

STAND TYPE	SITE CLASS	SPECIES COMPOSITION
1: Spruce Upland	X, 1 or 2	Sb ge 90%
2: Spruce Lowland	3 or 4	Sb ge 90%
3: Spruce Mixed	all	Sb lt 90%
4: Pine	all	Pw+Pr+Pj+Sb+Sw+Bf ge 70%
5: Pine Mixed	all	Pw+Pr+Pj+Sb+Sw+Bf le 70%
6: Poplar (high)	X, 1 or 2	Po+Bw ge 70%
7: Poplar Mixed (high)	X, 1 or 2	Po+Bw lt 70%
8: Poplar (low)	3 or 4	Po+Bw ge 70%
9: Poplar Mixed (low)	3 or 4	Po+Bw lt 70%
10: White Spruce	all	all
11: Larch	all	all
12: Cedar	all	all
13: Balsam Fir	all	all

Age-Dependent Food and Cover Curves

Each stand type is assigned a pair of summer food curves, early winter food curves and early winter cover curves. The curves indicate the food or cover available to moose for each stand type by age. The curve pairs represent opposite extremes of amount of food or cover available, as follows. The food supply curves depict the amount of available browse in a stand type at any stand age. Two curves showing available browse for each stand type were given - one for the stocking level of 10% and the other for the stocking level of 100%. The development of the curve sets was accomplished in consultation with a number of experts in the field of moose ecology. Food supply curves were generated with consideration of the following key points:

1. Forage production peaks 5-20 years after timber harvesting (Vallée *et al.*, 1976; Crête, 1977). Joyal (1987) stated that maximum browse production was achieved 5 to 15 years after cutting. After this period browse production begins to diminish (Joyal, 1987). The food supply curves used in M-HSAM peak at 5 to 20 years.

2. Food supply curves were maintained below maximums indicated in the literature. For summer the maximum was set at 450kg/ha, below the value of 458 kg/ha as indicated by Cumming (1989). For early winter the maximum was set at 167 kg/ha which conformed with values found by Todesco (1988).

The final curve sets were acceptable to each of the experts. Food supply for stands having stocking levels between these values are derived through linear interpolation between these extremes. The food supply or forage availability of a stand can be determined using the following formula:

$[(FS_{10} - FS_{100}) / 9] \times [10 \times (\text{Stocking level} - 0.1)] + FS_{100}$

where; FS_{10} = food supply from 10% curve
FS_{100} = food supply from 100% curve.

McNicol and Gilbert (1980) found that stands most used by moose during the early winter period were moderately stocked with scattered conifers and deciduous trees. The early winter cover curves for M-HSAM were developed to reflect this finding. It was assumed that stands with a stocking level of 50% would be consistent with the work of McNicol and Gilbert (1980). This stocking level provided the best early winter cover potential in each stand type. Stands that are more or less dense have lower early winter cover potential. Each stand type was assigned early winter cover curves for 10% stocking and 50% stocking levels. The 10% stocking curve is also the 100% stocking curve in this case. These curves are assumed to represent opposite extremes of early winter cover for moose. Again, interpolation is used to calculate early winter cover indices for stocking levels not equal to 10%, 50% or 100%. In all examples, stocking levels in excess of 100% are assumed to be 100% stocked. Figures 6, 7 and 8 show examples of summer food curves, early winter food curves and early winter cover curves, respectively. Full sets of summer food curves, early winter food curves and early winter cover curves used for this study are presented in Appendices IV, V and VI respectively. No curves are needed for late winter calculations, as shown later.

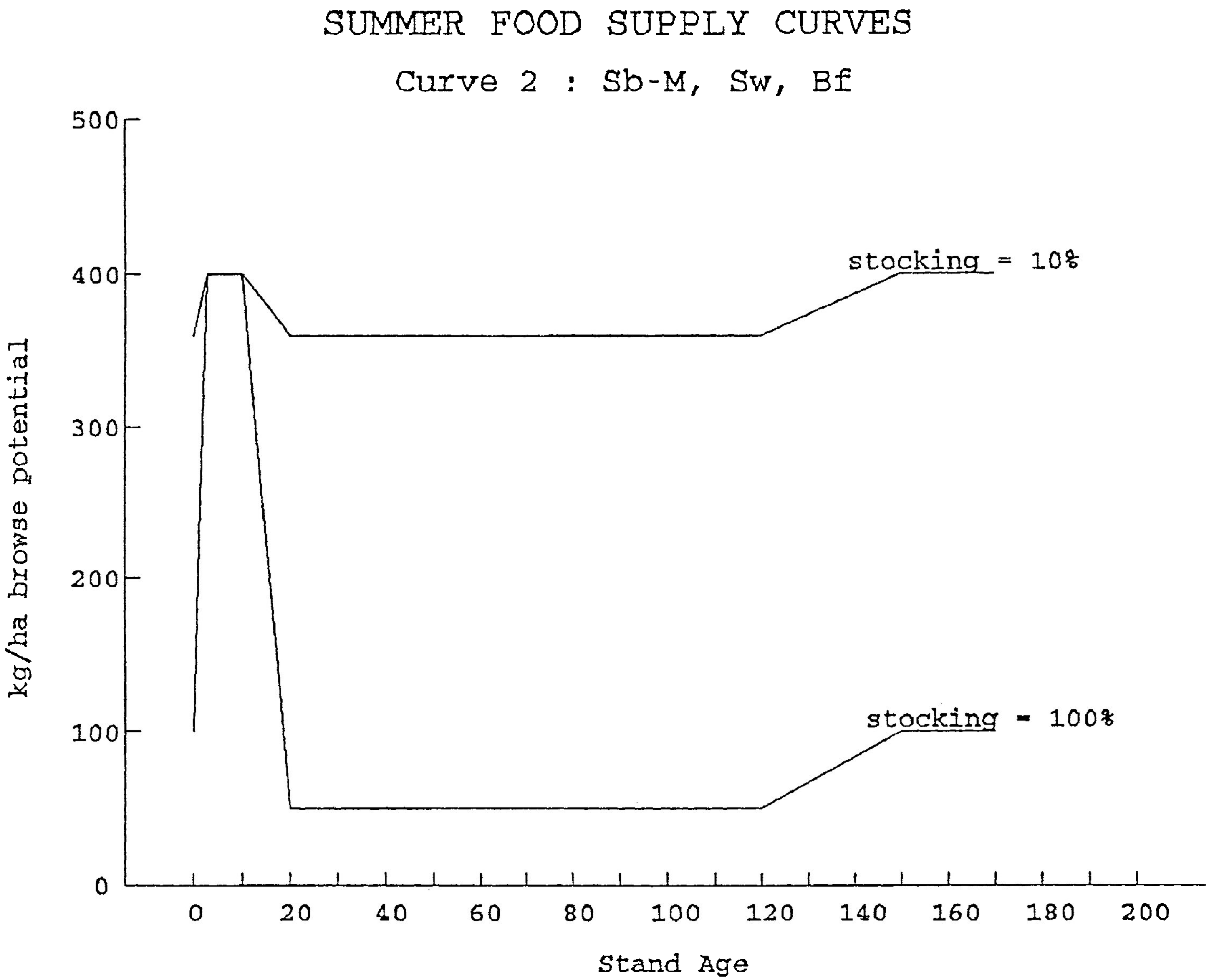


Figure 6. Example of a summer food curve pair used in M-HSAM.

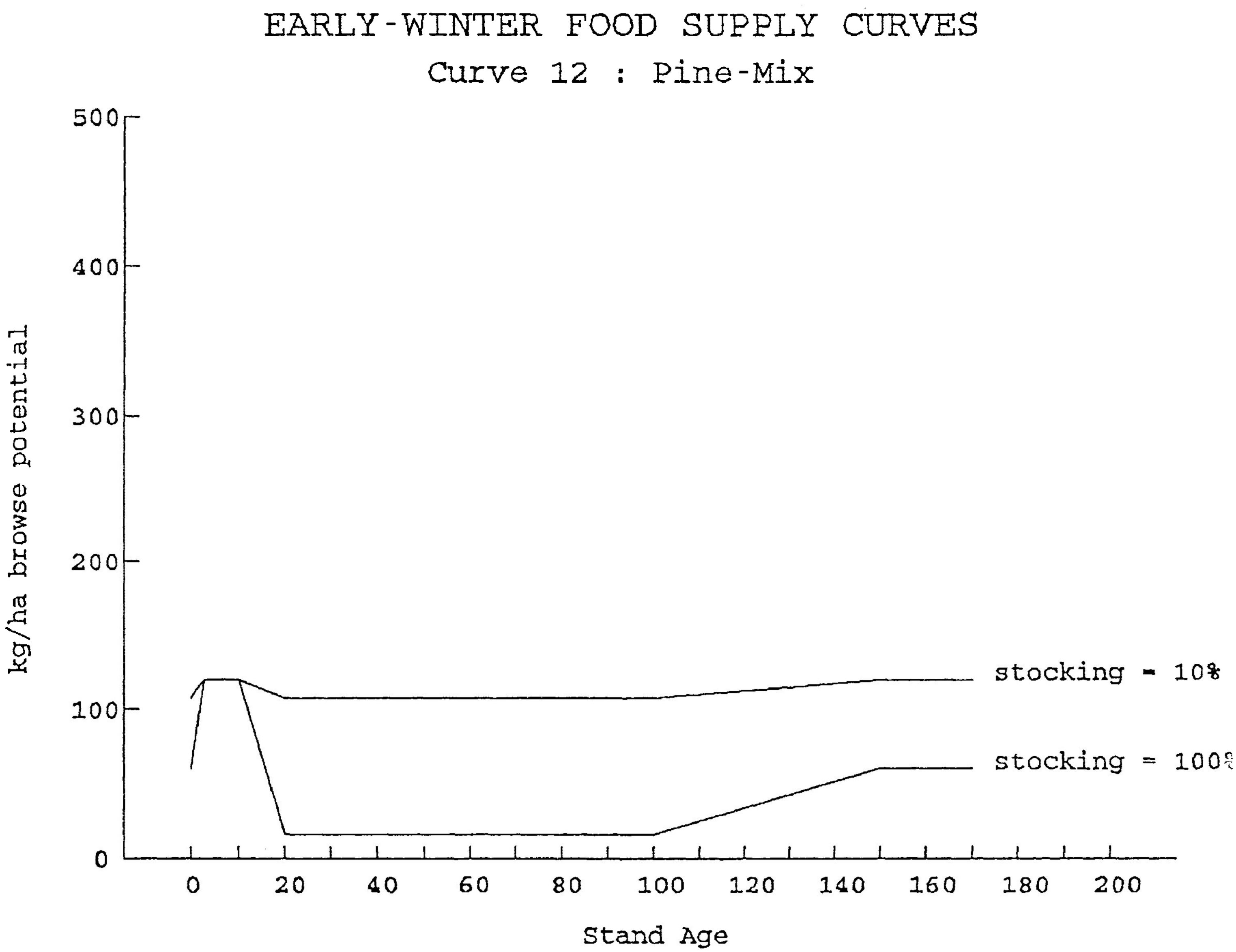


Figure 7. Example of early winter food curve pair used in M-HSAM.

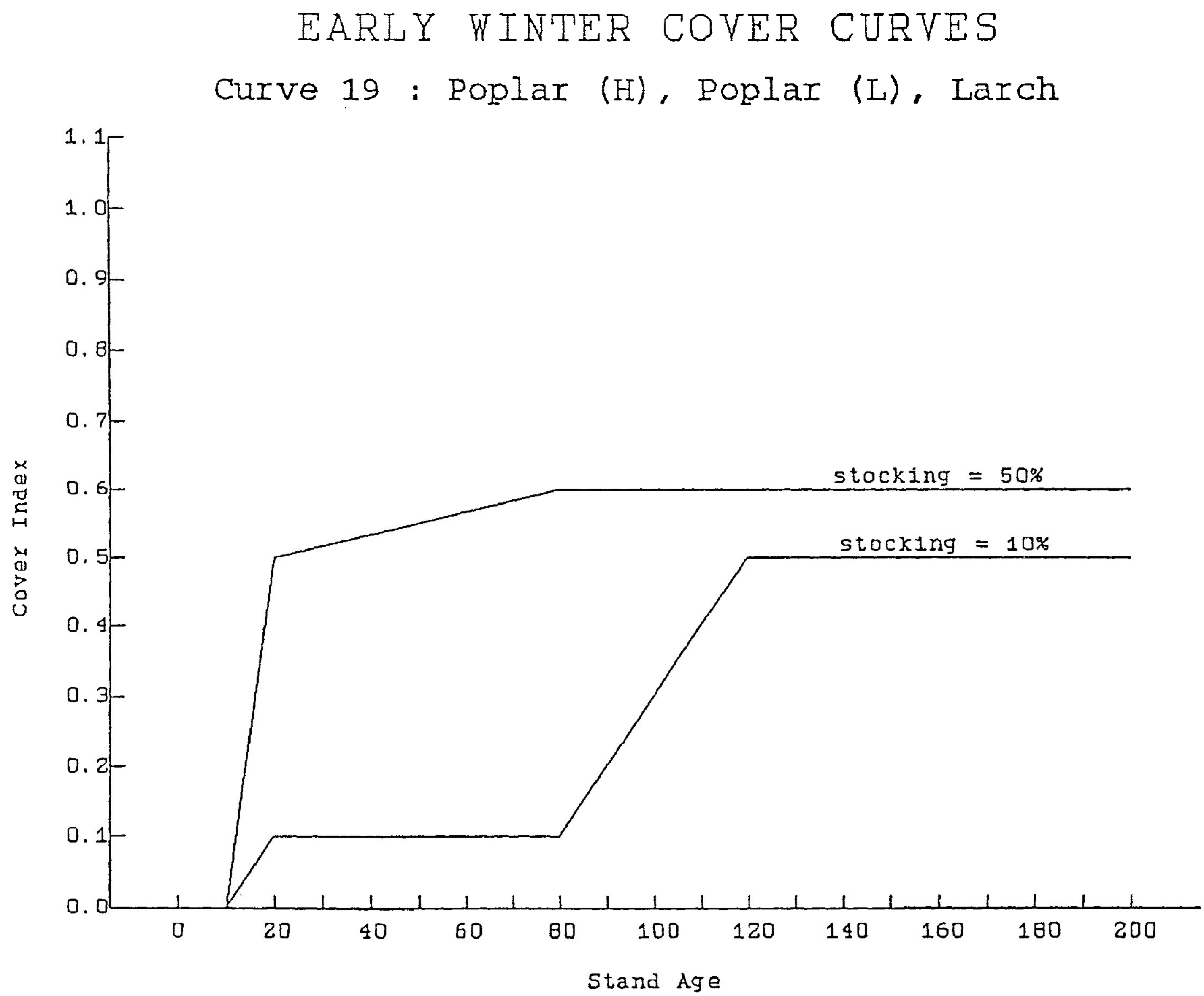


Figure 8. Example of an early winter cover curve pair used in M-HSAM.

Habitat Window MCC Calculation

1. Summer MCCs

In M-HSAM, summer MCC is based solely on the availability of food to moose. Food calculations are made for each point based on the species composition, stocking, and age of the stand that it represents. The information base from which these calculations were made is the FRI data set. Although from a wildlife ecology standpoint this information was deficient, it was the best available information for this study, and could provide usable results in the absence of a wildlife-specific habitat database. For each habitat window, the food values of all the points within it are summed as in EQN-I to arrive at its summer MCC:

$$MCCs_{ij} = \begin{cases} \left[\sum_{x=1}^{576} (0.2 * B_{xij} * 4)\right] \div K_s \div 23.04 & if\ m \geq 288 \\ 0 & if\ m < 288 \end{cases} \qquad EQN\text{-}I$$

where:

$MCCs_{ij}$	=	summer MCC (moose/km^2) for ith window in jth year
x	=	identity of point in ith window
576	=	the number of 200 m points in a habitat window
288	=	50% of the points in a habitat window
0.2	=	maximum cropping rate during summer

B_{xij} = kg/ha browse potential of point x in window i and year j, based on the stand in which it lies. This value is derived from age-dependent summer food supply curves.

4 = number of hectares represented by each 200 m point (grain)

K_s = total forage requirement for a lactating cow moose during the summer period. $K_s = 680$ (4 kg per day X 170 days)

m = the number of 200 m points in the habitat window that do not overlay a water polygon

23.04 = the conversion factor from moose/habitat window (area of 2304 ha) to moose/km^2

This equation was derived from the summer moose carrying capacity equation described by Allen *et al.* (1987). The equation has been changed to reflect the spatial consideration for grain size and habitat window carrying capacity used in M-HSAM.

2. Early Winter MCCs

The early winter MCC of a habitat window was a function of the availability of food in proximity to cover. This relationship has commonly been referred to as the edge effect as recorded by Leopold (1933). In addition to the food calculation made for all points, they were rated on a scale of 0 to 1 based on their suitability to provide cover to moose. The species composition, age and stocking of the stand represented by the point contributed toward the early winter cover index (see Appendix VI for the curves).

Early winter MCC calculations accounted for the interspersion of habitat patches providing food and those providing cover. The food supply potential of each 200 m sampling point was multiplied by the cover index that was found to be the highest amongst itself and its eight nearest neighbours (each point lies in the centre of a 3-by-3 grid of points). Similarly, the cover index of each point was multiplied by the highest of the nine food supply values. The greater of the two cover-adjusted food indices was selected and contributes towards the early winter MCCs of habitat windows.

The proximity calculation was an attempt to account for ecotones between stands. The early winter MCC of a grid point was adjusted upward if a neighbouring point had a higher early winter food supply value or a higher early winter cover index value. Grid points in ecotones between a stand of high food supply and low cover index and one of low food supply and high cover would assume higher cover-adjusted browse potentials. This reflects the preference of moose to browse near cover as found by Hamilton *et al.* (1980). The relationship for calculating early winter MCC for a habitat window is EQN-II:

$$MCCew_{ij} = \begin{cases} \left[\sum_{x=1}^{576} (0.6 * CAB_{xij} * 4)\right] \div K_{ew} \div 23.04 & if\ m \geq 288 \\ 0 & if\ m < 288 \end{cases} \qquad EQN\text{-}II$$

where:

$MCCew_{ij}$	=	early winter MCC (moose/km^2) of window i in year j
x	=	identity of point in ith window
576	=	the number of 200 m points in a habitat window
288	=	50% of the points in a habitat window
0.6	=	early winter browsing factor
CAB_{xij}	=	cover adjusted kg/ha browse potential of point x in window i and year j, based on the stand in which it lies
4	=	number of hectares represented by each 200 m point (grain)
K_{ew}	=	total browse requirement for an adult moose during the early winter period. K_{ew} = 420 (4 kg per day X 105 days)
m	=	the number of 200 m points in the habitat window that did not overlay a water polygon
23.04	=	the conversion factor from moose/habitat window (area of 2304 ha) to moose/km^2

This equation is similar to that described by Allen *et al.* (1987). However, in M-HSAM the spatial dimension is addressed in terms of life requisites of moose during the early winter period and in the habitat window MCC calculation.

Essentially, the capability of adjusting browse and/or cover values of a point by searching its nearest eight neighbours for a higher value permitted the creation of spatially independent transition zones between habitat types. These ecotone points could assume higher point values than points farther from edges. The higher value of habitat created as a result of edge is consistent with the concept that moose prefer ecotone habitats as discussed by LeResche *et al.* (1974). Figure 9 shows a schematic version of the process involved and the resulting higher habitat value points due to their proximity to better cover or browse.

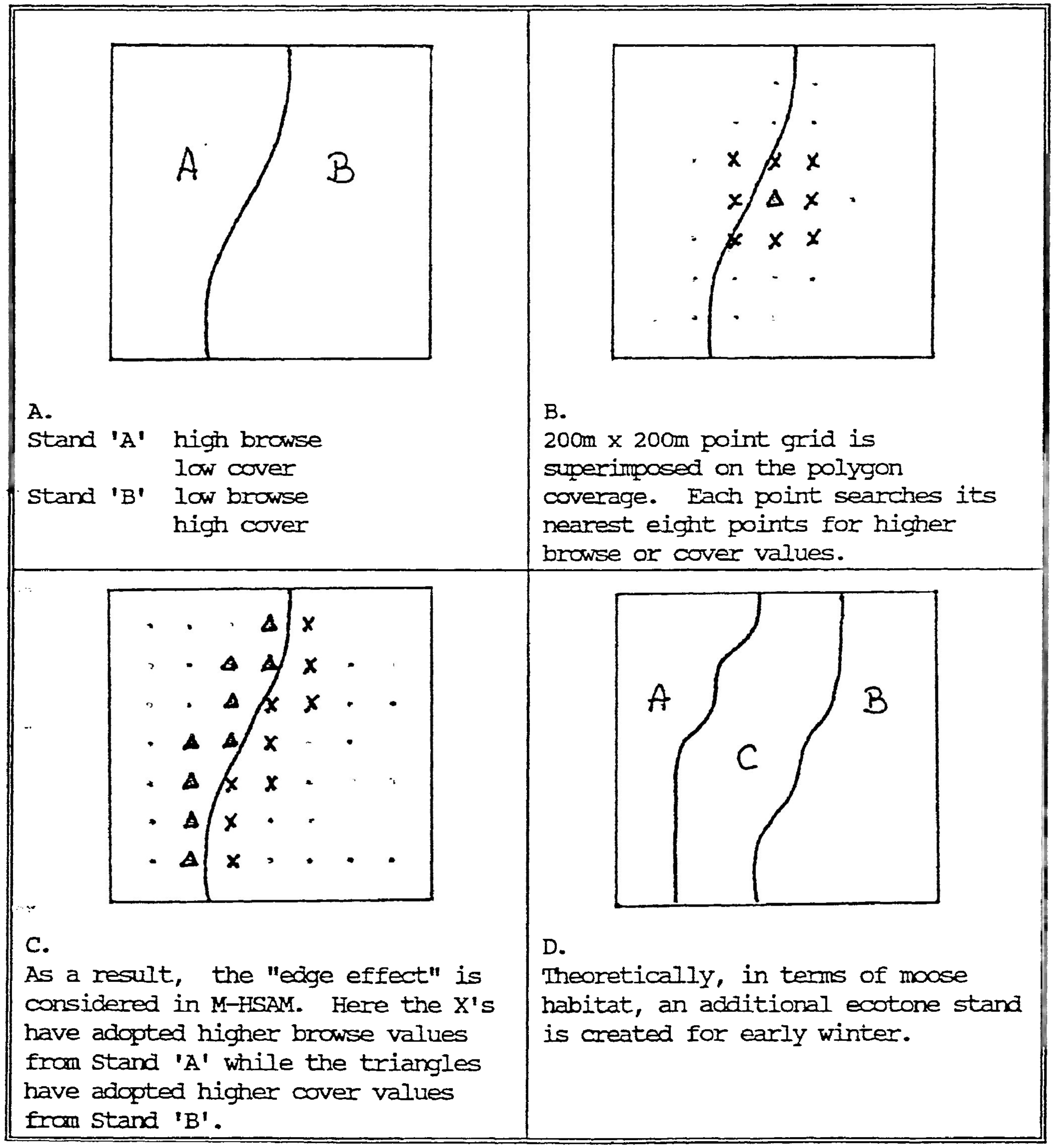


Figure 9. A schematic example of edge effect consideration and resulting transition zones in M-HSAM.

3. Late-winter MCCs

In late winter, moose become sedentary creatures greatly reducing their movements (Risenhoover, 1986; Thompson and Euler, 1987). During this season moose voluntarily reduce food intake (Schwartz *et al.*, 1988; Renecker and Hudson, 1989; Van Ballenberghe and Miquelle, 1990). Survival is based primarily on lowering metabolic rates and catabolizing body reserves (Regelin *et al.*, 1985; Risenhoover, 1986; Van Ballenberghe and Miquelle, 1990). The late-winter period is spent under thermal-regulatory cover (Thompson and Euler, 1987; Timmermann and McNicol, 1988). The late-winter MCCs, therefore, are based solely on cover availability. However, it is difficult to predict the potential carrying capacity of the habitat based on cover alone. M-HSAM adopts an approach similar to that described by Allen *et al.* (1987). Thus, late-winter cover reduces, or at most sustains, the early winter MCC of the habitat window. Since the late winter habitat value was a function of the early winter habitat value for the same habitat window, it was assumed that movements by moose from early winter habitat to suitable late winter habitat could be accomplished within the habitat window.

The late-winter MCC of a habitat window is derived from a relationship that reflects its early winter MCC as well as the stocking, height, and conifer components of the 200 m points that lie within it. EQN-III elaborates these relationships.

$$MCClw_{ij} = MCCew_{ij} * RF_{ij} \qquad EQN\text{-}III$$

where:

$MCClw_{ij}$ = late-winter MCC (moose/km^2) of i^{th} window in year j

$MCCew_{ij}$ = early winter MCC (moose/km^2) of i^{th} window in j^{th} year

RF_{ij} = factor used to reduce early winter MCC for window i in year j based on dormant season cover

The reduction factor used in EQN-III, RF_{ij}, is calculated as follows:

1. Use EQN-IV to determine the late-winter Dormant Season Cover Index (DSCI) for each stand y in year j of the study area:

$$DSCI_{yj} = \sqrt{SIV_7 * SIV_8} * SIV_9 \qquad EQN\text{-}IV$$

where:

SIV_7 = suitability index based on % canopy cover (stocking, in this case) of stand (Figure 10).

SIV_8 = suitability index based on % of stand made up of conifer species (Figure 11).

SIV_9 = suitability index based on the mean height of the conifer component of the stand (Figure 12).

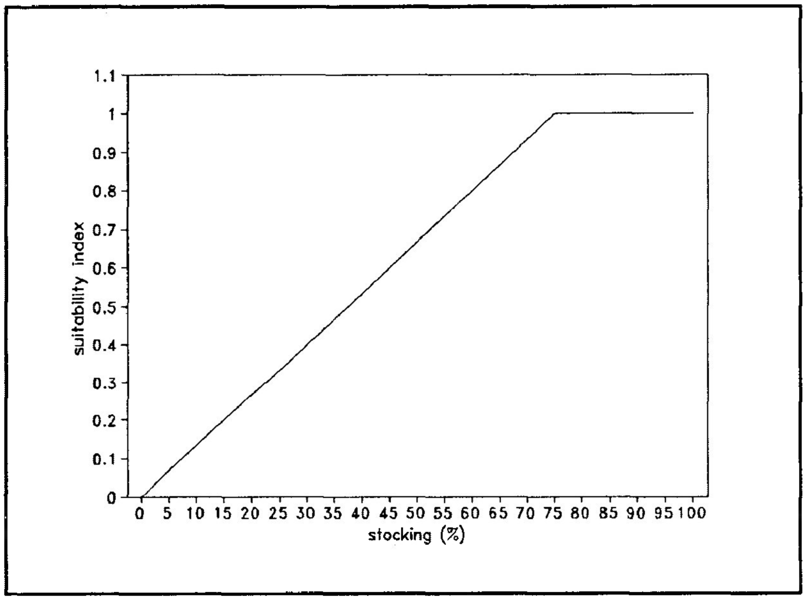


Figure 10. Suitability index (SIV7) for late winter cover based on stand stocking (%) from Allen *et al.* (1987).

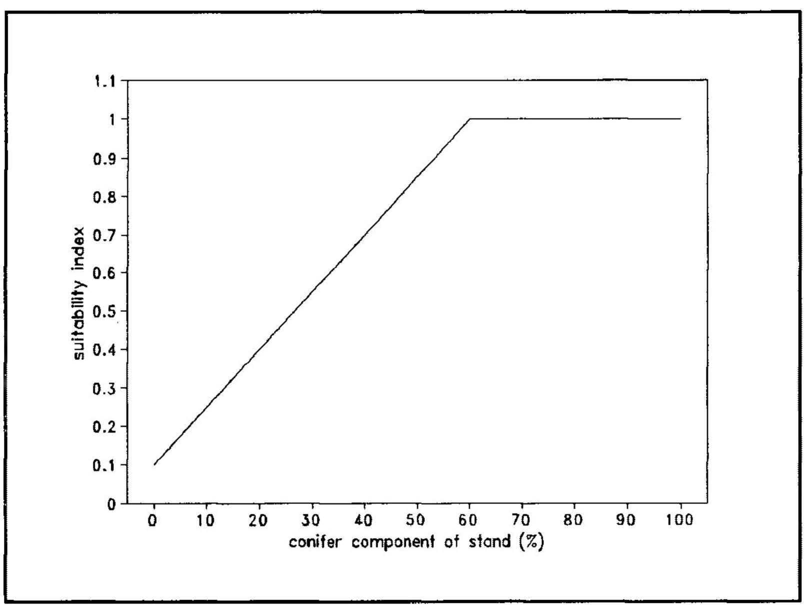


Figure 11. Suitability index (SIV8) for late winter cover based on conifer component of stand (%) from Allen *et al.* (1987).

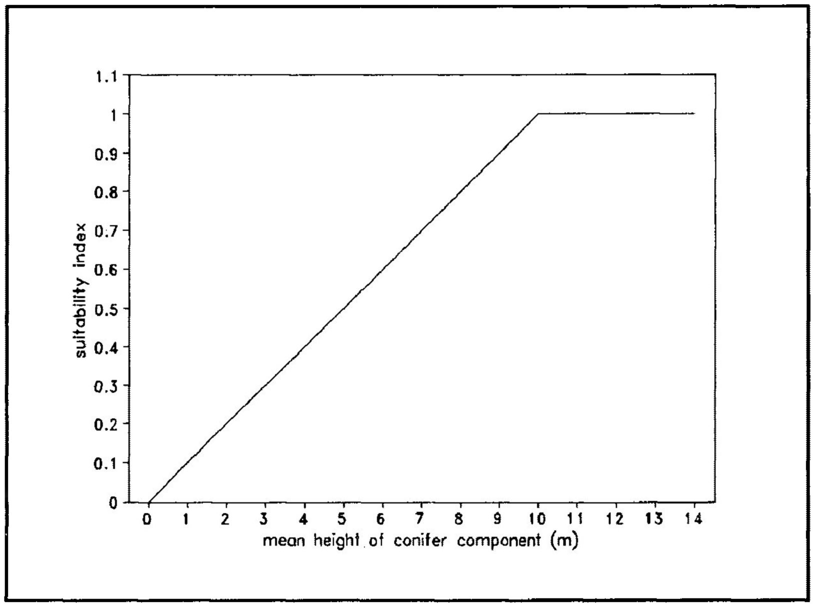


Figure 12. Suitability index (SIV9) for late winter cover based on height of conifer component of stand (m) from Allen *et al.* (1987).

2. Determine the point-equivalent DSCI for each 200 m point in the study area, based on relationship 1 in Figure 13;

3. Determine the habitat-window-equivalent DSCI for each window in the study area using EQN-V;

$$WEQ_{ij} = \left(\sum_{x=1}^{576} PEQ_{xij}\right) \div 576 * 100 \qquad EQN\text{-}V$$

where:

WEQ_{ij} = the window-equivalent DSCI for the i^{th} window in j^{th} year

PEQ_{xij} = the DSCI of point x in i^{th} window and j^{th} year

576 = the number of 200 m points in a habitat window

$DSCI_{yj}$ = Dormant Season Cover Index of stand y in year j

PEQ_{xij} = Point-Equivalent DSCI of point x in window i and year j (based on the stand in which it lies)

WEQ_{ij} = Window-Equivalent DSCI of window i in year j as a percentage of all 200 m points within it

RF_{ij} = factor used to reduce early-winter MCC for window i in year j based on availability of dormant season cover within that window

4. Use relationship 2 from figure 13 to determine the RF for the i^{th} window in j^{th} year.

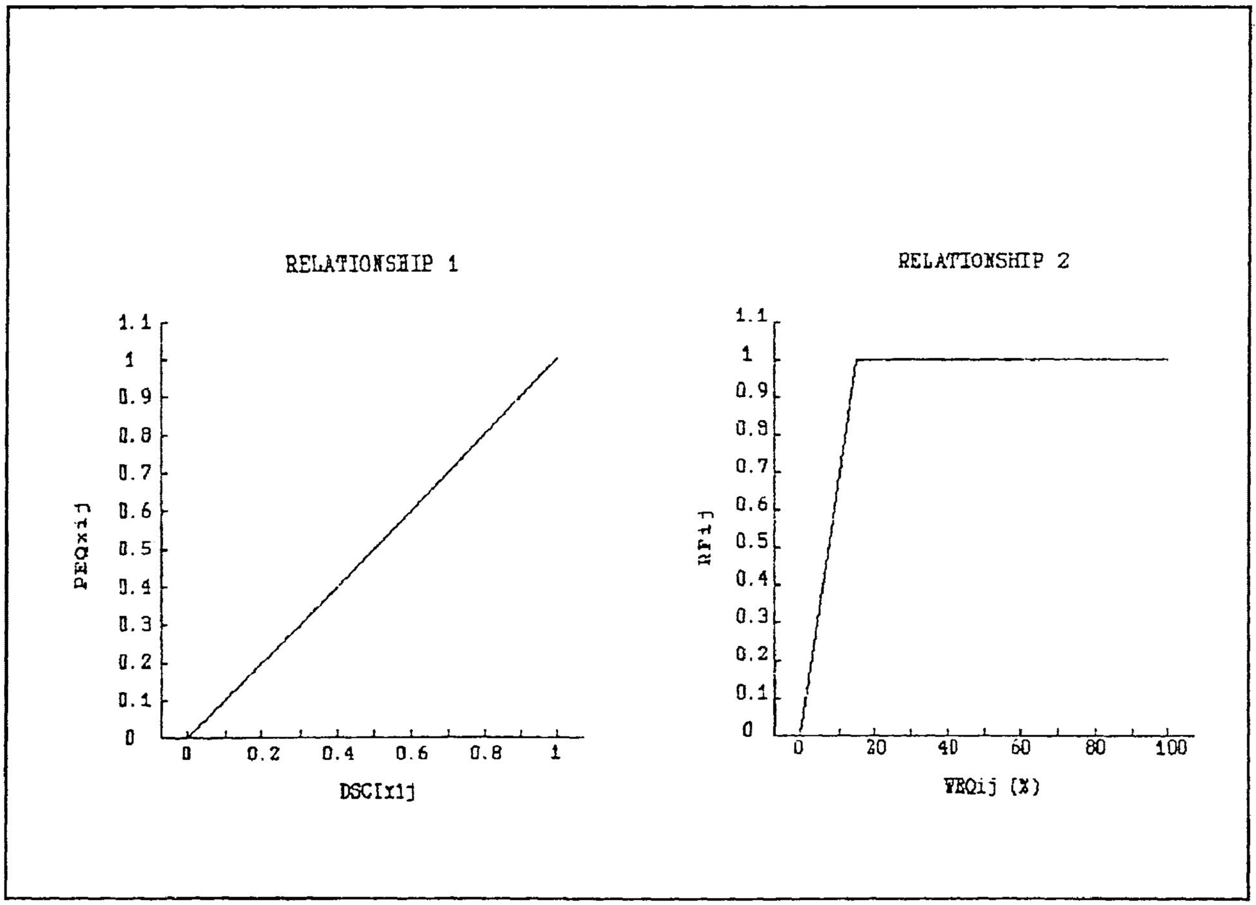


Figure 13. Curves used to calculate late-winter MCC (from Allen *et al.*, 1987).

Silviculture Rules

The following rules provide the framework for the regeneration of stands in the study area after timber harvest:

- all stands of the pine and spruce working groups will be returned to their original level of stocking and species composition as indicated by the FRI maps;

  stands of the balsam fir working groups will be returned to spruce;

  stands of the hardwood working groups (poplar, birch) on site class 1 or 2 will be returned to their original level of stocking and species composition; on site class 3, they will be converted to spruce as the primary species and hardwood as the secondary species;

  free-to-grow (an established forest stand) will be deemed as having been achieved in the second five-year sequence after harvest (in year 10 for the purpose of this model).

Table 5 shows how the silviculture rules are implemented in M-HSAM.

Table 5. Silviculture rules used for M-HSAM.

CLASS	STATE-1	STATE-2	STATE-3
1	Spruce Upland	Spruce Upland	Spruce Upland
2	Spruce Lowland	Spruce Lowland	Spruce Lowland
3	Spruce-Mix	Spruce-Mix	Spruce-Mix
4	Pine	Pine	Pine
5	Pine-Mix	Pine-Mix	Pine-Mix
6	Poplar (H)	Poplar (H)	Poplar (H)
7	Poplar-Mix (H)	Poplar-Mix (H)	Poplar-Mix (H)
8	Poplar (L)	Poplar (L)	Spruce-Mix
9	Poplar-Mix (L)	Poplar-Mix (L)	Spruce-Mix
10	White Spruce	White Spruce	White Spruce
11	Larch	Larch	Larch
12	Cedar	Cedar	Cedar
13	Balsam	Balsam	Spruce

- STATE-2 comes into effect the same simulation year that the stand is harvested.

  STATE-3 comes into effect 10 simulation years after the stand is harvested.

  When stands change their type in STATE-3, they are assigned a stocking of 60%.

  When a Balsam type becomes a Spruce type in STATE-3, it is assigned a conifer composition of 70%; when a Poplar (L) or Poplar-Mix (L) type becomes a Spruce-Mix type in STATE-3, it is assigned a conifer composition of 60%.

Simulation Length

The length of the simulation for M-HSAM was set at 25 years. The reasons for this choice were:

1. Moose habitat in summer and early winter is a function of food availability. The food and cover characteristics of developing stands fluctuate the greatest during the first 20 years after stand establishment. The 25-year simulation horizon was sufficient to capture much of this dynamic fluctuation for stands harvested early in the simulation.
2. An entire timber management plan horizon (20 years) could be analyzed within this simulation period.

Model Outputs

M-HSAM was designed to produce an MCC for each of three seasons for each habitat window centre in the study area having at least 50% of its grid points overlaying land (≥ 288 of the 576 grid points). The remaining habitat windows were assigned zero. The resulting seasonal MCCs were assigned to the window centre points of each respective habitat window. The results of simulations were stored in user-named data files accessible through a menu-driven graphical output package. The package permits the user to produce time-dependent line graphs of seasonal MCCs of up to two model runs for any selected set or subset of habitat window centres of the study area. The graphs display time on the x-axis and MCC values on the y-axis. The window centres one selects, and the position of each on the study area landscape, are also displayed. Figures 14 and 15 provide examples of M-HSAM output.

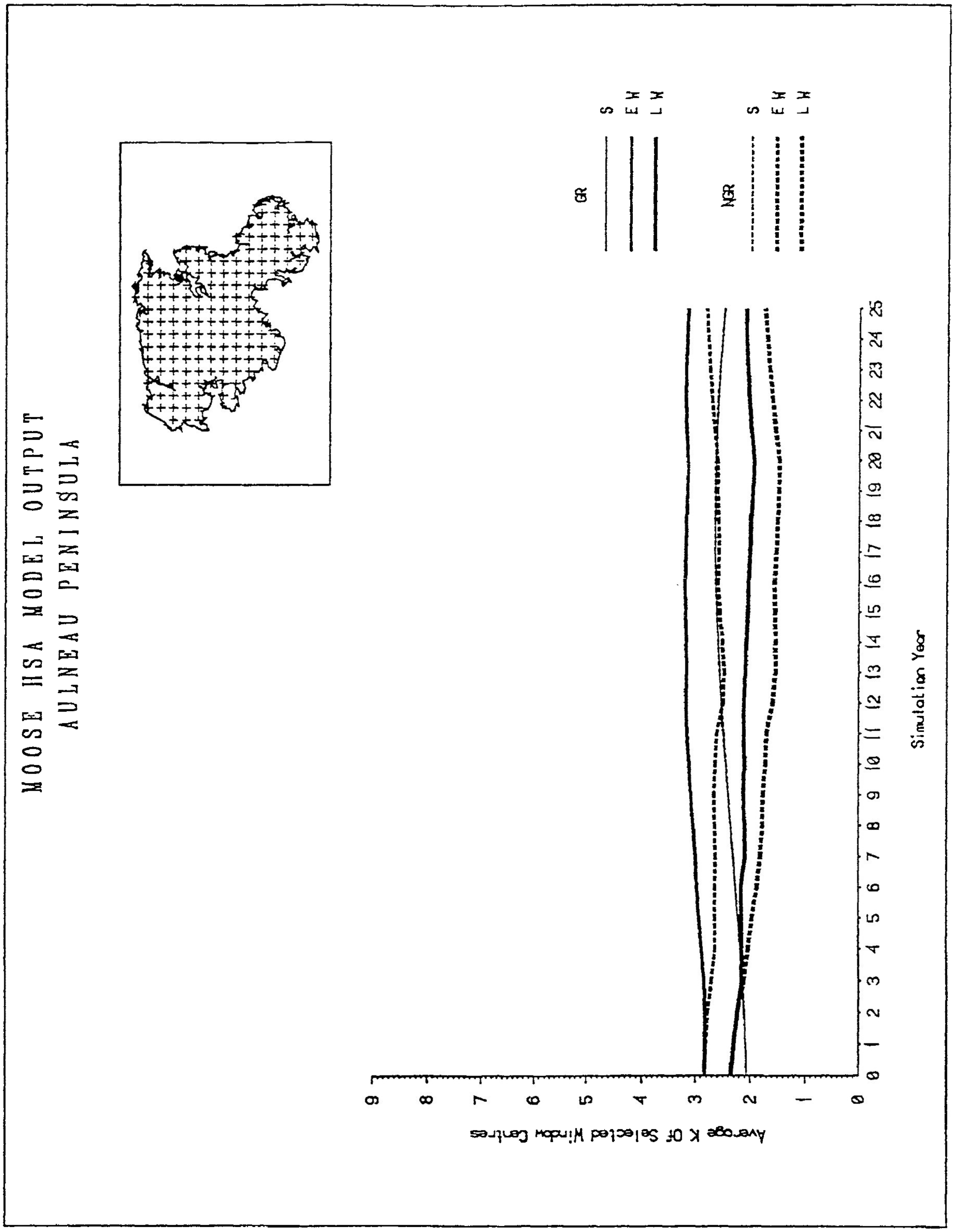


Figure 14. An example of M-HSAM output for all window centres on the study area. K represents carrying capacity in terms of number of moose per km^2.

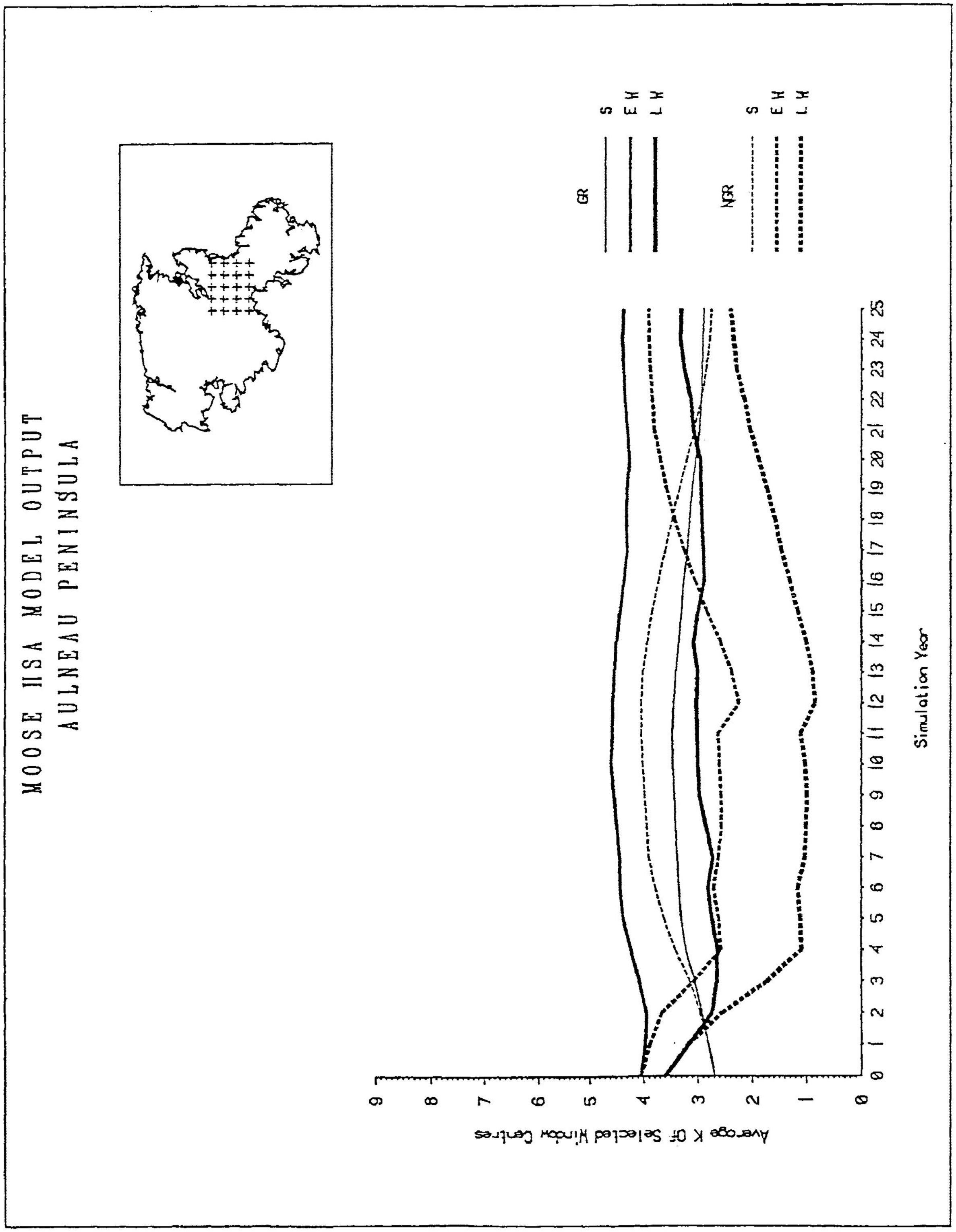


Figure 15. An example of M-HSAM output for two simulations for a selected subset of window centres on the study area. K represents carrying capacity in terms of number of moose per km^2.

APPLICATION OF THE MODEL

M-HSAM was applied to the Aulneau Peninsula FRI data set to generate moose habitat supply forecasts for two forest-management strategies. The scenarios consisted of 20-year timber harvest schedules, one to simulate timber harvest with consideration of the moose-habitat guidelines, and the other to imitate timber harvest without regard for the guidelines. Both alternatives were planned using the area allotment method with each working group assigned an annual allowable harvest area (Table 6). The resulting timber harvest patterns over the 25-year period are presented in Figure 16.

Table 6. Annual allowable harvest on the Aulneau Peninsula by working group.

WORKING GROUP	AREA (ha)
White and Red Pine	45
Jack pine	598
Spruce	68
Balsam Fir	69
Other Conifer	0
Poplar	445
Other Hardwood	14
TOTAL	1,239

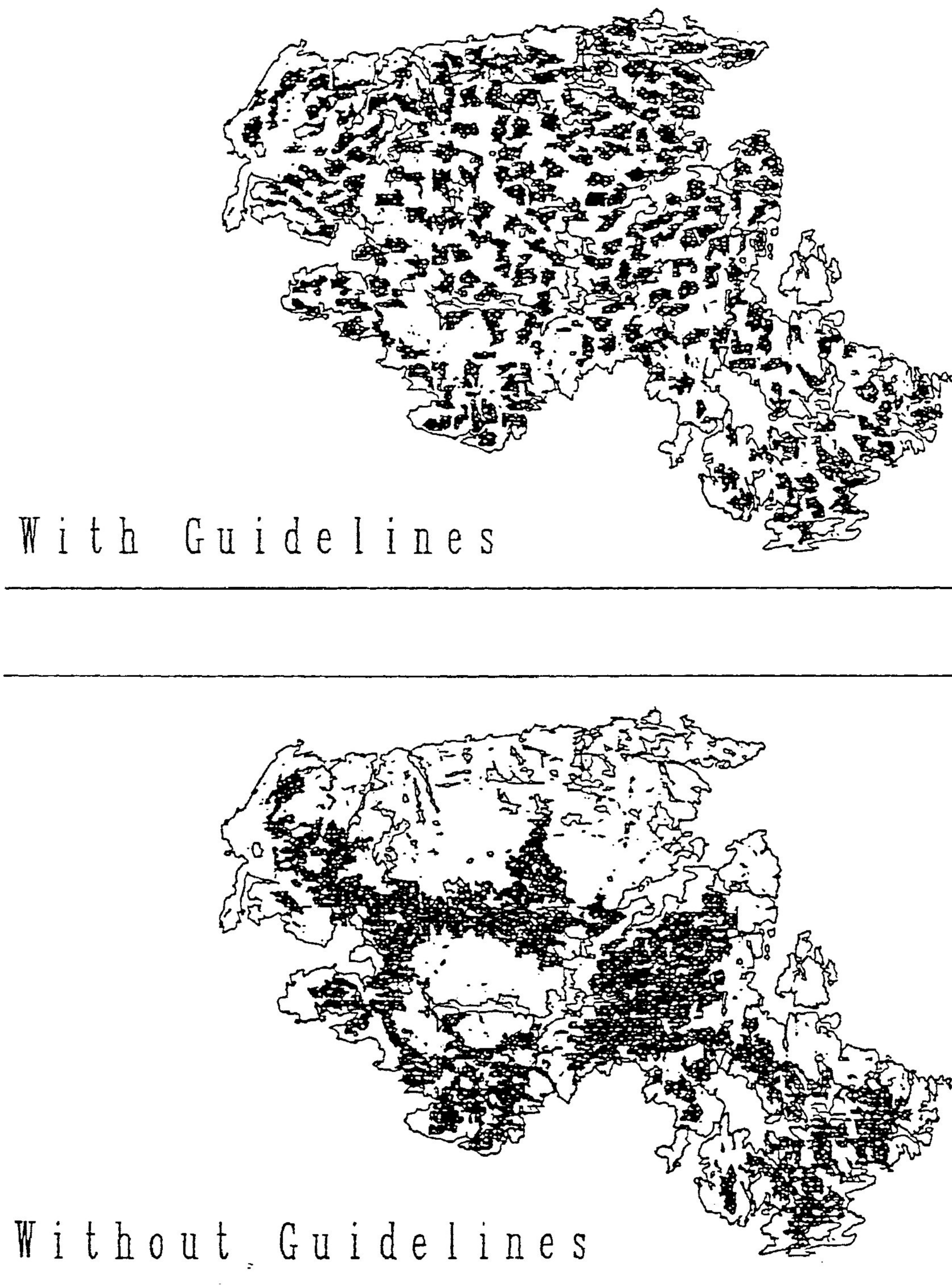


Figure 16. Resulting timber harvest patterns over the 25-year simulation period for both alternatives.

Since the guidelines were specifically intended to affect the extent and pattern of timber harvest, the spatial component of the GIS-based FRI dataset was altered to reflect these spatial limitations for the guidelines scenario. Proposed harvest blocks were limited in size to the maximums indicated in the guidelines. The FRI stand boundaries were adjusted to reflect the appearance of the forest stand boundaries 25 years into the future, when all timber harvests in the scenario were completed. Proposed cutover boundaries which did not coincide with FRI stand boundaries were added to the dataset. In other words, all new boundaries created by planned cutovers in the 25-year period were added to the spatial component of the GIS database. Non-spatial information (e.g.: original stand number, species composition, height, stocking, year of origin) was copied to ensure that new stands, created by the addition of new cutover boundaries, maintained linkages to respective FRI attributes. Proposed harvest blocks consisted of portions of single stands when original stands were larger than the guidelines maximums, or combinations of several stands to conform with size limitations and to retain adjacent cover for moose.

Both the guidelines and the non-guidelines timber harvest schedules were laid out on an annual operations basis. Proposed harvest blocks were added to the harvest queue until annual allowable harvest figures were achieved. The process was repeated for the entire 20-year planning horizon. The forest stand polygons were each assigned a number indicating the year of scheduled harvest. Stands not scheduled for harvest were assigned a zero.

The scenarios were laid out with consideration for the following three operational constraints: (1) access onto the Aulneau Peninsula; (2) road access to the proposed timber harvest areas; and, (3) reasonable annual operating areas. Initial access onto the Aulneau for both alternatives was at the west end of Knickerbocker Inlet (see Figure 2). This location was chosen by OMNR staff after field inspections. Primary access corridors from this access point were to the south, to the southwest and west, and to the northwest. Secondary and tertiary roads would permit access to the entire Aulneau from these primary corridors. Reasonable annual sequences were maintained by ensuring that the chronological sequence of planned harvest followed a theoretical access development pattern and that operations could not be severely scattered during any one year. In theory, harvested timber would be transported by truck to the west end of Knickerbocker Inlet where an appropriate means of water transport would permit moving the timber to the mainland. The spatial pattern of the theoretical 20-year timber harvest with consideration of the guidelines was similar to actual timber harvest patterns in northwestern Ontario, as determined using satellite imagery (R. Rempel, 1994, pers. comm.).

With the GIS database for the two timber-management alternatives in place, M-HSAM was implemented to forecast future moose habitat supplies for each. The M-HSAM model runs for the two timber-management scenarios were completed on a Prime 9955 minicomputer at the Lakehead University Centre for the Application of Resource Information Systems.

To overcome the data overload with both the spatial and temporal dimensions of model runs, the spatial information was merged into a single annual figure for reporting purposes. The annual results for the 25-year simulation period are reported to preserve the temporal heterogeneity. Each model run produced 26 data points for each of the three seasons, one for time zero (t = 0) plus one for each year of the 25-year simulation period (t = 1,2,3...25). Spatial heterogeneity is not represented in this reporting. Spatial analysis of a rudimentary form can be undertaken using the subset selection and reporting feature of the model. This feature involves use of the zooming function of M-HSAM to select a subset of habitat windows for reporting.

CHAPTER 6

RESULTS AND DISCUSSION

M-HSAM, as previously described, permitted analysis of potential impacts of alternative timber harvest strategies in terms of moose habitat. Outputs produced by the model were seasonal MCC calculations for each habitat window for each year of the simulation. These values were assigned to the centres of the respective habitat windows.

The results and discussion below pertain to simulations of the two timber-management scenarios under investigation in this study. Results from a "Guidelines Run" (GR) are compared to those from a "Non-Guidelines Run" (NGR). GR and NGR are used below to identify the two respective scenarios.

The results are described below in three sections. The first discusses the model runs and impacts on the entire study area. The second section deals with basemap 40546 (BM40546), a selected subset of the study area. This basemap provided the greatest difference between the two timber management strategies in terms of amount of forest area scheduled for timber harvest in the 25-year simulation period. Therefore, if the two timber management alternatives were to affect moose habitat potential differently, the greatest differences should be expected for this subset of the study area.

ENTIRE STUDY AREA

The first step in the analysis was to compare the results of the two timber-management strategies over the entire study area. In this comparison, the schedules for timber harvest in each alternative involved planning for equivalent areas of forest to be harvested over the 25-year period. The amount of area scheduled for harvest by working group by year, and by working group for the 25-year period were nearly equal (Table 7).

Timber harvest affected the supply of moose habitat early in the simulations (Table 8, and Figures 17 and 18). At time zero, the summer MCCs were lower than those of early winter and late winter. The forests of the Aulneau Peninsula were largely near, at or past maturity, effectively past the stage of providing substantial food for moose. The MCC for summer increased as the availability of food for moose increased within newly-created cutovers. As the summer habitat improved, the late winter habitat deteriorated. In both the GR and NGR model runs, late winter MCCs fell below those of summer, becoming the lowest seasonal MCC values for the duration of the respective simulations. High rates of harvest of the coniferous working groups caused this deterioration.

Table 7. Scheduled annual harvest area for the whole Aulneau in each of the timber-management alternatives.

YEAR	WITH GUIDELINES	WITHOUT GUIDELINES
1	1042	996
2	1020	1080
3	1087	1055
4	917	1081
5	1061	993
6	978	1072
7	1074	952
8	1094	986
9	969	969
10	1063	967
11	952	1011
12	949	994
13	996	1099
14	1045	898
15	995	987
16	912	911
17	906	950
18	897	917
19	1043	906
20	908	920
TOTAL	19907	19745

In the GR run (Table 8 and Figure 17), the early winter MCC value remained the highest throughout the simulation, increasing slightly through the first half. Even as the summer component increased, the summer values failed to achieve those of early winter. The NGR run (Table 8 and Figure 18) produced different results. Early winter MCCs decreased marginally for much of the first half of the model run, falling below the summer levels for several years. The early winter values eventually surpassed those of summer in the NGR run, due to the decrease in summer MCCs as well as the marginal increase in early-winter MCCs.

Table 8. Seasonal results of Guidelines and Non-Guidelines simulations for the entire Aulneau Peninsula. Data are potential moose carrying capacities as number of moose per square kilometre.

	GR			NGR		
YEAR	SUMMER	EARLY WINTER	LATE WINTER	SUMMER	EARLY WINTER	LATE WINTER
0	2.06	2.83	2.36	2.06	2.83	2.36
1	2.08	2.83	2.31	2.08	2.82	2.31
2	2.10	2.83	2.24	2.11	2.79	2.23
3	2.14	2.84	2.16	2.13	2.71	2.13
4	2.19	2.89	2.15	2.18	2.64	2.04
5	2.23	2.94	2.16	2.22	2.65	1.97
6	2.28	2.97	2.17	2.27	2.65	1.88
7	2.32	2.99	2.10	2.31	2.64	1.82
8	2.36	3.04	2.10	2.36	2.65	1.78
9	2.41	3.08	2.12	2.40	2.67	1.77
10	2.46	3.12	2.11	2.44	2.65	1.73
11	2.50	3.15	2.12	2.49	2.62	1.71
12	2.53	3.17	2.12	2.53	2.50	1.60
13	2.56	3.16	2.10	2.57	2.48	1.55
14	2.59	3.17	2.08	2.60	2.52	1.55
15	2.61	3.18	2.05	2.63	2.56	1.56
16	2.64	3.19	2.04	2.65	2.59	1.57
17	2.64	3.17	2.01	2.66	2.58	1.53
18	2.65	3.17	2.00	2.66	2.59	1.51
19	2.65	3.15	1.96	2.67	2.61	1.49
20	2.64	3.14	1.94	2.66	2.61	1.49
21	2.62	3.17	2.00	2.64	2.67	1.55
22	2.60	3.18	2.03	2.61	2.71	1.61
23	2.57	3.18	2.06	2.57	2.75	1.66
24	2.52	3.16	2.09	2.53	2.78	1.71
25	2.48	3.14	2.09	2.49	2.81	1.75

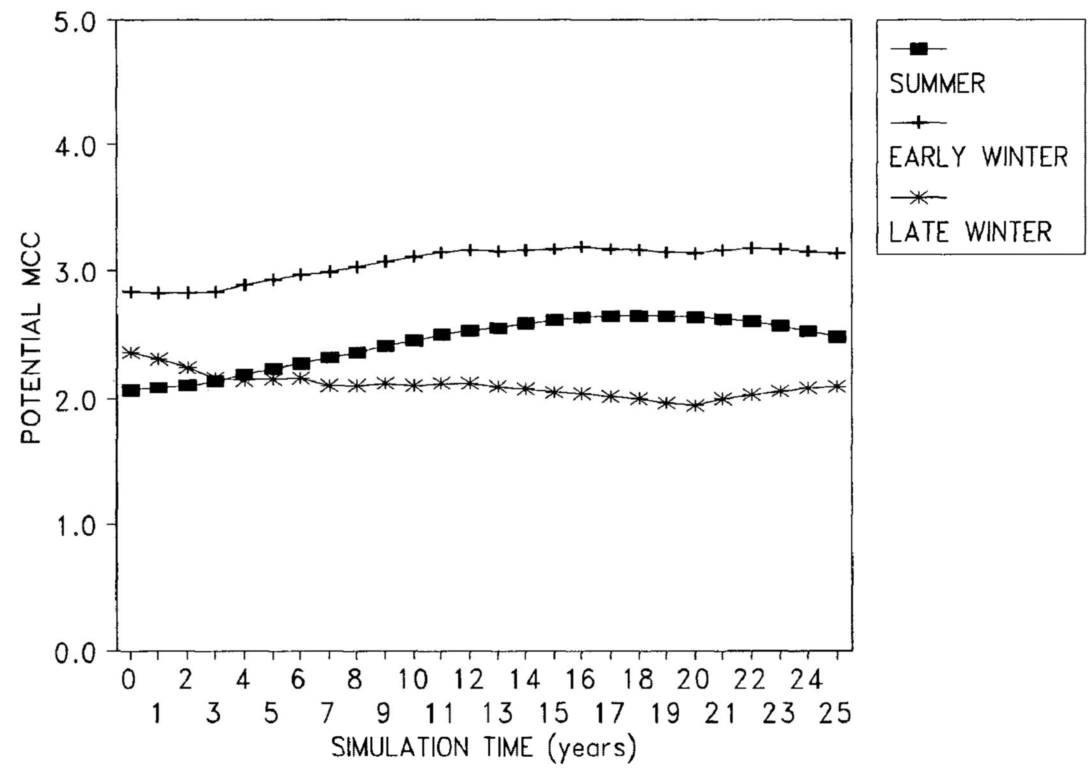


Figure 17. Seasonal MCCs (in terms of number of moose per square kilometre) of the Guidelines simulation for the entire Aulneau Peninsula.

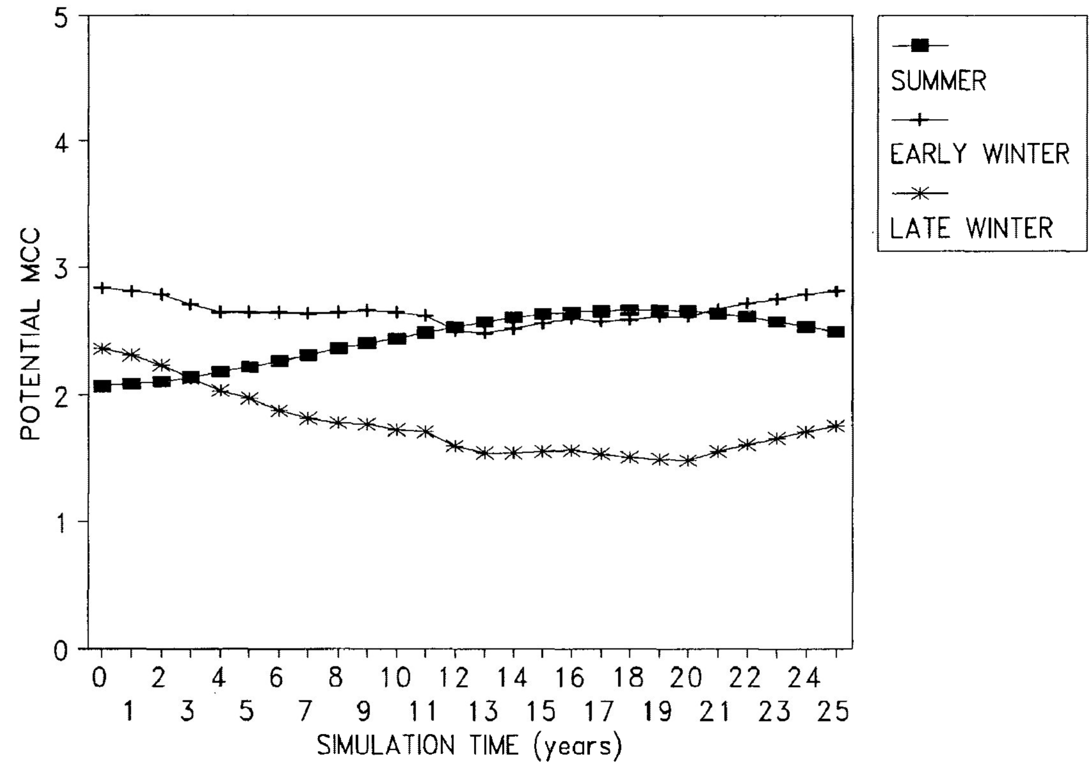


Figure 18. Seasonal MCCs (in terms of number of moose per square kilometre) of the Non-Guidelines simulation for the entire Aulneau Peninsula.

Summer

The summer MCCs for the two timber-management alternatives were similar (Table 9 and Figure 19). Percent differences between GR and NGR (Table 9) were calculated using the formula

$$| [(GR - NGR) / NGR] | X 100 .$$

The values remained within 1% of each other while the average difference between the alternative strategies over the 25-year period was 0.4%. This similarity was expected since: (a) similar areal values by working group were scheduled for timber harvest each year; (b) similar food values were predicted for developing stands of the same working group; and (c) food was the only habitat feature evaluated by M-HSAM for summer habitat. The differences are negligible.

Table 9. The summer MCCs (in terms of number of moose per square kilometre) for the Guidelines and Non-Guidelines simulations, and percent differences between the two.

YEAR	GR	NGR	%DIFF
0	2.06	2.06	0.0
1	2.08	2.08	0.1
2	2.10	2.11	0.1
3	2.14	2.13	0.1
4	2.19	2.18	0.5
5	2.23	2.22	0.6
6	2.28	2.27	0.5
7	2.32	2.31	0.2
8	2.36	2.36	0.2
9	2.41	2.40	0.4
10	2.46	2.44	0.6
11	2.50	2.49	0.7
12	2.53	2.53	0.3
13	2.56	2.57	0.6
14	2.59	2.60	0.6
15	2.61	2.63	0.7
16	2.64	2.65	0.5
17	2.64	2.66	0.5
18	2.65	2.66	0.5
19	2.65	2.67	0.7
20	2.64	2.66	0.6
21	2.62	2.64	0.6
22	2.60	2.61	0.4
23	2.57	2.57	0.4
24	2.52	2.53	0.4
25	2.48	2.49	0.3
		AVERAGE	0.4

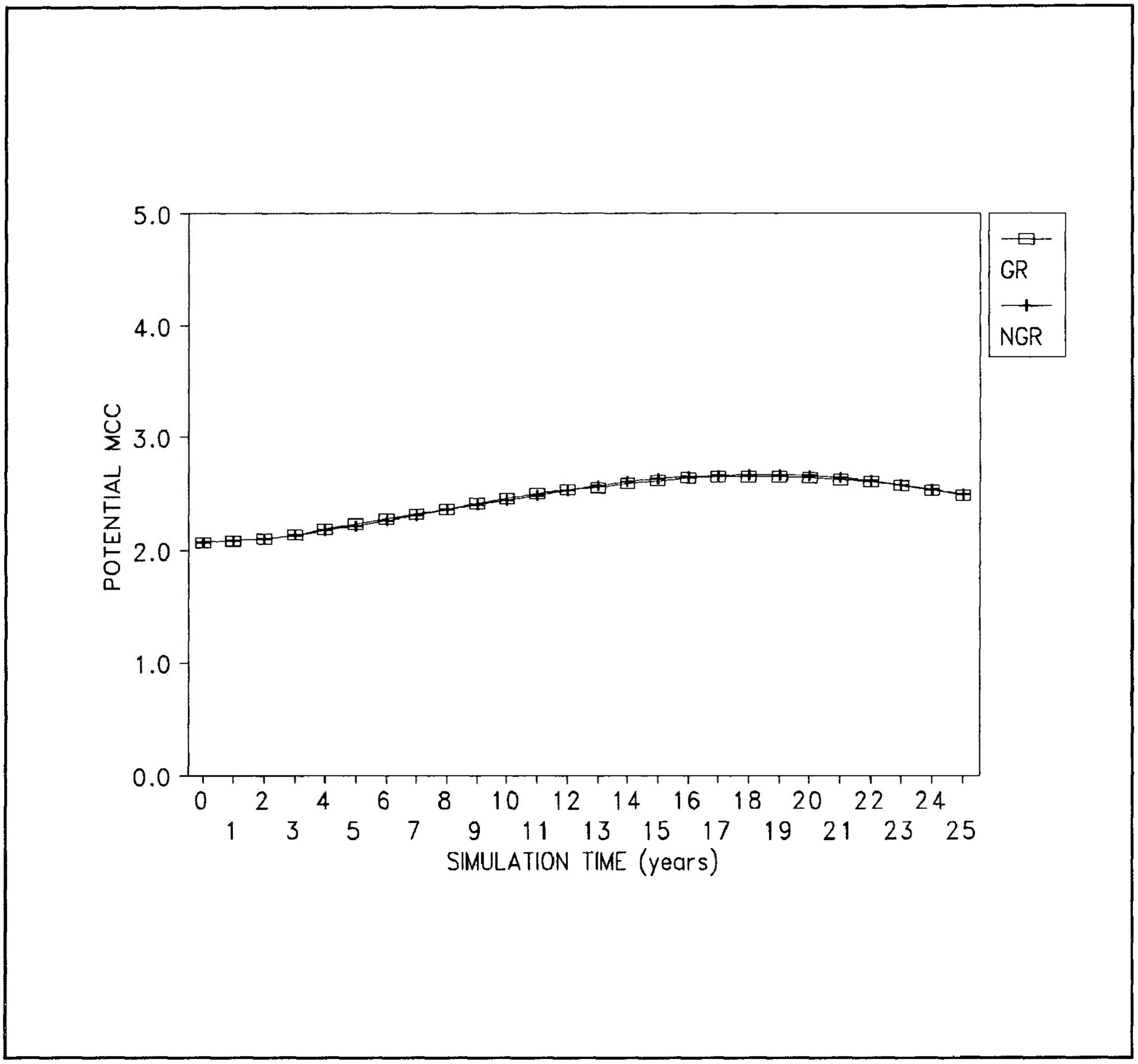


Figure 19. Summer MCCs (in terms of number of moose per square kilometre) of the Guidelines and Non-Guidelines runs for the entire Aulneau Peninsula.

Early Winter

Contrary to the summer values, the early winter values demonstrated substantial differences between the two timber-management alternatives (Table 10 and Figure 20). The values for GR were consistently higher than those of the NGR series, peaking at 27.4% in year 13. The early winter GR MCC values averaged 15.8% greater than those of the NGR alternative.

The MCC values for early winter in M-HSAM were a function of food in proximity to cover. The impact of smaller cutovers with buffer zones of residual forest represented in the GR runs was beneficial to early winter moose habitat in the study area. The superior edge effect, i.e. good food and good cover in close proximity, created in the GR alternative was captured by M-HSAM and contributed to this increase.

Table 10. The early winter MCCs (in terms of number of moose per square kilometre) for the Guidelines and Non-Guidelines simulations, and percent differences between the two.

YEAR	GR	NGR	%DIFF
0	2.83	2.83	0.0
1	2.83	2.82	0.4
2	2.83	2.79	1.6
3	2.84	2.71	4.8
4	2.89	2.64	9.2
5	2.94	2.65	10.8
6	2.97	2.65	12.3
7	2.99	2.64	13.4
8	3.04	2.65	14.5
9	3.08	2.67	15.5
10	3.12	2.65	17.8
11	3.15	2.62	20.4
12	3.17	2.50	26.5
13	3.16	2.48	27.4
14	3.17	2.52	25.8
15	3.18	2.56	24.3
16	3.19	2.59	23.0
17	3.17	2.58	23.0
18	3.17	2.59	22.5
19	3.15	2.61	20.6
20	3.14	2.61	20.3
21	3.17	2.67	18.5
22	3.18	2.71	17.4
23	3.18	2.75	15.7
24	3.16	2.78	13.5
25	3.14	2.81	11.7
		AVERAGE	15.8

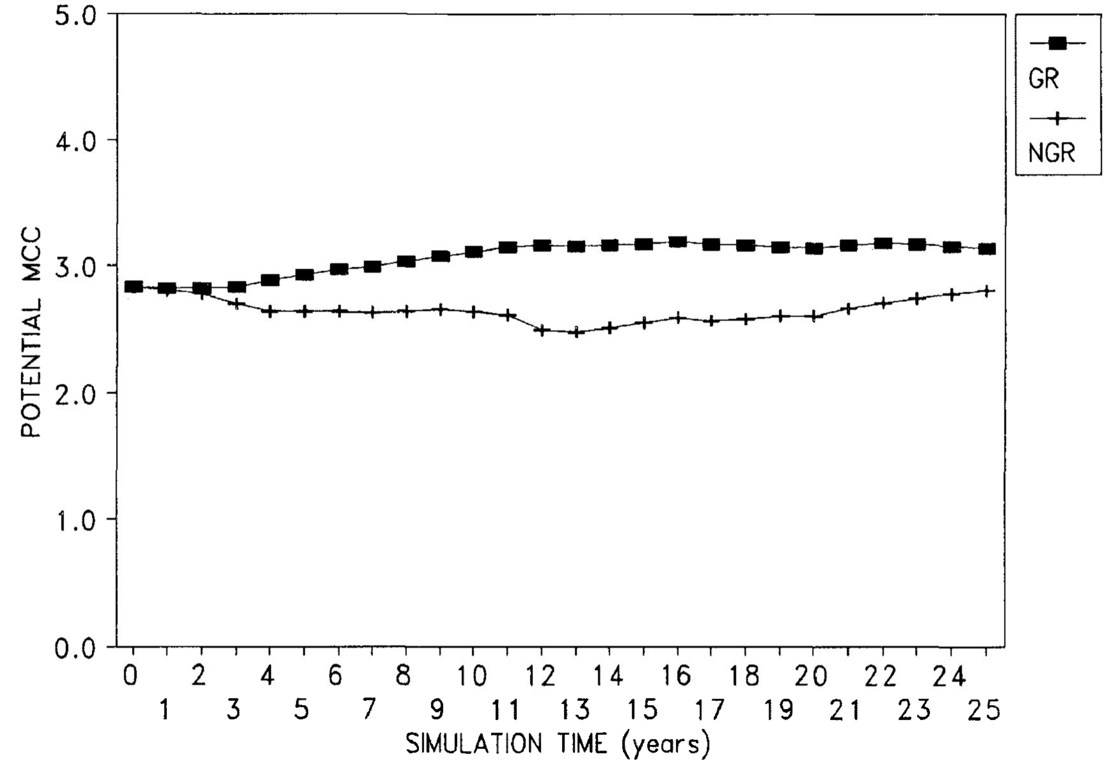


Figure 20. Early winter MCCs (in terms of number of moose per square kilometre) of the Guidelines and Non-Guidelines runs for the entire Aulneau Peninsula.

Late Winter

For late winter the GR MCCs were higher in 25 of the 26 values (Table 11 and Figure 21). The differences between GR and NGR were substantial, averaging 20.8% over the 25-year period. The greatest difference was in year 13 where GR was 35.4% higher than NGR.

Both runs produced decreasing values for the first four years at which point the GR values tended to stabilize. At year 20 both runs started to recover, likely due to recruitment of additional cover from stands which had been harvested early in the simulations.

Table 11. The late winter MCCs (in terms of number of moose per square kilometre) for the Guidelines and Non-Guidelines simulations, and percent differences between the two.

YEAR	GR	NGR	%DIFF
0	2.36	2.36	0.0
1	2.31	2.31	0.1
2	2.24	2.23	0.3
3	2.16	2.13	1.5
4	2.15	2.04	5.5
5	2.16	1.97	9.6
6	2.17	1.88	15.2
7	2.10	1.82	15.3
8	2.10	1.78	18.1
9	2.12	1.77	19.8
10	2.11	1.73	21.9
11	2.12	1.71	24.1
12	2.12	1.60	32.4
13	2.10	1.55	35.4
14	2.08	1.55	34.0
15	2.05	1.56	31.8
16	2.04	1.57	30.4
17	2.01	1.53	31.1
18	2.00	1.51	32.0
19	1.96	1.49	31.1
20	1.94	1.49	30.7
21	2.00	1.55	28.6
22	2.03	1.61	26.3
23	2.06	1.66	23.9
24	2.09	1.71	22.1
25	2.09	1.75	19.4
		AVERAGE	20.8

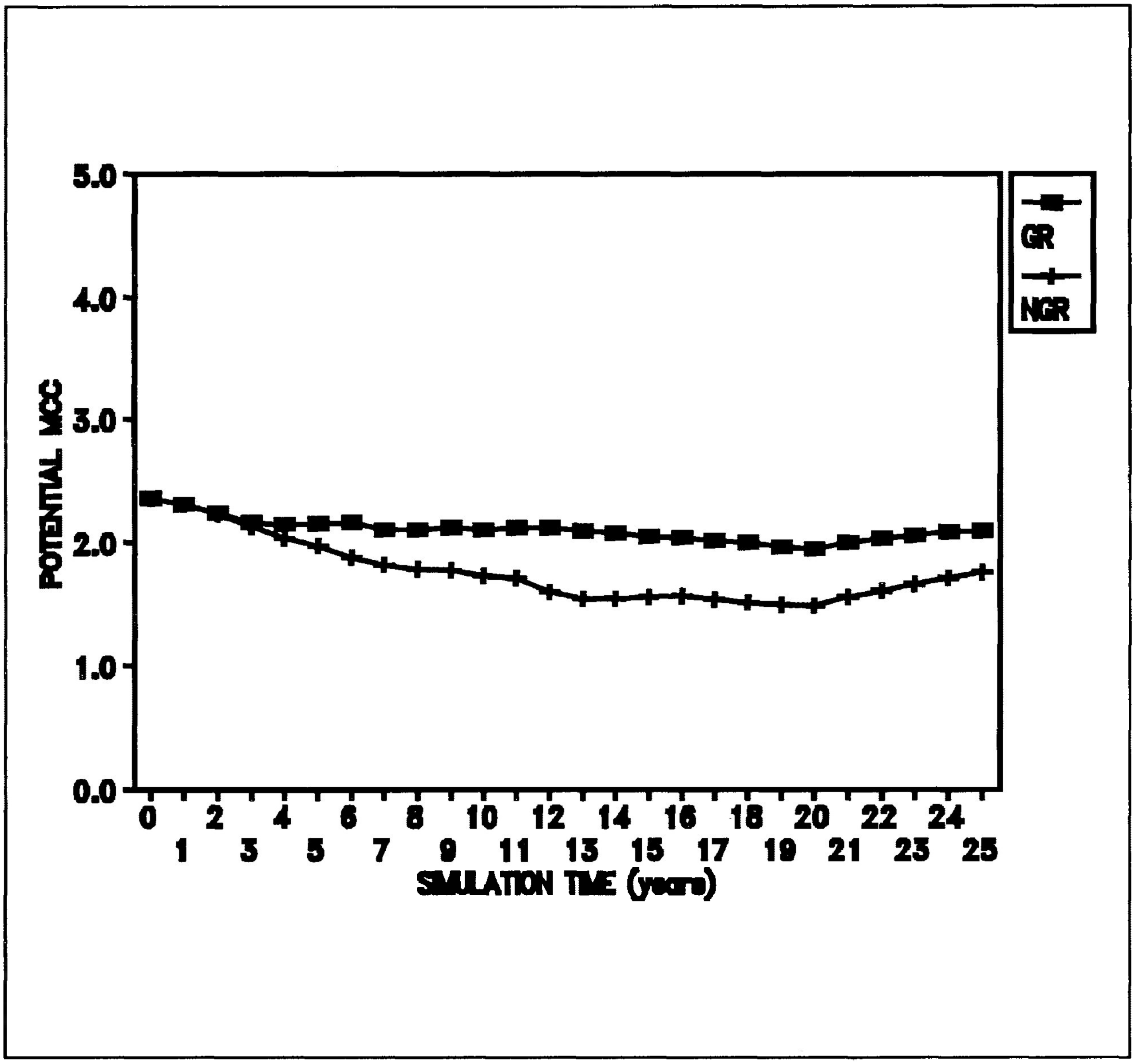


Figure 21. Late winter MCCs (in terms of number of moose per square kilometre) of the Guidelines and Non-Guidelines runs for the entire Aulneau Peninsula.

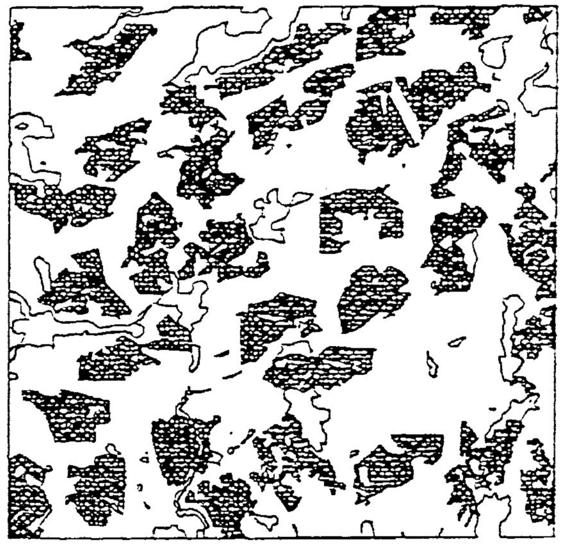
BM40546

Simulation results of M-HSAM on a selected subset of the Aulneau Peninsula database are presented in this section. Basemap 40546 (BM40546) was selected since: (a) it was subjected to a very high timber harvest in the NGR alternative and a relatively high timber harvest in the GR alternative (5,240 ha in the NGR and 2,920 ha in the GR) (Table 12); (b) the majority of timber harvests in this case were scheduled early in the simulation period, permitting the effects of forest renewal and development to affect moose habitat forecasts during the 25-year simulation period; and (c) it would provide the best opportunity to compare progressive clearcutting with the guidelines approach to laying out timber harvests (Figure 22). The majority of the timber harvests in BM40546 occurred in the first 10 years of the simulation in the GR, while all timber harvests occurred in the first 12 years in the NGR.

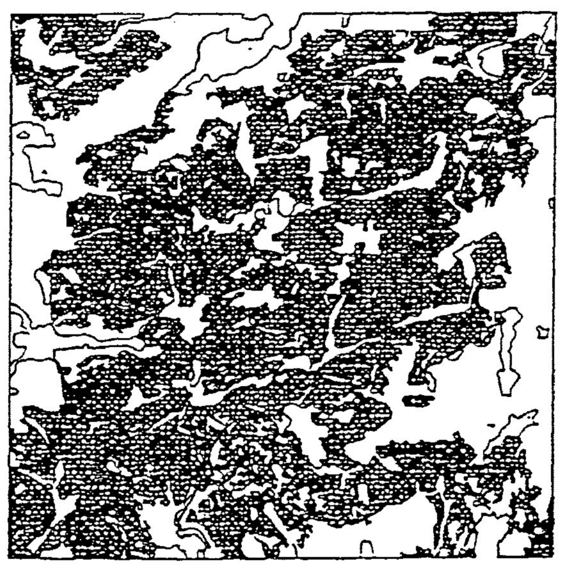
Except for late winter habitat in the NGR, the results of the simulations indicate marginal MCC changes when year zero is compared to year 25 (Table 13, Figure 23 and Figure 24). The MCCs which were reduced by the timber harvests began to recover soon afterward. GR showed minor changes through time compared to the dramatic changes of the NGR run. In it, early and late winter values fell rapidly until year four, while summer values increased from year 0 to year 12. Timber management using the moose habitat guidelines produced more stable trends than did the non-guidelines alternative.

Table 12. Annual area harvested (ha) in BM40546 for the Guidelines and Non-Guidelines alternatives.

YEAR	GR	NGR
1	1042	996
2	686	1104
3	279	1089
4	242	1060
5	0	53
6	0	0
7	144	266
8	0	43
9	0	187
10	46	0
11	47	0
12	0	439
13	0	0
14	0	0
15	167	0
16	213	0
17	0	0
18	0	0
19	0	0
20	52	0
TOTAL	2938	5237



With Guidelines



Without Guidelines

Figure 22. Stands scheduled for harvest during the 25-year simulation period for BM40546 for the Guidelines and Non-Guidelines alternatives.

Table 13. Seasonal results of Guidelines and Non-Guidelines simulations for the BM40546. Data are potential moose carrying capacities as number of moose per square kilometre.

	GR			NGR		
YEAR	SUMMER	EARLY WINTER	LATE WINTER	SUMMER	EARLY WINTER	LATE WINTER
0	2.70	4.05	3.60	2.70	4.05	3.60
1	2.80	3.97	3.17	2.81	3.89	3.18
2	2.92	3.95	2.74	2.96	3.67	2.57
3	3.06	4.08	2.66	3.15	3.08	1.74
4	3.22	4.22	2.64	3.41	2.57	1.09
5	3.30	4.36	2.73	3.62	2.62	1.12
6	3.34	4.42	2.82	3.78	2.71	1.16
7	3.37	4.43	2.72	3.90	2.62	1.03
8	3.40	4.48	2.85	3.93	2.56	1.01
9	3.43	4.53	2.96	3.97	2.57	0.99
10	3.45	4.58	3.00	4.01	2.60	1.02
11	3.47	4.56	3.02	4.04	2.63	1.11
12	3.44	4.55	3.02	4.04	2.25	0.84
13	3.40	4.52	3.00	4.01	2.38	0.89
14	3.35	4.49	3.08	3.93	2.58	1.01
15	3.30	4.42	3.00	3.85	2.83	1.17
16	3.26	4.34	2.88	3.72	3.05	1.31
17	3.19	4.28	2.90	3.60	3.24	1.47
18	3.15	4.30	2.93	3.47	3.42	1.58
19	3.10	4.29	2.94	3.34	3.57	1.73
20	3.03	4.24	2.95	3.20	3.68	1.88
21	2.97	4.28	3.08	3.06	3.80	2.04
22	2.93	4.32	3.12	2.93	3.83	2.14
23	2.91	4.35	3.24	2.84	3.87	2.28
24	2.90	4.36	3.31	2.77	3.89	2.34
25	2.88	4.34	3.30	2.74	3.90	2.39

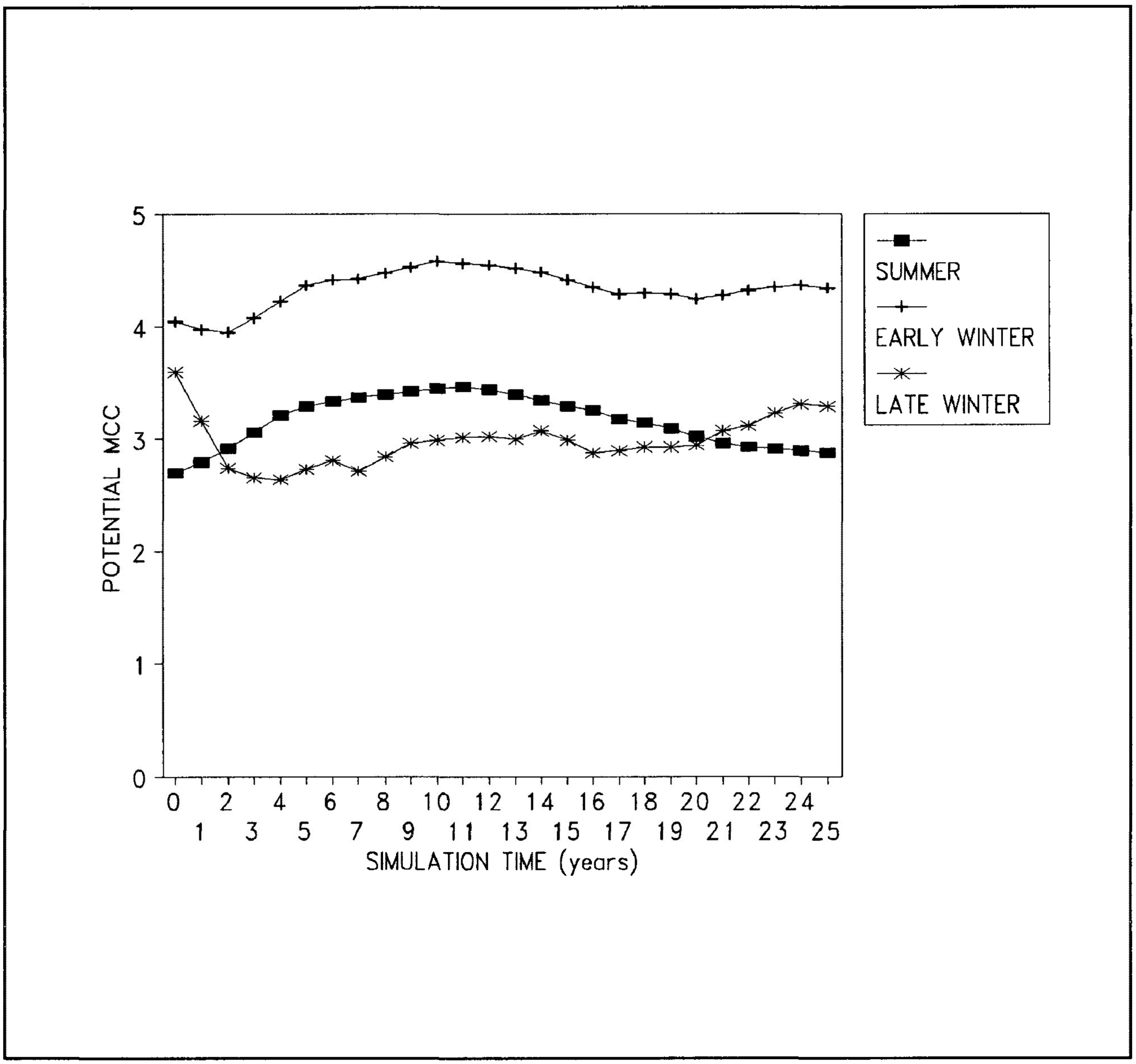


Figure 23. Seasonal MCCs (in terms of number of moose per square kilometre) of the Guidelines simulation for the BM40546.

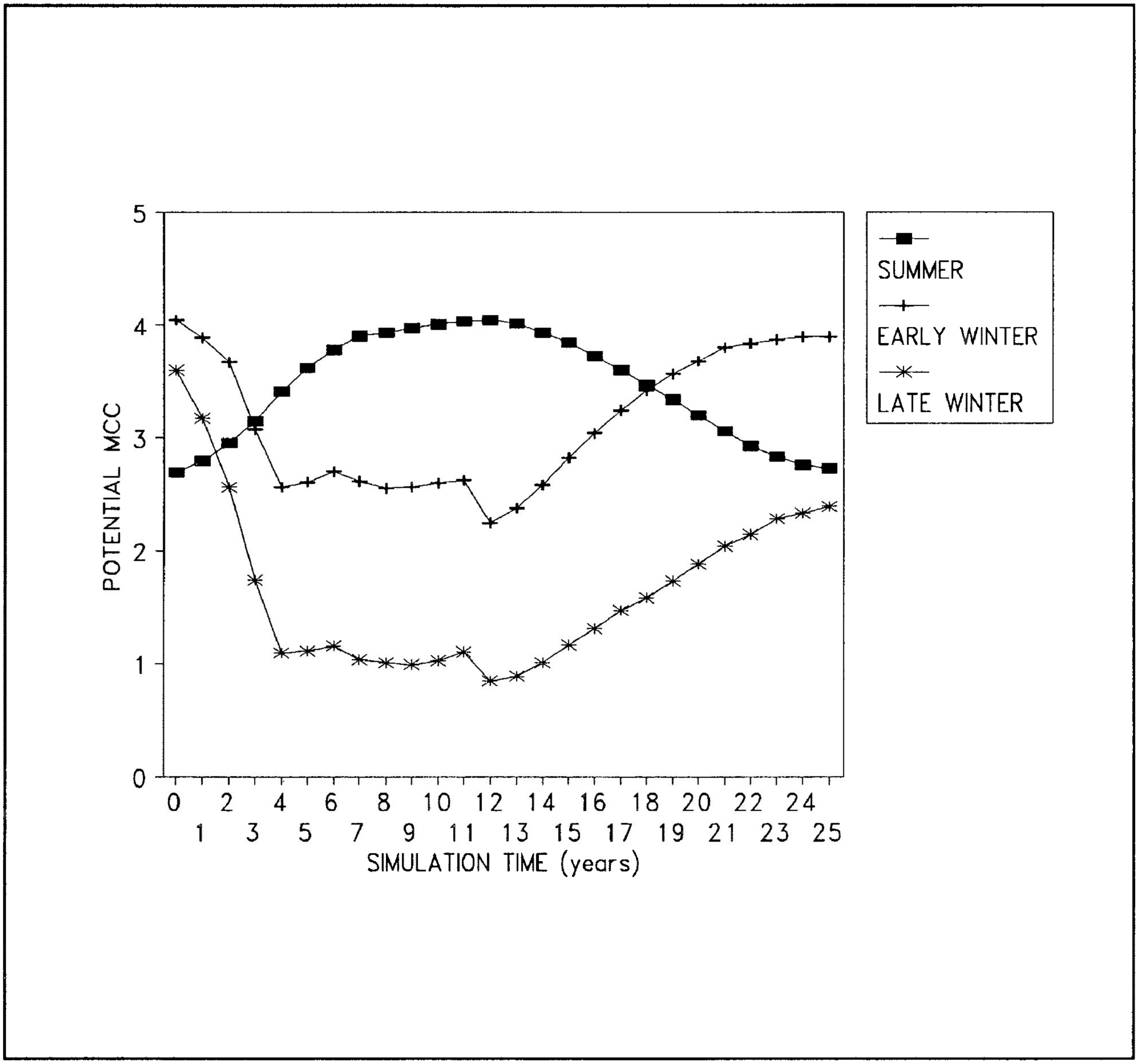


Figure 24. Seasonal MCCs (in terms of number of moose per square kilometre) of the Non-Guidelines simulation for the BM40546.

Summer

The NGR alternative demonstrated better summer habitat forecasts for much of the 25-year period since more forest area was scheduled for timber harvest than in GR (Table 14 and Figure 25). This greater harvested area provided more total browse for moose, the single factor contributing to summer moose habitat. However, with time the capability of harvested stands to produce browse decreased, which in turn resulted in decreased summer MCCs. The high level of timber harvest for NGR in the first five years of the simulation could not be sustained thereafter, making it impossible to maintain the high summer MCCs.

The GR simulation displayed far less dramatic fluctuations as the timber harvest level in BM40546 was much lower in the early years of the simulation than the NGR harvest.

Table 14. The summer MCCs (in terms of number of moose per square kilometre) for the Guidelines and Non-Guidelines simulations, and percent differences between the two.

YEAR	GR	NGR	%DIFF
0	2.70	2.70	0.0
1	2.80	2.81	0.3
2	2.92	2.96	1.2
3	3.06	3.15	2.8
4	3.22	3.41	5.7
5	3.30	3.62	8.9
6	3.34	3.78	11.7
7	3.37	3.90	13.5
8	3.40	3.93	13.5
9	3.43	3.97	13.8
10	3.45	4.01	13.8
11	3.47	4.04	14.1
12	3.44	4.04	14.7
13	3.40	4.01	15.3
14	3.35	3.93	14.8
15	3.30	3.85	14.3
16	3.26	3.72	12.5
17	3.19	3.60	11.5
18	3.15	3.47	9.3
19	3.10	3.34	7.2
20	3.03	3.20	5.3
21	2.97	3.06	3.1
22	2.93	2.93	0.1
23	2.91	2.84	2.8
24	2.90	2.77	4.7
25	2.88	2.74	5.3
	AVERAGE		8.5

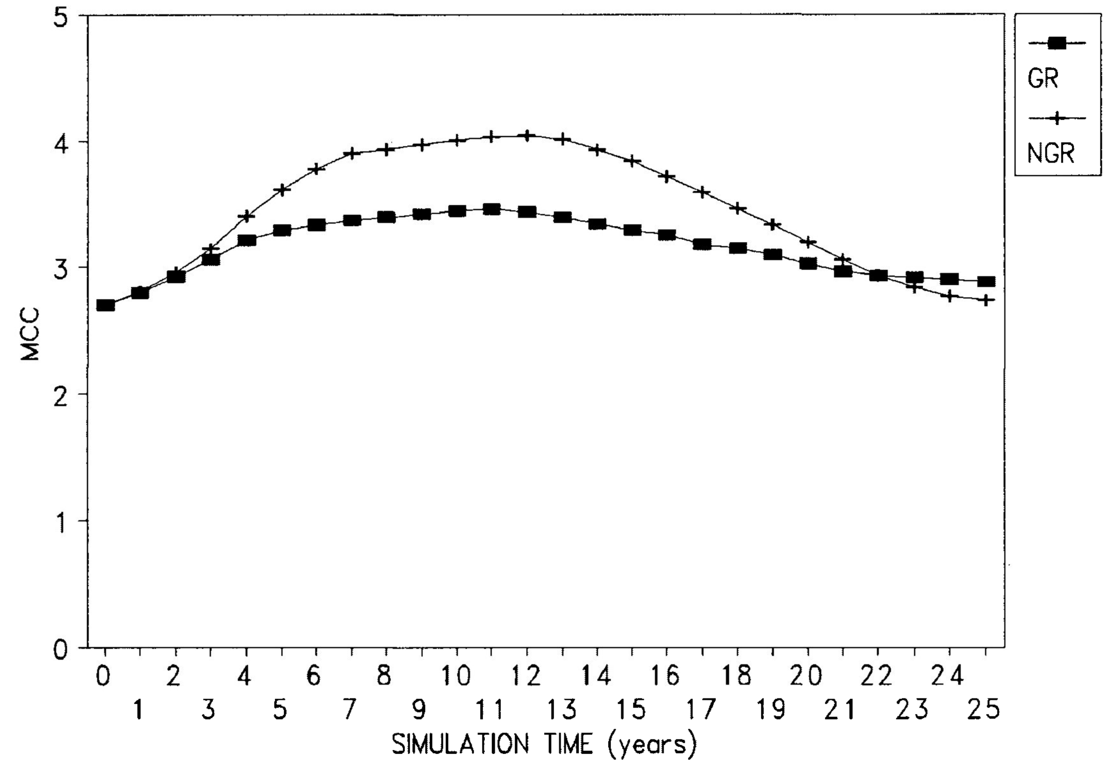


Figure 25. Summer MCCs (in terms of number of moose per square kilometre) for the Guidelines and Non-Guidelines runs for BM40546.

Early Winter

The guidelines approach to timber management demonstrated substantial advantages over the non-guidelines approach with respect to projected moose habitat potential (Table 15 and Figure 26). Not only were the values higher but the 25-year trend was relatively stable. The differences between GR and NGR achieved a maximum of 102.6% in year 12 and averaged 43.2% for the 25-year period. GR values increased after year two and virtually levelled off for the duration, while NGR plunged during the first four iterations, levelled for a period and then ascended steadily from year 12.

The reason for the rapid drop in the early stages of the NGR simulation is related to the relatively high level of timber harvest during this period, as well as the excessive distances between cover and food. The area subjected to harvest for the first four years of the simulation averaged in excess of 1000 ha per annum. Obviously, many of the stands which had provided early winter cover had been harvested. At year 12, the supply of early winter cover began to increase as previously harvested stands began again to provide suitable early winter cover for moose. However, from the trend in the latter years of the simulation it was evident that the non-guidelines approach would remain below the guidelines approach in terms of moose habitat potential.

Table 15. The early winter MCCs (in terms of number of moose per square kilometre) for the Guidelines and Non-Guidelines simulations, and percent differences between the two.

YEAR	GR	NGR	%DIFF
0	4.05	4.05	0.0
1	3.97	3.89	2.1
2	3.95	3.67	7.6
3	4.08	3.08	32.4
4	4.22	2.57	64.3
5	4.36	2.62	66.7
6	4.42	2.71	63.2
7	4.43	2.62	68.9
8	4.48	2.56	74.7
9	4.53	2.57	76.2
10	4.58	2.60	76.0
11	4.56	2.63	73.3
12	4.55	2.25	102.6
13	4.52	2.38	90.0
14	4.49	2.58	73.6
15	4.42	2.83	55.9
16	4.34	3.05	42.5
17	4.28	3.24	32.0
18	4.30	3.42	25.6
19	4.29	3.57	20.2
20	4.24	3.68	15.1
21	4.28	3.80	12.6
22	4.32	3.83	12.8
23	4.35	3.87	12.4
24	4.36	3.89	12.1
25	4.34	3.90	11.3
		AVERAGE	43.2

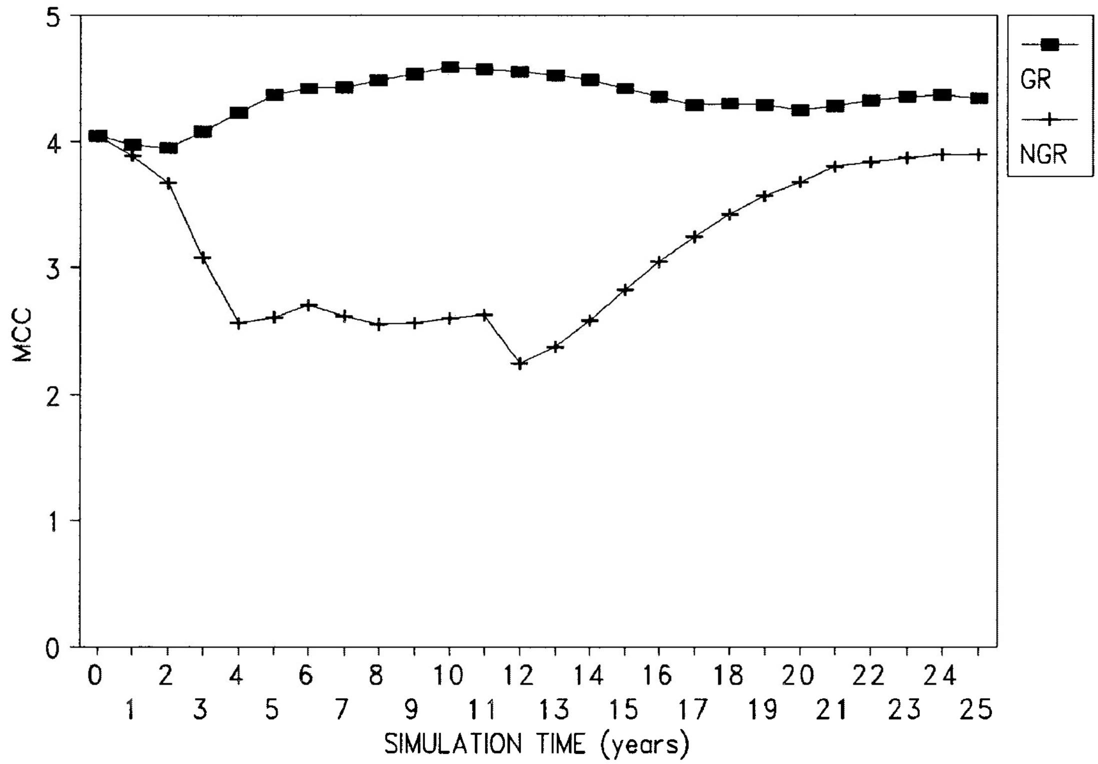


Figure 26. Early winter MCCs (in terms of number of moose per square kilometre) for the Guidelines and Non-Guidelines runs for BM40546.

Late Winter

The GR late-winter MCCs were up to 259% higher than the NGR MCCs, averaging 111.7% higher over the simulation period (Table 16). In both model runs, initial decreases in late winter MCCs were experienced, with increases later on (Figure 27). The difference between GR and NGR changed by 141.4% (141.6 - 0.2) in only three years (years 1 - 4). This dramatic shift was due to the high timber harvest within BM40546 in the NGR simulation. The smaller cutovers and the requirements for residual forest cover in the GR forced timber harvests to be more evenly dispersed across the whole study area. The residual stands contributed to improved late winter moose habitat and therefore higher MCCs than in NGR.

Table 16. The late winter MCCs (in terms of number of moose per square kilometre) for the Guidelines and Non-Guidelines simulations, and percent differences between the two.

YEAR	GR	NGR	%DIFF
0	3.60	3.60	0.0
1	3.17	3.18	0.2
2	2.74	2.57	6.9
3	2.66	1.74	52.8
4	2.64	1.09	141.6
5	2.73	1.12	144.8
6	2.82	1.16	142.5
7	2.72	1.03	163.4
8	2.85	1.01	181.6
9	2.96	0.99	198.4
10	3.00	1.02	193.0
11	3.02	1.11	172.1
12	3.02	0.84	259.5
13	3.00	0.89	237.7
14	3.08	1.01	206.1
15	3.00	1.17	156.9
16	2.88	1.31	119.5
17	2.90	1.47	97.1
18	2.93	1.58	85.6
19	2.94	1.73	70.0
20	2.95	1.88	56.9
21	3.08	2.04	51.1
22	3.12	2.14	45.7
23	3.24	2.28	41.8
24	3.31	2.34	41.7
25	3.30	2.39	37.7
		AVERAGE	111.7

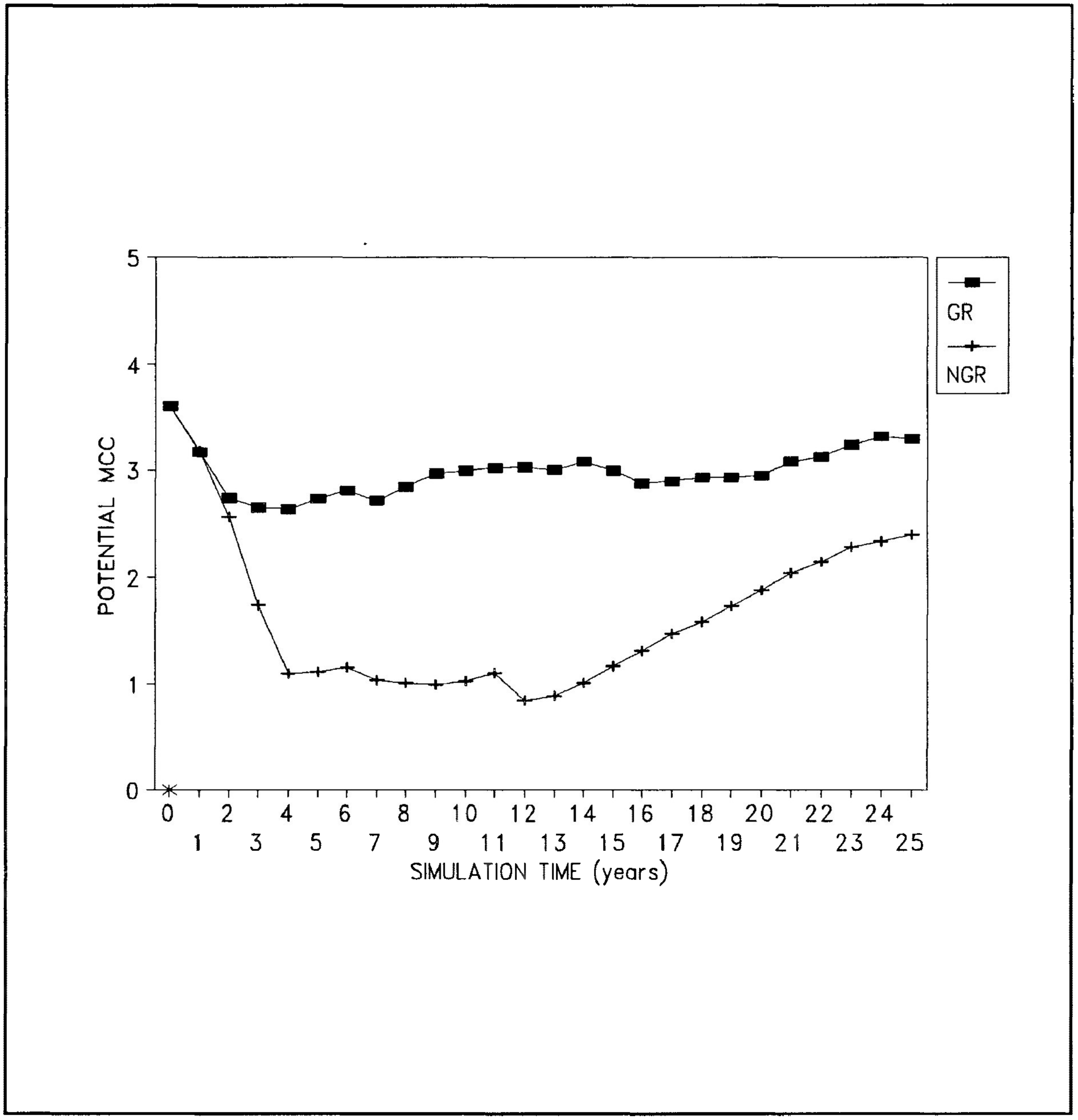


Figure 27. Late winter MCCs (in terms of number of moose per square kilometre) for the Guidelines and Non-Guidelines runs for BM40546.

SUMMARY

In both seasons where cover contributed to moose habitat (early and late winter), the GR delivered better future habitat than the NGR. Summer habitat forecasts for the entire Aulneau Peninsula were equal. In BM40546, summer results of the NGR were the higher of the two timber-management scenarios. This was due simply to the amount of food made available to moose by the high level of timber harvest in this scenario during the early stages of the simulation period. Overall the moose habitat forecasts for timber management following the moose-habitat guidelines were substantially better than those of the non-guidelines alternative.

The numbers forecast by M-HSAM were higher than the actual moose population densities on the Aulneau Peninsula in 1990 (A. Clark pers. comm., 1990) and in 1994 (A. Bisset pers. comm., 1994). This trend conforms to the explanation of Cooperrider (1986) - the carrying capacity of the landscape is unaffected by weather, hunting, or other decimating factors that are not habitat related, so numbers present may be lower than the carrying capacity.

Applying the basic assumption that higher carrying capacities of the landscape suggest greater potential moose densities, habitat information is used to make some type of prediction about animal populations (Jones, 1986). Under ideal conditions, population levels would reach carrying capacity limits. In reality, however, numerous other factors hold these levels below the carrying capacity limits. Actual moose densities have been recorded at values in excess of 3 moose/km^2 on Isle Royale (Timmermann and Whitmore, 1992). As an unhunted population, these Isle Royale figures might more closely approach the carrying capacity of the landscape than figures for a hunted population.

The time 0 (zero) MCC forecasts from the M-HSAM simulations were 2.06 moose/km^2 for the Aulneau Peninsula. Moose numbers for the Aulneau were calculated at approximately 800 animals (1.09 moose/km^2) in 1990 (A. Clark, 1990, pers. comm.) and 940 animals (1.28 moose/km^2) in 1994 (A. Bisset, 1994, pers. comm.). Considering that the Aulneau is relatively remote, and that hunting is restricted to the use of primitive weapons only, it is reasonable to assume that the numbers might continue to increase towards the carrying capacity levels indicated in the M-HSAM simulations (at time = 0). It is also reasonable to assume that some form of timber harvest on the Aulneau would create improved moose habitat, which again was forecast in the M-HSAM simulations in each of the two timber-management scenarios.

CHAPTER 7

CONCLUSIONS

M-HSAM provided a conceptual model of the forest system of the Aulneau Peninsula in terms of moose habitat. The HSI model for moose, as documented by Allen *et al.* (1987), was used as the starting point for the development of M-HSAM. The purpose of this HSI model (Allen *et al.*, 1987) was to evaluate moose habitat at a single point in time, given required moose habitat measurements of the forest. Proximity of habitats was not considered.

However, relevant spatial and temporal considerations for determining moose habitat potentials were addressed in the development of M-HSAM. Model modifications were based on a review of the literature, and expert opinion, in instances where knowledge gaps were disclosed in the literature. As well as incorporating spatial and temporal considerations the development of M-HSAM focussed on treatment of a specific geographic area (the Aulneau Peninsula), while the moose HSI of Allen *et al.* (1987) was designed for use on a broader geographic scale. This increased degree of specificity involved first grouping forest stands into classes based on moose food and cover potentials and then developing moose food and cover interpretations of these Aulneau forest stand types. The framework of M-HSAM was designed to permit flexibility in terms of its applicability to other territories by changing the stand type classification scheme and/or altering any of the food and cover curves to reflect local conditions.

A lack of empirical data regarding age-specific food and cover potentials by stand type for the Aulneau Peninsula was discovered. Pooled expert opinion was used for the development of these curves for this study. Further research in the development of age-specific food and cover curves by stand type is recommended as a first step in model invalidation (Holling, 1978).

In M-HSAM, forest stands of the Aulneau Peninsula were evaluated on the basis of their capability to produce food and provide shelter for moose, over a 25-year period, with a series of food and cover curves. Every stand in the study area was assigned the necessary curves to depict its development over the 25-year simulation in terms of summer food, early winter food and early winter cover for moose. Late winter moose habitat potential was a function of the early winter habitat and the late winter cover characteristics of the forest stands within each habitat window. These parameters provided the simulation techniques necessary for forecasting moose habitat potential. GIS techniques were incorporated into M-HSAM to address stand interdependency and moose home range, and served also to limit travel distance requirements between early winter habitat and late winter habitat to within habitat windows. The model uses moose habitat as the indicator to compare forest management strategies on the forest.

M-HSAM represents a tool to forecast impacts of forest management strategies on potential moose-habitat supply. The model provides an essential tool for simultaneously accounting for the future dynamics of vegetative change and future spatial patterns of timber harvests as they affect moose-habitat potential. Results of alternative forest management strategies can be compared to determine which provides better future moose habitat forecasts. M-HSAM thus provides a medium through which forest management strategies are testable to determine effects on moose habitat over a 25-year period. A forest manager might use this tool to design a forest management strategy which yields the best forecasts of moose habitat while simultaneously achieving a desired level of timber harvest.

The results of the M-HSAM runs clearly indicate that timber management with consideration of the moose-habitat guidelines is beneficial in terms of moose habitat when compared to timber management without regard for the guidelines on the Aulneau Peninsula FRI database. Habitat supply analysis for the summer season, which was solely a function of available food, produced similar results for the two scenarios. This is expectable since the area subjected to timber harvest in each of the two alternative strategies was nearly equal, by working group, by year. Newly cutover areas represent the primary supply of food for moose in managed forests. The greatest benefit was realized in the early winter season where MCCs were a function of food and cover, and their proximity to one another. The guidelines imposed reduced cut block sizes when compared to timber harvest without consideration of the guidelines. A consequence of smaller cut blocks is increased availability of food to moose in the early winter period since moose tend not to wander far from cutover edges in search of food. Late winter results, influenced primarily by cover, also favoured the guidelines approach to timber management. By breaking up the cuts into smaller blocks and leaving residual areas of unharvested timber, the guidelines approach preserved areas conducive to providing late winter habitat. Thus, whenever cover influenced moose habitat forecasts, the guidelines approach provided moose habitat values superior to those of the non-guidelines approach.

MCCs forecast by the model were higher than the actual moose population levels on the Aulneau Peninsula (A. Bissett, 1994, pers. comm.). This was expected since M-HSAM assesses habitat potential exclusively, while in reality numerous other factors (e.g.: disease, predation, hunting and fecundity) affect actual moose densities or population levels. Populations might actually achieve habitat potentials if not for these other factors which limit population growth. As hunting and habitat are the two factors influenced by human activities and are therefore manageable, moose management efforts focus almost exclusively on hunting regulations and habitat management. Habitat alone dictates the upper limit which a population can attain. Low carrying capacities of the landscape will yield lower population potentials than will habitats with high carrying capacities, regardless of the other factors. Therefore, non-habitat factors being constant, habitat management efforts directed at habitat improvement will produce higher moose populations.

Although the cumulative browse values for the summer equation (B_{xij}) and cover adjusted browse values for the early winter equation (CAB_{xij}) exert the same influence for the respective equations, these values warrant priority for further research. Not only would reducing uncertainty for these parameters increase confidence in the model, but this research would also provide a strong basis for assessing forest stands from the basis of moose habitat (food and cover), an important change in a timber-oriented forest-management regime. Field work for this research could simultaneously focus on evaluation of stands in terms of late winter cover as well as investigating the stand type classification system. Assessments of forest stands in terms of cover and food for moose would provide a solid ecological foundation for the model while increasing confidence in its use and interpretations of the results. The Northwestern Ontario Forest Ecosystem Interpretations (Racey *et al.*, 1989) provide such assessments, although for much of this part of the province, including the Aulneau Peninsula, the the landscape had not been classified accordingly.

Incorporation of GIS techniques in M-HSAM proved invaluable for this study for a number of reasons, including:

1. maintaining the spatial integrity of the forest. Non-spatial models only permit landscape-average calculations while with M-HSAM higher resolution assessments were possible (habitat window level). The effects of habitat diversity, including forest stand shape and size, and proximity to other stands, are considered;

2. representing spatial patterns of timber harvest. M-HSAM captured more than simply the area harvested by working group by year. The size and shape of cutovers and their proximity to potential moose cover, important components of moose habitat, were captured;

3. capturing the values of ecotones for species such as moose; and

4. permitting all forested parts of the study landscape to contribute to the habitat values of multiple habitat assessment units.

M-HSAM was designed for the specific purpose of forecasting impacts of timber management actions in terms of future moose habitat. The model should therefore not be perceived as a general-purpose moose habitat supply analysis model. Landscape features which contribute to moose habitat but which were assumed to be unaffected by timber management perturbations were not included in the model. A general-purpose moose habitat supply analysis model must incorporate all of the important landscape features which contribute to the life requisites of moose. Further work might be directed at incorporating missing habitat features into the model. Such habitat features include:

1. Aquatic feeding areas of sodium-rich aquatic forage that help moose meet dietary sodium requirements (Timmermann and McNicol, 1988).
2. Areas for summer thermoregulation to provide a cool environment during hot periods as moose are relatively intolerant to heat stress (Timmermann and McNicol, 1988; Demarchi, 1991). Not only have these thermoregulation habitats been gaining recognition as important summer cover, but the proximity of this cover to available summer forage might also play an important function in the habitat capability of a forest in a manner similar to the proximity of cover to food in the early winter as implemented in M-HSAM.

The forecasting model was useful not only as a means of determining whether timber management according to the guidelines provided better moose habitat, but also to help describe the dynamics of the natural system being explored and assess the impacts of interventions on the forest system in terms of moose. Although the actual numbers (carrying capacity of moose in terms of number of animals per km^2) produced by M-HSAM may be questioned, the model provided an invaluable tool for fulfilling the objectives of this study which involved comparing impacts of alternative intervention strategies. Actual numbers are a function of fine-tuning the model. The relative numbers under the two scenarios over time are the important aspect as these provide the basis for a comparative assessment of alternative forest management strategies.

The moose-habitat guidelines are based on site-specific moose habitat relations with energetics implicitly considered. M-HSAM was developed from concepts of moose ecology similar to those which support the guidelines and is therefore similar to the guidelines except that (a) energetics are explicitly considered; and (b) M-HSAM provides a bridge to landscape-scale habitat assessment over time.

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APPENDICES

APPENDIX I

TIMBER MANAGEMENT GUIDELINES FOR THE PROVISION OF MOOSE HABITAT

Timber Management Guidelines for the Provision of Moose Habitat

1.0 Preface

Not all wildlife species can be managed for maximum populations on the same land area. Thus managers must often make local decisions about which species warrant special forest prescriptions. The legitimate concerns for other wildlife will often be accommodated to a large degree within the prescription for the key species. These particular guidelines deal with moose in the context of timber management. The timber management terms used in this document (eg. selection cutting, shelterwood cutting) are as defined in the "Class Environmental Assessment For Timber Management on Crown Lands in Ontario" (MNR, Dec. 1985).

The purpose of this set of guidelines is to assist forest and wildlife managers in planning timber management activities. Virtually all efforts designed to manage moose habitat will involve working with timber companies to manage the forest in order to produce good moose habitat with a minimum loss of wood fiber. In many circumstances, the practice of good timber management is consistent with good wildlife habitat management. For example, disturbances to the forest cover by timber harvesting will create the kind of openings and young growth that are necessary elements of good moose habitat. Without such disturbance, moose populations would be lower. There is not usually a concern over whether timber is harvested, or how much timber is harvested. It is mainly a question of how and when harvesting takes place and the relative sizes of cut and uncut blocks that is of concern in moose habitat management. The challenge of integrating timber and moose management is to retain all of the necessary habitat components for moose while extracting the available merchantable timber.

These guidelines include general requirements and specific suggestions for providing habitat, although it is impossible to foresee every conceivable situation the manager might encounter. The attached papers provide more complete information concerning moose habitat.

Essentially, the guidelines are designed to produce good moose habitat by cooperating with forest managers. It must be emphasized, however, that moose management involves many variables other than the actual habitat work itself. For instance, the best habitat will not necessarily contain good moose populations if hunting pressure is excessive or if wolf predation is extensive. The goal should be to achieve a proper combination of moose population management, control of hunters and careful habitat manipulation.

Moose range in Ontario encompasses a wide variety of physiographic site conditions. It extends from the western boundary of Ontario to the eastern border, and south to the edge of the Precambrian Shield. Habitat management for moose in northwestern Ontario may be substantially different from habitat management in eastern Ontario due to the diversity of site, climatic factors and other environmental conditions across the Province. Prescriptions for management thus vary. These guidelines provide the principles for moose habitat management which local managers can adapt to meet needs within their own district or region.

Moose habitat guidelines will also be used in wildlife planning processes. Wildlife plans may not coincide in time period and area with forest plans, but wildlife objectives and habitat strategies should be consistent among these plans.

2.0 Moose Program Development

On October 22, 1980, the Government of Ontario adopted specific objectives, targets, guidelines and management policy for moose in Ontario (for a complete listing of these items, see Policy WM.3.01.02, 1980 12 15).

THE BROAD PROGRAM OBJECTIVE IS: To protect and enhance the moose resource and to provide opportunities for recreation from moose for the continuous social and economic benefit of the people of Ontario.

The program targets are:

1. To increase the moose population from 80,000 to 160,000 animals by the year 2000.
2. To provide from this herd an annual harvest of 25,000 animals by the year 2000.
3. To provide a hunter success rate of at least 12 percent.
4. To provide 1.2 – 1.4 million viewing opportunities at 24 – 30 sites by the year 2000.

The policy for moose habitat management is: "...to ensure that the quality of moose habitat is maintained or enhanced by direct involvement in the timber management planning process." and, "to ensure that timber production will not reduce the quality of moose habitat, wildlife managers will emphasize upper limits on sizes of clear-cutting operations, within the planning process for timber management." Regional targets are:

	Population	Harvest
Northwestern	47,500	7,300
North Central	44,500	7,000
Northern	37,500	5,600
Northeastern	30,500	4,600
Algonquin	5,000	500
	165,000	25,000

Moose inventories by wildlife management unit may be obtained by reference to current regional data. Moose population targets by wildlife management unit (WMU) are listed in strategic land use plans for Northwestern and Northeastern Ontario, and are reproduced here with the inclusion of the Algonquin Region (Appendix I).

Population targets for WMUs may change over time, but these occurrences are expected to be accompanied by compensating target revisions in nearby WMUs.

Much of the target for viewing opportunities may be satisfied from use of wildlife management areas, Crown Game Preserves, Areas of Natural and Scientific Interest (ANSI's) or provincial parks. This will be dictated to some extent by the presence of visible moose in relation to existing or potential aggregations of people, and our abilities to provide security for moose and onlookers under these circumstances.

3.0 Summary of Moose Habitat Requirements

Moose are found predominantly in the Boreal Forest Region, though they also live in the Great Lakes–St. Lawrence Region. Moose are generally absent in southern Ontario because of the clearing of land and perhaps overlap with white-tailed deer that carry a brainworm that is fatal to moose. Moose are generally animals of the forest edge, living in proximity to young deciduous stands which provide food, and semi-mature and mature conifer which provide shelter from weather and predators, including hunters. They are well adapted to extreme cold and snow when food and shelter conditions are adequate. Their large bodies are well insulated and their long legs make movement through snow relatively easy. Unless they are hampered by very deep snow (greater than 80 cm), their size and strength is sufficient to cope with most factors in their environment.

In spring and early summer, moose feed extensively on selected species of aquatic plants whenever they are available. These plants contain important dietary items and may supply certain nutrients (e.g., sodium) not found in other items of their diet. Travel to these aquatic feeding areas is often along well-defined routes or corridors. Mineral licks are also used at this time of year. In summer, fall and early winter, most feeding occurs in early successional, terrestrial plant communities. Cutovers and burns are especially important. In winter, moose seek out areas of conifer for shelter, and may use portions of nearby cutovers or burns for feeding provided that snow is less than about 80 cm (35 inches) and is not heavily crusted. During the winter months, moose feed almost exclusively on twigs and branches of woody plants, such as willow, birch, aspen, hazel and mountain ash. In addition, their metabolic rate is lower than in summer and they use their own stored body fat to supplement food sources. Moose conserve energy by decreasing their movements to a minimum. These adaptations to cold and snow help them to survive in northern forest areas.

Moose and other wildlife are active throughout the entire forest. The ability of the forest to support moose changes through time. These changes can occur slowly as a forest develops and matures, or they may occur quickly as a result of such events as fire, insect damage or logging. Such factors acting throughout moose range affect the type, quantity and quality of vegetation, and thus affect the numbers, location and physical condition of moose that the forest will support.

Prime moose areas are those that produce or attract, or have the potential to produce or attract, a significantly higher number of moose than surrounding areas at certain times of the year. These areas can be identified as being key components of moose habitat on a local basis.

Boreal Forest Region

There are two main types of prime moose areas in the Boreal Forest Region. The first type is seasonal high-use or winter concentration areas which are known to be important to moose for a wide variety of reasons (see the attached papers for details). The second type includes special sites such as mineral licks, calving areas, and aquatic feeding areas that may require reserves of timber to protect the special nature of the site. The second type will remove a small percentage of the land base from timber production. The first type will not remove any land from timber production, but will require modified harvesting techniques and may require removing the allowable cut for the 5 year operating period from a larger planning area.

Early winter concentration areas may be typified by mature or over mature, open canopy, mixed-wood stands of relatively low stocking (less than 60 percent). Stocking is an expression of the relationship between actual basal area as measured in the field and normal basal area obtained from normal yield table. The need is to leave portions of these stands uncut for a period of time to allow the animals to continue to use them. As well, burns and cutovers, usually from 5 to 20 years of age, are also often used. Because of the open canopy, early winter concentration areas usually have considerable browse. These sites are also important to moose as they provide some lateral protection from winds as well as predators. The shape, abundance and nature of these areas is so variable that each must be treated on an individual basis.

Late winter concentration areas, usually fairly large in size, are those where the average moose density is higher than the surrounding area. Generally, they are well stocked stands of mature conifer (greater than 70 percent stocking) with complete crown closure which provides overhead protection from snow accumulation and severe cold. These areas are most functional when near early winter or other feeding habitat so that travel distance between food and shelter is minimal.

Aquatic feeding areas, mineral licks and calving sites are important to moose because they attract moose and contain critical components of their diet or important life history features. Identification of these areas, their shape and importance must be determined by district staff. It is important to maintain both the integrity of the sites and sheltered access by moose to them.

Great Lakes – St. Lawrence Forest Region

Moose populations in the Great Lakes – St. Lawrence Forest Region have the same basic habitat requirements as those in the Boreal Forest Region, a diverse series of plant communities in early to late successional stages. Tolerant hardwood forests may have relatively little browse available to either moose or deer, and often insufficient, semi-mature and mature conifer shelter. In the mixed wood (eg. poplar-pine) areas browse and shelter are more abundant. Group selection cutting and shelterwood cutting have contributed to browse production in both tolerant hardwood and mixed wood forests.

Summary

Although much remains to be learned about the ecology of moose, here is a brief summary of their known needs:

1. Moose populations need the early successional plant communities which follow a major disturbance such as a forest fire, insect damage or a logging operation. Populations may expand after disturbance provided that excessive hunting or predation does not occur and adequate shelter remains.
2. Moose also require semi–mature or mature stands of conifer in winter. These stands provide protection from severe weather and predation, and minimize snow depth and crusting thereby allowing easier access to food.
3. Aquatic plant communities in certain waterbodies are used extensively during spring and summer. Both preferred emergent and submergent vegetation is utilized.
4. Mineral licks are important in certain areas.
5. Calving sites such as islands and peninsulas are important in certain areas.
6. The best moose habitat contains food (early successional plant communities) and cover (semi–mature and mature conifer) in close proximity such that the animals need not travel far between these important items.

4.0 Impacts of Timber Management on Moose

In many situations the practise of good timber management is consistent with good wildlife habitat management. For example, disturbances of forest cover by timber harvesting will generally create young growth that is a necessary element of moose habitat. If an adequate amount of shelter eg. unallocated areas, protection forest, remains nearby, then good moose habitat can be provided. The challenge of integrating timber and moose management is to retain all of the necessary vegetation components for moose while extracting the available merchantable timber. There is not usually a conflict over whether timber is harvested. It is a question of how and when harvesting occurs and the relative sizes of cut and uncut blocks that is of concern in moose habitat management.

The timber management undertaking involves five basic processes. These are: (i) forest access, (ii) harvest operations, (iii) site preparation, (iv) regeneration, and (v) maintenance operations. The last four steps (ii–v) are referred to as the silviculture system. Each of these procedures may directly impact the quality of moose habitat and indirectly affect the size of the moose population. The impacts cited below are normally related to the immediate areas of the treatment. They are concerns of a general nature and in practice the impact may be substantially mitigated by vegetation surrounding the area of timber operations. The real potential significance of these impacts must be assessed within the entire context of each operating plan. Local managers must try to balance potential negative impacts by positive ones.

As well, the implications to moose of nearby, past and future silvicultural operations may also influence decisions when developing an operating plan.

4.1 Forest Access

Forest access, principally by roads, may have both positive and negative impacts on moose management. While roads may subject newly accessed moose populations to local over exploitation, they also allow for distribution of hunting pressure over a wider geographic area. As permanent access stabilizes, within a Wildlife Management Unit, the moose harvest will stabilize and the benefits of road access to moose management will outweigh the adverse effects. Within the concept of Ontario's Selective Moose Harvest Program general overharvest of moose within a Wildlife Management Unit (WMU) should not occur. If local overharvest occurs in one part of the WMU it should be offset by underharvest in another part. If an overharvest of moose from the entire WMU occurs or is anticipated the harvest quotas for the Unit can be established to correct or avoid the problem.

Road construction and use within or near aquatic feeding sites, mineral licks, calving site and winter concentration areas could destroy habitat or disrupt normal moose activities, and possibly result in an increase in vehicle accidents.

In the Great Lakes–St. Lawrence Forest Region concerns relating to access and silviculture are similar to those in the boreal forest, although the impacts are probably less significant because of the shelterwood and selection harvesting systems more commonly practiced in the southern portion of the moose range.

4.2 Harvest Operations

The effects of harvest operations may also be either beneficial or detrimental to moose populations, depending on the manner in which food (young deciduous vegetation) and shelter (semi-mature to mature conifer) are left, or produced, by timber harvesting. When cutting operations produce irregularly shaped cuts, scattered shelter patches, and a high diversity of age-class and species composition, moose populations will benefit. In the Boreal Forest where clear-cutting is a common timber-harvesting technique, some standing timber with its associated subordinate vegetation should be retained to provide a variety of plant communities close to each other.

Generally, the greater the amount of edge produced between food and shelter habitat components, the better will be the quality of habitat.

4.3 Site Preparation

Preparing the site to accept seeds or seedlings may have an impact on moose, particularly in the Boreal Forest where clear cutting and site preparation are commonly practiced. The objective of site preparation is to bare some mineral soil and if possible reduce potential competition from broadleaf species. These are often preferred browse species and an important source of nutrition to moose. Except on more infertile soils, site preparation often encourages the establishment of herbaceous or deciduous plants.

Mechanical preparation may remove residual clumps of vegetation within a cut, which could contribute to good wildlife habitat by providing diversity and visual barriers as protection from hunters and predators. The value of residual vegetation to wildlife increases with the size of clear cut. Some types of mechanical preparation encourage coppicing or root suckering which increase browse.

The effect of chemical site preparation depends largely on the chemical being used. Chemicals, such as 2, 4–D used at approved rates, suppress growth but generally do not kill most deciduous woody plants and they can encourage root suckering. Recently approved chemicals, such as "Roundup/Vision" (glyphosate), appear to be very effective at killing herbaceous and woody plants and may substantially reduce browse species for an extended period.

Prescribed burning, where it leaves needed shelter and does not damage the soil, benefits moose by quickly returning nutrients to the soil thereby increasing the nutritional quality of the browse growing on the site. Mechanical site preparation may have advantages where the retention of needed shelter components cannot be assured by prescribed burning.

4.4 Regeneration

The objective of forest regeneration is to return the cut over area to desirable commercial species in a manner that minimizes competition and maximizes growth of the desired tree species. Regeneration in the boreal forest strives for even-aged stands of coniferous species. Artificial regeneration, along with tending, attempts to increase the growth of the crop species by reducing competing vegetation. Where regeneration is very effective, there could be a negative impact on moose in the initial stages. This could be partially compensated for by leaving residual or nearby stands of young deciduous vegetation.

4.5 Maintenance

Maintenance of the forest includes tending, protection and improvement activities.

The objective of tending is to further reduce competition and in most respects the impacts of tending are the same as for site preparation. Manual, mechanical and some chemical treatments do not kill most deciduous growth, but will set it back. Later, coppicing and root suckering may occur. Forest improvement by converting mixed wood stands to more pure conifer may create winter shelter but remove a significant source of browse for moose.

In the Great Lakes–St. Lawrence Region there are often too few stands of semi-mature and mature conifer to provide shelter. Silvicultural treatments which produce these will often benefit both moose and deer.

5.0 Providing Moose Habitat in Timber Management

The objective of habitat management is to provide all of the necessary habitat components within the area of activity normally inhabited by moose. The size of this area will be dictated to a large extent by topography, the nature of the forest, and the size of the moose population. The purpose of these Guidelines is to demonstrate how to produce good vegetation patterns necessary to meet moose requirements.

Moose are animals of the forest edge requiring young deciduous growth for food, and semi-mature and mature coniferous forest as shelter from weather and predators. To benefit moose, timber management should produce irregularly shaped cuts with scattered shelter patches and a high diversity of age classes and species of vegetation.

Following are a set of general principles which will lead to the maintenance or improvement of moose habitat in Ontario, recognizing prevalent timber harvesting practices. Moose habitat needs vary during the day, different times of the year, and across their range. Also, the topography and climatic conditions in Ontario are not uniform and timber management practices vary widely across the Province. Because of this variation, the Guidelines for use in planning timber management are set down in a general way to ensure that average habitat conditions are provided. Local managers and planners will decide how to best apply the principles to meet local situations. In addition, not all areas can be managed in such a way that maximum timber production will coincide with maximum wildlife production. Compromise and discussion among managers is essential to the management process.

Figure 1 illustrates a possible scenario resulting from the implementation of these principles.

5.1 Boreal Forest Region

5.1.1 **Forest Access.** Where new access is created to harvest the forest, the potential for local overharvest of moose exists. Although legislation (eg. Public Lands Act, Game and Fish Act), may be used to inhibit or prevent hunting within these areas for either short or long periods of time, it tends to postpone problems of overharvest rather than solving them. In special cases where it is desirable to minimize hunting by controlling access, roads may be closed by signing or they may be kept away from the area of concern, or wood may be extracted using winter roads. As well, in some circumstances it may be appropriate to scarify and remove access roads after extraction is complete.

Access roads should avoid mineral licks, aquatic feeding areas, and calving sites to protect these important habitat features and minimize disturbance and accidents to moose using these areas.

Road use and location must be addressed as early as possible in the planning process so that field examinations can identify possible alternatives.

Moose Habitat Management in Ontario

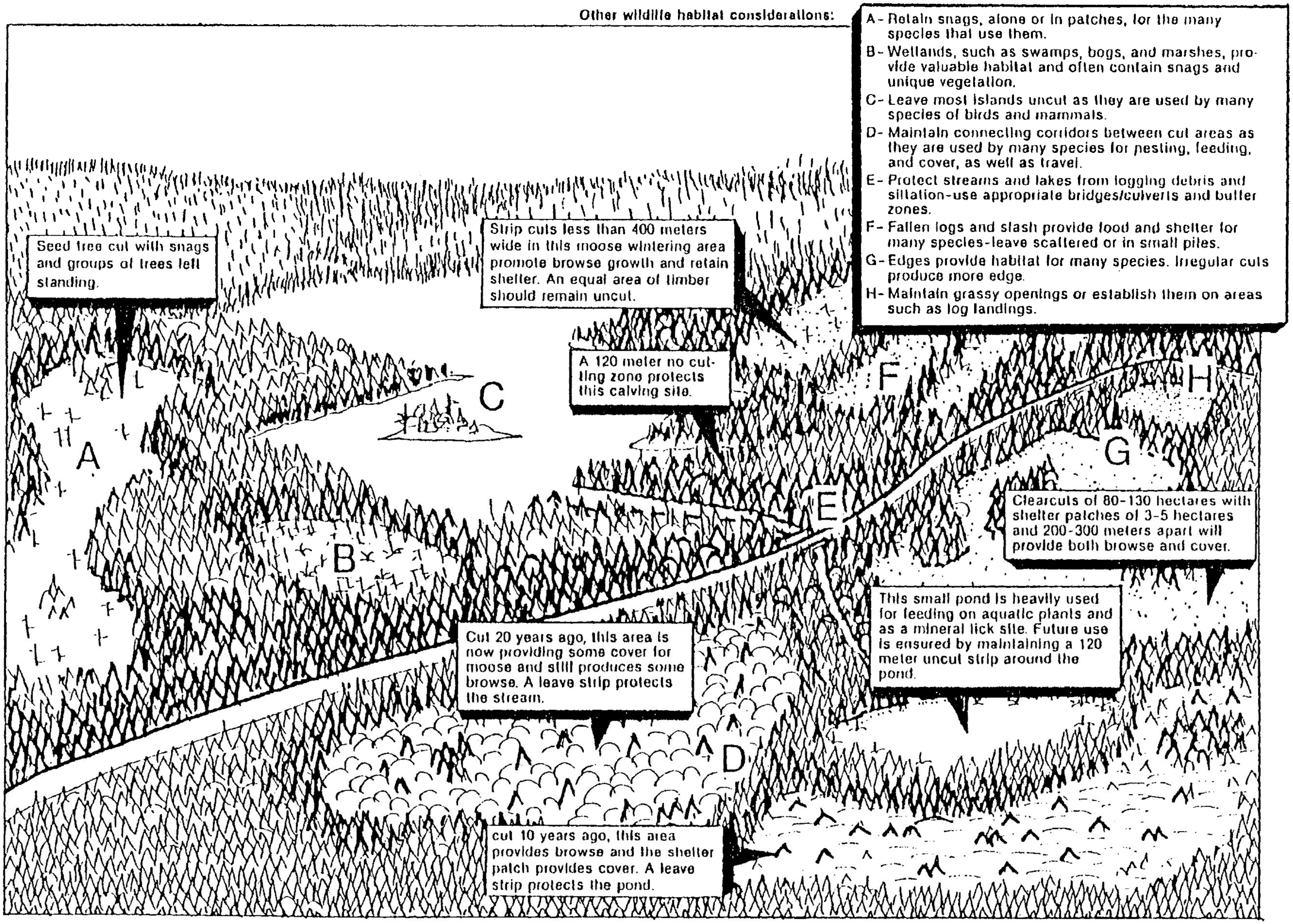


Figure 1.

5.1.2 Harvest Operations. The moose management objective of maintaining or enhancing the quality of moose habitat includes the concept of protecting key features (eg. aquatic feeding areas) and providing food (early successional plant communities) close to shelter (semi-mature or mature conifer stands).

This objective may be met by no or modified cutting in the vicinity of key features, by reducing the size of planned clear cuts or by providing shelter patches within cutovers. Additionally, a diverse vegetative pattern may be obtained if cutting is dispersed among all eligible stands rather than cutting them in a contiguous manner during the planning period.

In some areas, clear-cutting in blocks of 80–130 ha (200–320 acres) with buffer zones between cuts, and scattered clumps of trees within the cutovers, will provide the desired conditions. Clear-cuts greater than 100 ha (250 acres) should have scattered shelter patches within the cut area. This would keep the overall vegetative diversity of the area high and still provide a reasonable timber harvest.

The best habitat should provide conditions enabling a moose to be within 200 m (650 feet) of shelter patches or other cover. These shelter patches should preferably be of conifer but could be of mixed-wood, with at least 1/3 in conifer. They should be at least 3–5 ha (7–12 acres) in size, be spaced 300–400 m (1000–1300 feet) apart, be at least 6 m (20 feet) high, and have about 11 square metres/ha basal area (50 square feet/acre). The stocking densities of immature and mature stands with this basal area will be approximately 70% and 40% respectively. If the objective of the shelter patches is to provide late winter cover for moose, shelter patches should be conifer with stocking of 70% or greater. Where these shelter patches are composed of mature conifer, basal areas will be greater than 11 square meters/ha. It may be beneficial to moose and advantageous to the timber industry to leave shelter patches large enough to inhibit blowdown problems and to warrant future harvest (eg. > 8 ha).

If late winter habitat will be adequate in the area, a return cut of shelter patches can occur when nearby regeneration has reached 2 metres in height. Regeneration of this size will provide lateral shelter, and function as early winter habitat if the regenerated site contains sufficient browse.

If late winter habitat will be inadequate in the area after an early return cut, the cutting of shelter patches should not occur until nearby regeneration has reached 6 metres in height, thereby providing overhead cover for moose.

Clear cut and shelterwood harvesting techniques can produce these patterns, but selection cutting, seldom practiced in the Boreal Forest, may not disturb the forest canopy enough to create significant successional growth. Some selection harvesting of conifer could be practiced within mixed wood shelter patches provided adequate protection remains. There may be a need or opportunity to provide early winter habitat where it does not currently exist. This can be achieved by selection cutting within mature conifer and mixed-wood stands to remove some of the larger conifers.

In late winter concentration areas, width of individual cuts should not exceed 400 m (1300 feet). Uncut areas equal in size to cut areas should be left.

To protect aquatic feeding areas, mineral licks and calving sites, generally reserves are required with the shape and extent dictated by surrounding habitat conditions. Usually a 120 m reserve should be left around these areas. Some merchantable conifer may be removed by selection cutting provided the general nature of the reserve remains intact.

Figure 2 is a stylized illustration of some of the principles of timber harvesting impacts on wildlife and timber production.

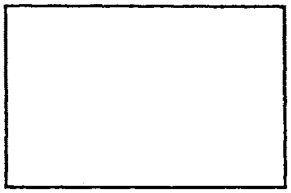
5.1.3 Site Preparation To benefit moose, mechanical preparation should not destroy shelter patches. Residual clumps of conifer or mixed wood within the cut should not be destroyed unless these seriously threaten the success of regeneration. Chemical site preparation is acceptable provided there is adequate browse in nearby stands.

5.1.4 Regeneration Natural regeneration, on suitable sites that produce deciduous woody growth, is of benefit to moose where food supplies are inadequate. Harvest methods which facilitate this should be encouraged in these areas. Artificial regeneration to conifer may be best where moose shelter is in short supply.

5.1.5 Maintenance This aspect of the silviculture system, as those above, should be considered in relation to the vegetation surrounding the treatment area.

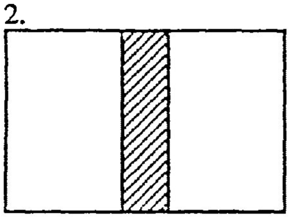
Figure 2.
Stylized Illustration of Principles of Timber Harvesting Impacts on Wildlife and Timber Production

1.



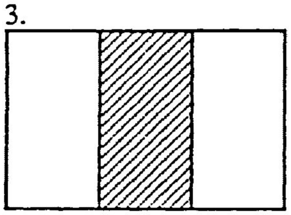
Large clear cut. Total timber utilization, no shelter of any kind for wildlife.

2.



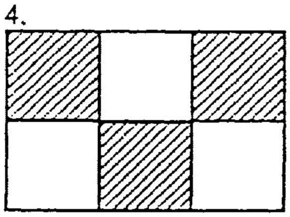
Narrow travel corridor or uncut block (eg. <120m) Some blowdown possible. Possible return for remaining wood. Shelter good for visual barrier, wind and possibly snow depth. Some edge provided.

3.



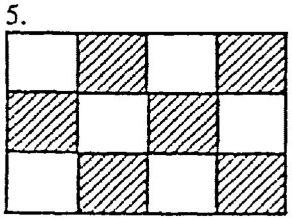
Wide corridor or uncut block (eg. 400m). Timber volume warrants future harvest. Shelter good for visual barrier, wind, snow and radiation. Same edge as #2.

4.



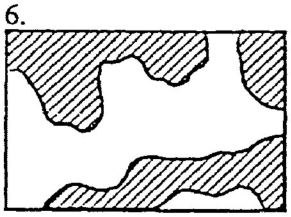
Large cut block pattern. Timber volume warrants future harvest. Shelter good for visual barrier, wind, snow and radiation. Much more edge than #2 and #3. Browse and shelter nearly equal and available.

5.



Small block pattern. Same timber volume as #4, but small blocks particularly if scattered may make future harvest impractical. Shelter good for visual barrier wind, snow and radiation. Strip and shelterwood cuts are variations of this. Much more edge than#4.

6.



Large uncut, irregular patches (eg. >5 ha.) Some loss of timber unless patches are connected. Shelter good for visual barrier, wind, snow and radiation. Large amounts of edge.

Note: A rigid checkerboard harvest pattern is not desirable to produce the best wildlife habitat nor is it practical on most sites. This is a stylized representation.

Where browse is abundant, most tending is acceptable. Where shelter is or will be in short supply, and browse is adequate, tending is encouraged.

Tending efforts should not destroy deciduous growth within shelter patches. Treatments which increase browse in these areas are beneficial. The use of herbicides that suppress deciduous growth for long periods of time should be carefully considered for their potential negative impacts on the quantity of moose browse.

Some chemicals, notably 2,4–D, can have the effect of encouraging browse production (coppice growth).

5.2 Great Lakes – St. Lawrence Forest Region

5.2.1 Forest Access. There are similar concerns about access in both the Boreal and Great Lakes – St. Lawrence Forest Regions. See section 5.1.1 for appropriate recommendations.

5.2.2 Harvest Operations. In the Great Lakes – St. Lawrence Forest Region the emphasis in forest operations is primarily on natural regeneration through the selection or uniform shelterwood systems. Since these systems obtain regeneration under the shelter of a residual stand, they normally provide optimum moose habitat.

Cutting in tolerant hardwoods can create good habitat if it produces sufficient disturbance to stimulate early succession species growth. Cutting should not remove, and it may help regenerate, conifer that is necessary for shelter from extreme weather.

At least 15 per cent of the total area should have mature conifer cover at all times, preferably in patches or clumps at least 3–5 ha in size. This objective can be met using the shelterwood harvest system and, if feasible, by undertaking some artificial regeneration to conifer.

The principles for protecting winter concentration areas, aquatic feeding areas, mineral licks, and calving sites are the same as in northern forest regions. Each area should be identified, its importance determined and the site treated on an individual basis by district staff. See Section 5.1.2 for appropriate harvesting recommendations.

5.2.3 Site Preparation. Recommendations for site preparation in the Boreal Forest Region (Section 5.1.3) are applicable in a few isolated cases to the Great Lakes–St. Lawrence Forest Region. As harvest blocks are generally small, site preparation operations are seldom implemented over large enough areas to have a significant impact on moose habitat.

5.2.4 Regeneration. Because conifer shelter is frequently lacking in the Great Lakes – St. Lawrence Forest Region, regeneration to conifer will generally benefit both moose and deer. Also see Section 5.1.4.

5.2.5 Maintenance. The recommendations for tending, protection and improvement operations in the Boreal Forest Region apply here as well. See Section 5.1.5. Most maintenance in the Great Lakes – St. Lawrence Region is in the form of thinning and improvement of established stands which has little impact on moose habitat.

6.0 Application of Guidelines

Moose habitat needs vary during the day, different times of the year, and across their range. Also, the topography and climatic conditions in Ontario are not uniform and timber management practices vary widely across the Province. Because of this variation, the Guidelines for use in planning timber management are set down in a general way to ensure that average habitat conditions are provided. Local managers and planners will decide how to best apply the principles to meet local situations. In addition, not all areas can be managed in such a way that maximum timber production will coincide with maximum wildlife production. Compromise and discussion among managers is essential to the management process.

In general, if the individual harvest blocks in the proposed five year allocation do not exceed approximately one hundred hectares, there should be no or few moose concerns. In such cases concerns should be restricted to known specific areas (concentration areas, mineral lick sites, calving sites, aquatic feeding areas).

If cuts are proposed which exceed general guidelines over large areas, the district must consider existing and potential moose habitat requirements prior to approving the plan. When a district proposes a cut that greatly exceeds the general guidelines they must, in advance, receive the Regional Director's approval. In addition, if a region intends to routinely sanction deviation from the general guidelines, the Assistant Deputy Minister's approval must be obtained in advance of approving the plans.

7.0 Basis for Guidelines and Sample Plans

These guidelines are based upon a body of scientific literature which is summarized in two appended papers, Thompson and Euler (Swedish Wildlife Research: Viltrevy. in press), and McNicol and Timmermann (1981. in Boreal Mixedwood Symposium Proc. p. 141–154). Examples of plans are provided in Appendix II.

APPENDIX II

RASTER AND VECTOR GIS

RASTER vs VECTOR GIS

The primary classification of GIS (Geographic Information Systems) is based on the spatial data structure (Starr and Estes, 1990) or the data encoding methodology (Tomlin, 1990). This classification scheme separates GIS into two categories - raster or vector.

Both systems involve separating a map into a series of layers (or planes). Determination of the layers is based first on the distinction of a point, line or polygon. A point being an entity that occupies a single X,Y coordinate on the landscape. Examples would include an eagle's nest or a camp site. A line is a series of X,Y coordinates with a start and an end point. Examples of a line would be a stream or a road. A polygon represents a series of X,Y coordinates which bound an area. In other words, polygons have area and boundaries. Examples of polygons are forest stands and lakes.

Further separation of layers is based on themes. Where more than one data theme are included within the same point, line or polygon category, separation is based on the data theme. For example, roads, streams and administrative boundaries are all line, yet they would in all likelihood be separated into three distinct information layers for data manipulation and analysis purposes.

The difference between raster and vector GIS is simply that raster systems are based on representing the landscape as a grid while vector systems do this through points and lines, without the positional constraints of a grid. Figure 1 shows, schematically, the difference between the two systems, in terms of representation of spatial data.

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Starr, J. and J. Estes. 1990. Geographic Information Systems: An Introduction. Prentice Hall, Englewood Cliffs, N.J. 303 pp.

Tomlin, C.D. 1990. Geographic Information Systems and Cartographic Modeling. Prentice Hall, Englewood Cliffs, N.J. 249 pp.

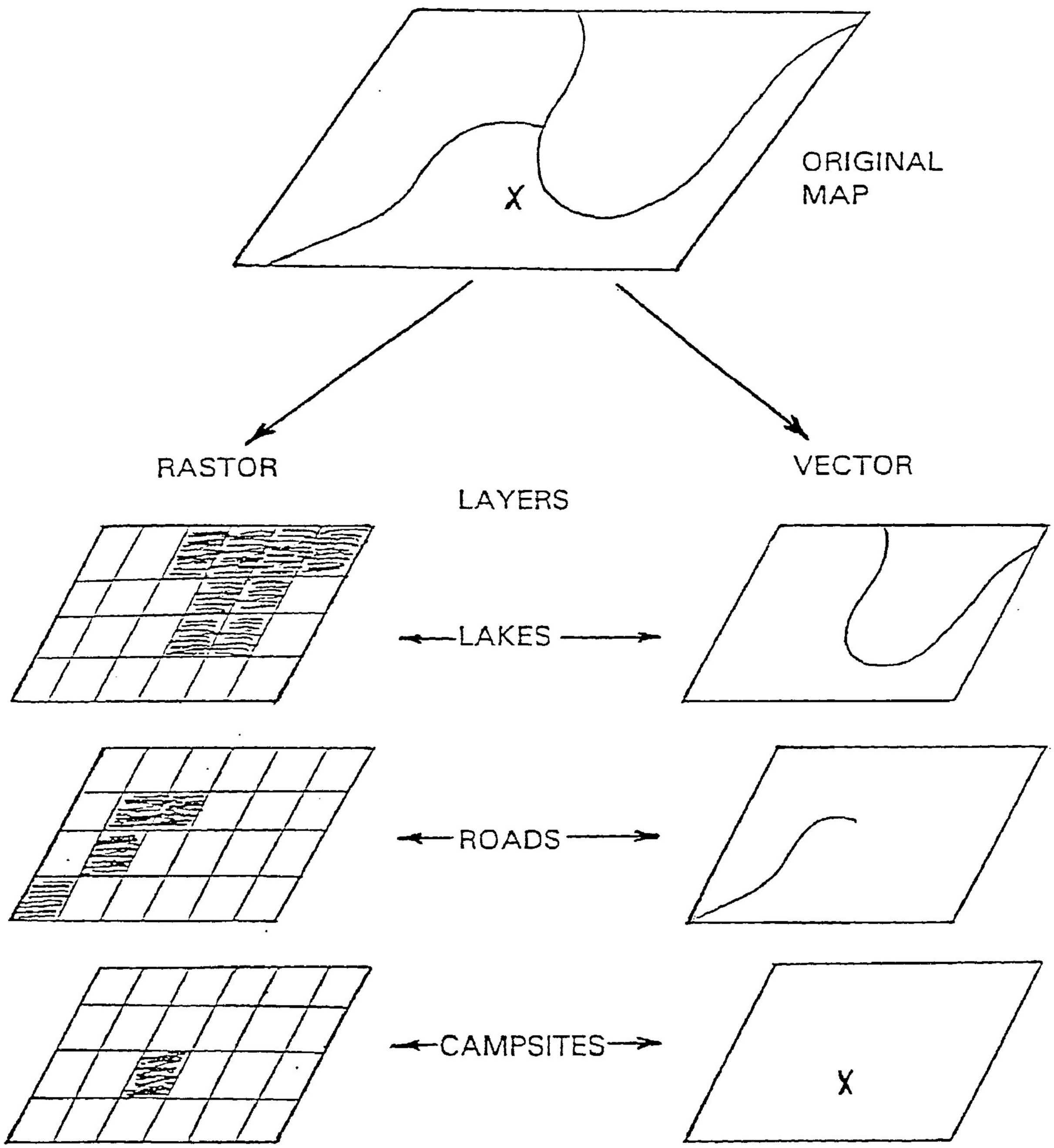


Figure 1. Schematic representation of spatial data in Raster and Vector GIS.

APPENDIX III

GEOMETRIC CORRELATION FOR THE DETERMINATION OF HABITAT WINDOW SIZE

GEOMETRIC CORRELATION FOR THE DETERMINATION OF HABITAT WINDOW SIZE

The choice of habitat window size was related to several factors, one corresponding to moose ecology, the others to spatial geometry parameters established in M-HSAM. These factors are:

1. The habitat window must be large enough to encompass at least the area of moose home range, 20 km^2;
2. The dimensions of the habitat window should be equal in the X and Y direction to simplify the 50% overlap in the X and Y axes; and,
3. To ensure that an equal number of 200m grid points were sampled by each habitat window, the dimensions of the window should be:
   a. a factor of 200, the grid point distance; and,
   b. a factor of 2.

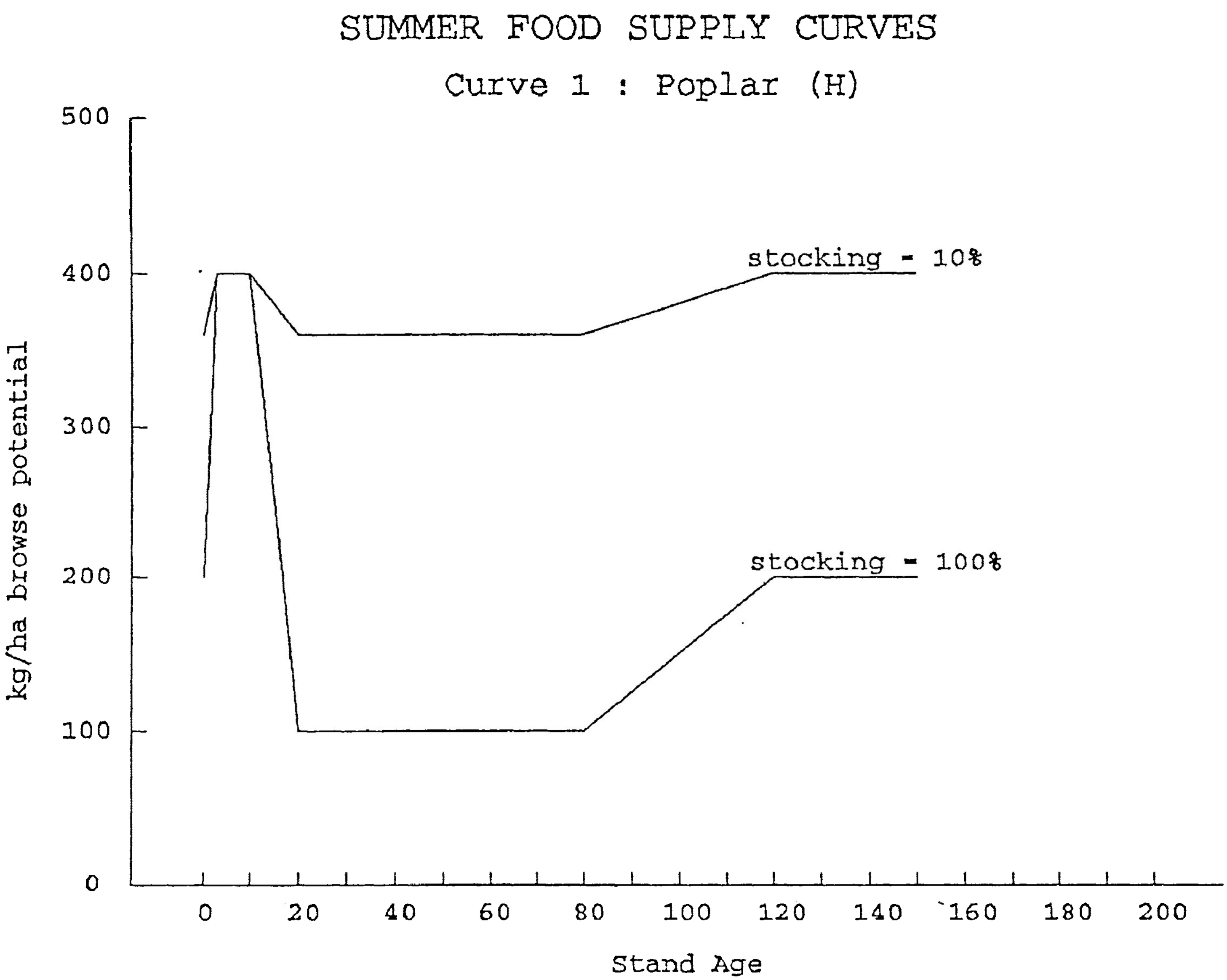
The 2,304-ha habitat window provided the smallest unit which conformed to all of the above criteria. The 2,304-ha window represented a sample of 576 grid points, 24 on the X axis and 24 on the Y axis.

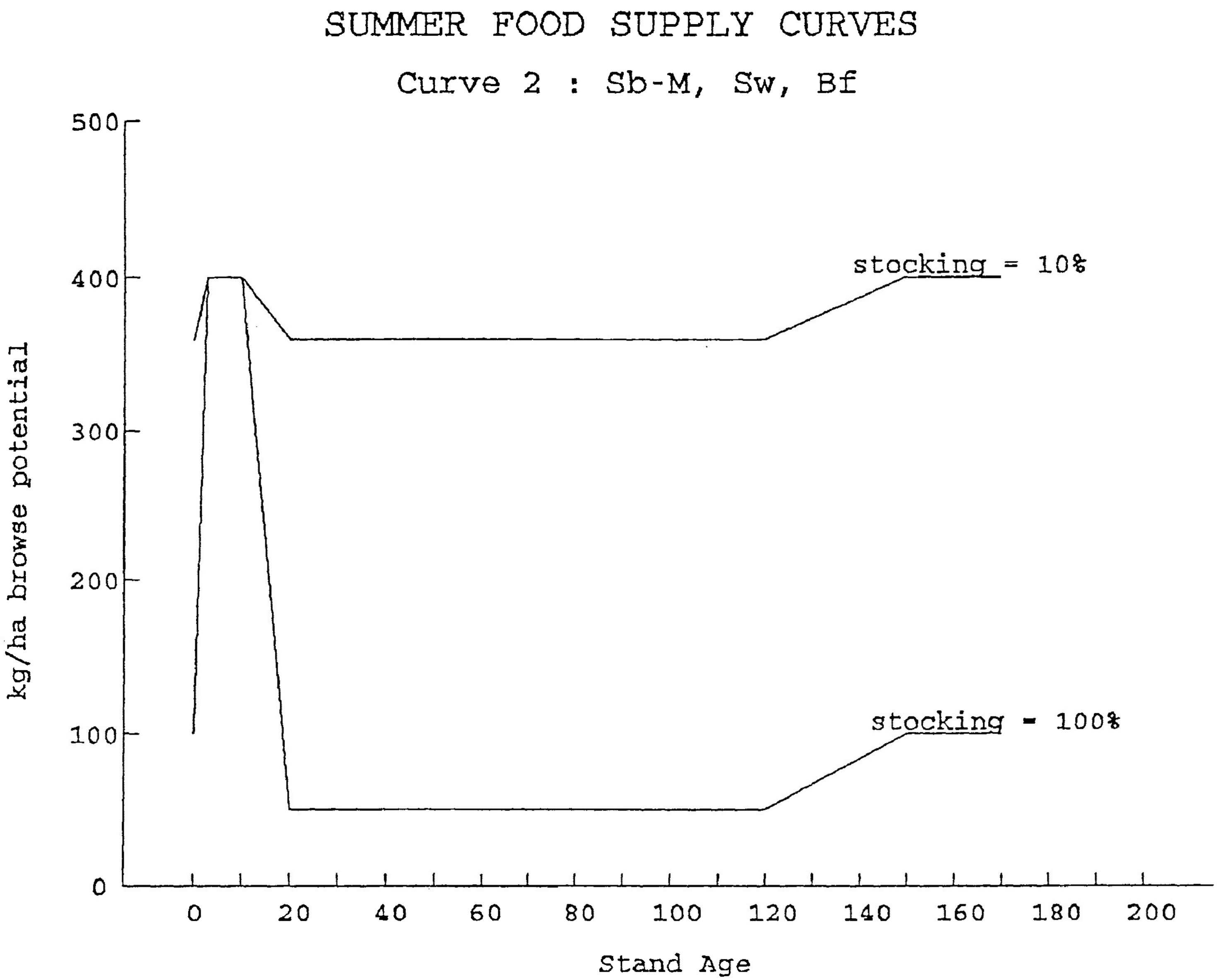
Using 22 grid points on each axis the window size would have been 1,936 ha. This value was below the 20-km^2 moose home range size, and was therefore assumed too small an area to provide the life requisites for a moose.

The next size of 23 X 23 grid points resulted in a habitat window of 2,116 ha. Although this fit points 1, 2, and 3a in the above selection criteria, by not conforming to point 3b the 50% overlap rule would have been unattainable. Equal numbers of grid points could not have been sampled across the landscape, thereby introducing sampling bias.

APPENDIX IV

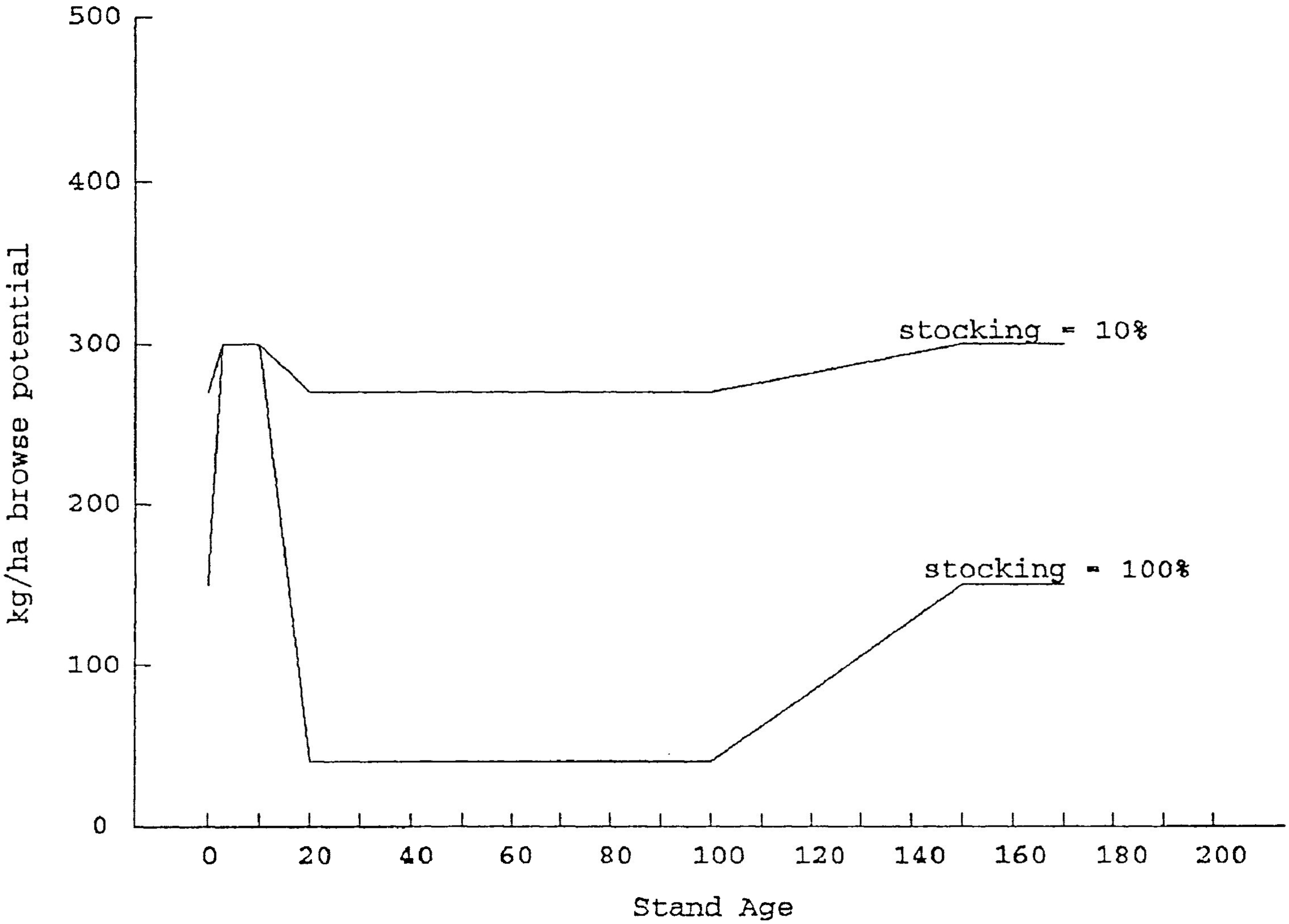
SUMMER FOOD SUPPLY CURVES


SUMMER FOOD SUPPLY CURVES
Curve 1 : Poplar (H)
kg/ha browse potential
500
400
300
200
100
0
stocking = 10%
stocking = 100%
0
20
40
60
80
100
120
140
160
180
200
Stand Age


SUMMER FOOD SUPPLY CURVES
Curve 2 : Sb-M, Sw, Bf
stocking = 10%
stocking = 100%
kg/ha browse potential
0
100
200
300
400
500
0
20
40
60
80
100
120
140
160
180
200
Stand Age

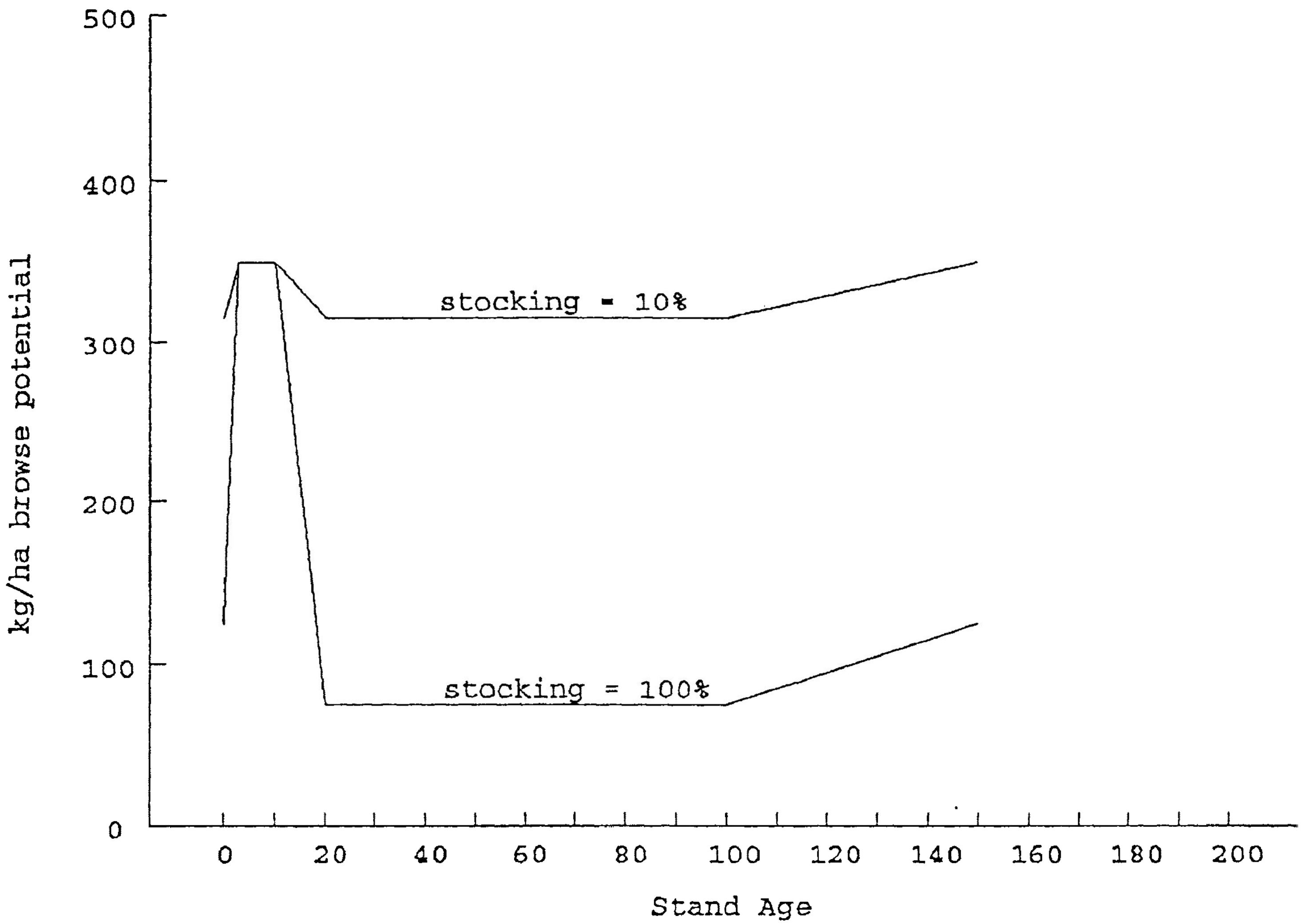
SUMMER FOOD SUPPLY CURVES

Curve 3 : Pine-Mix



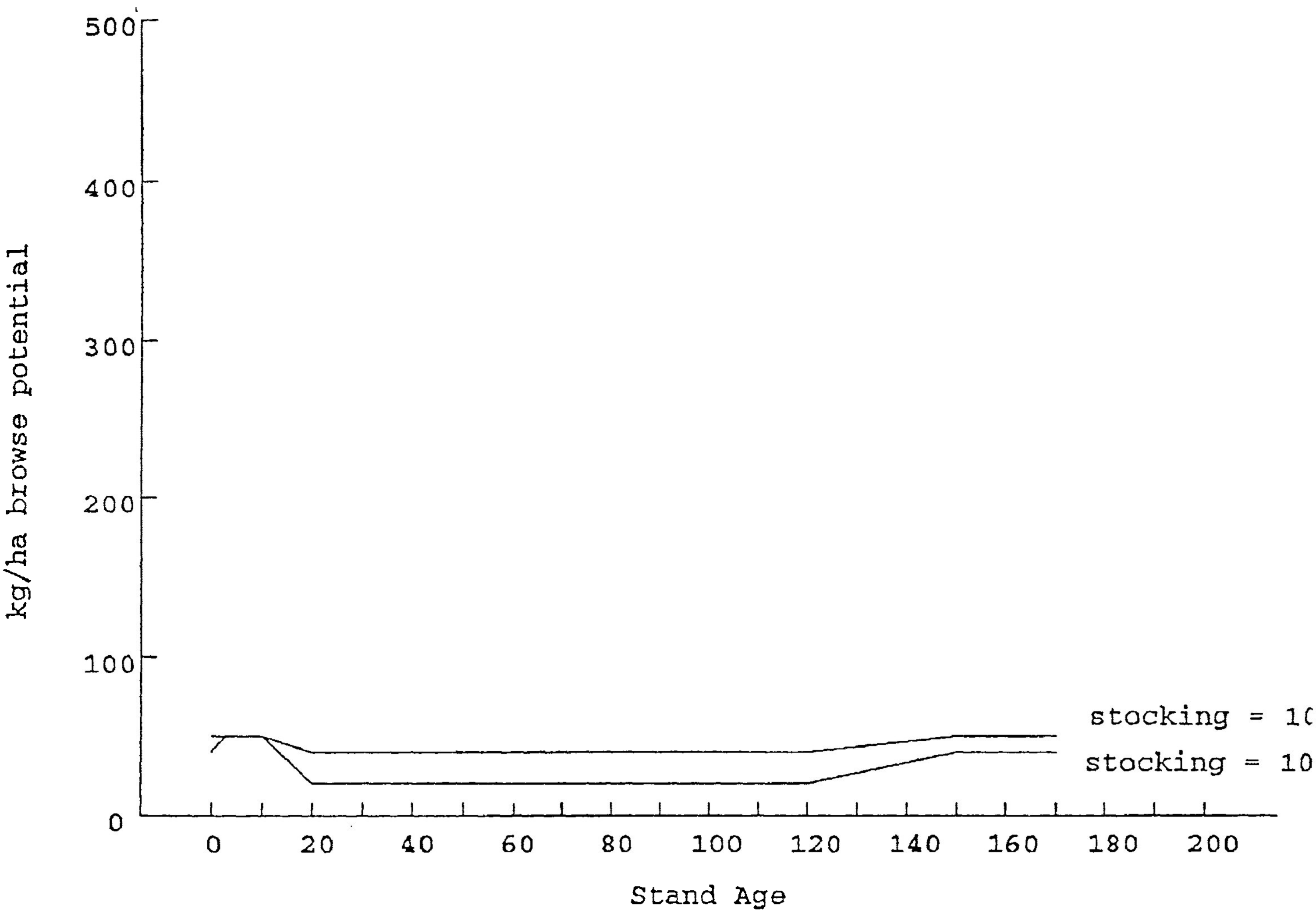
SUMMER FOOD SUPPLY CURVES

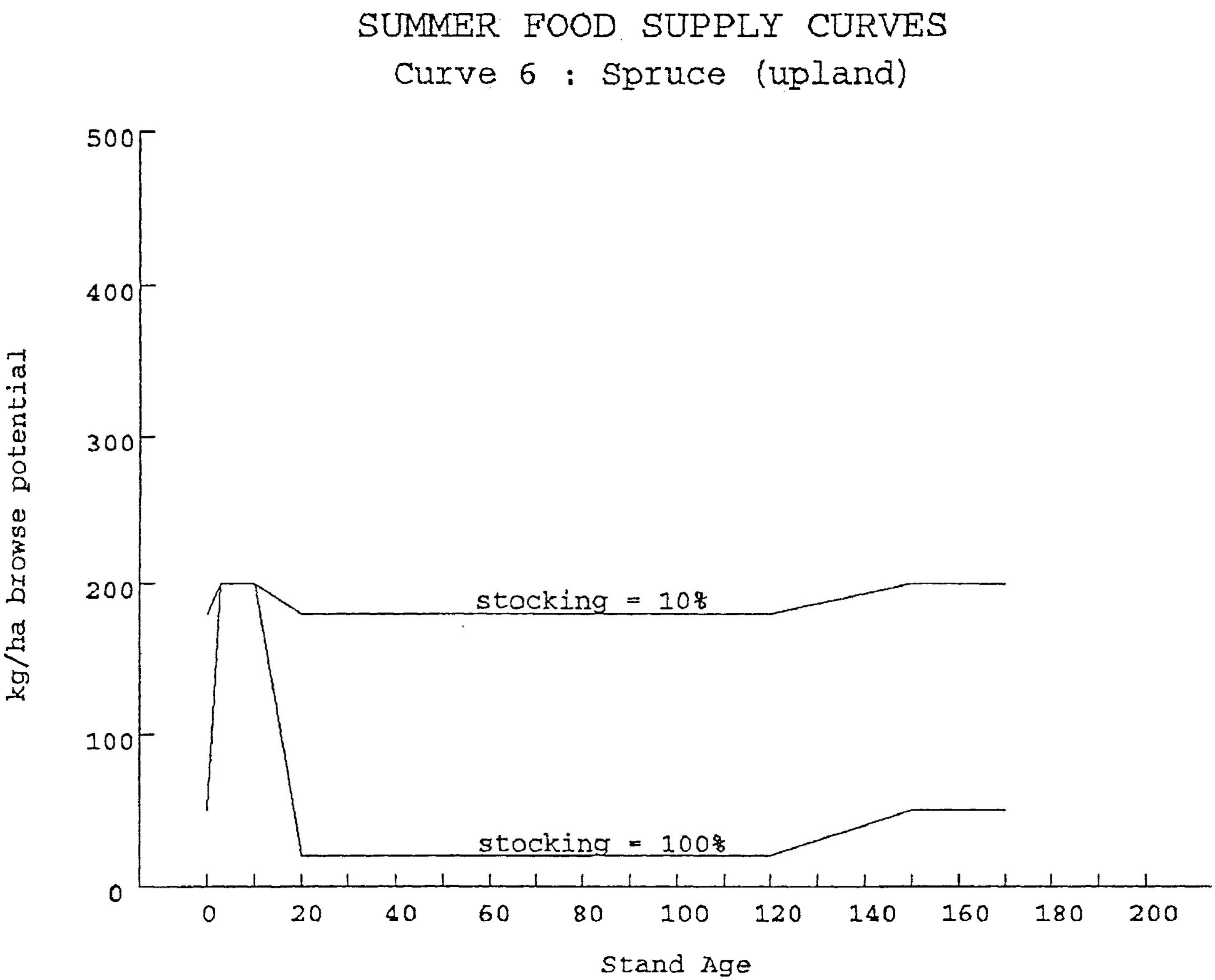
Curve 4 : Poplar-Mix (H)

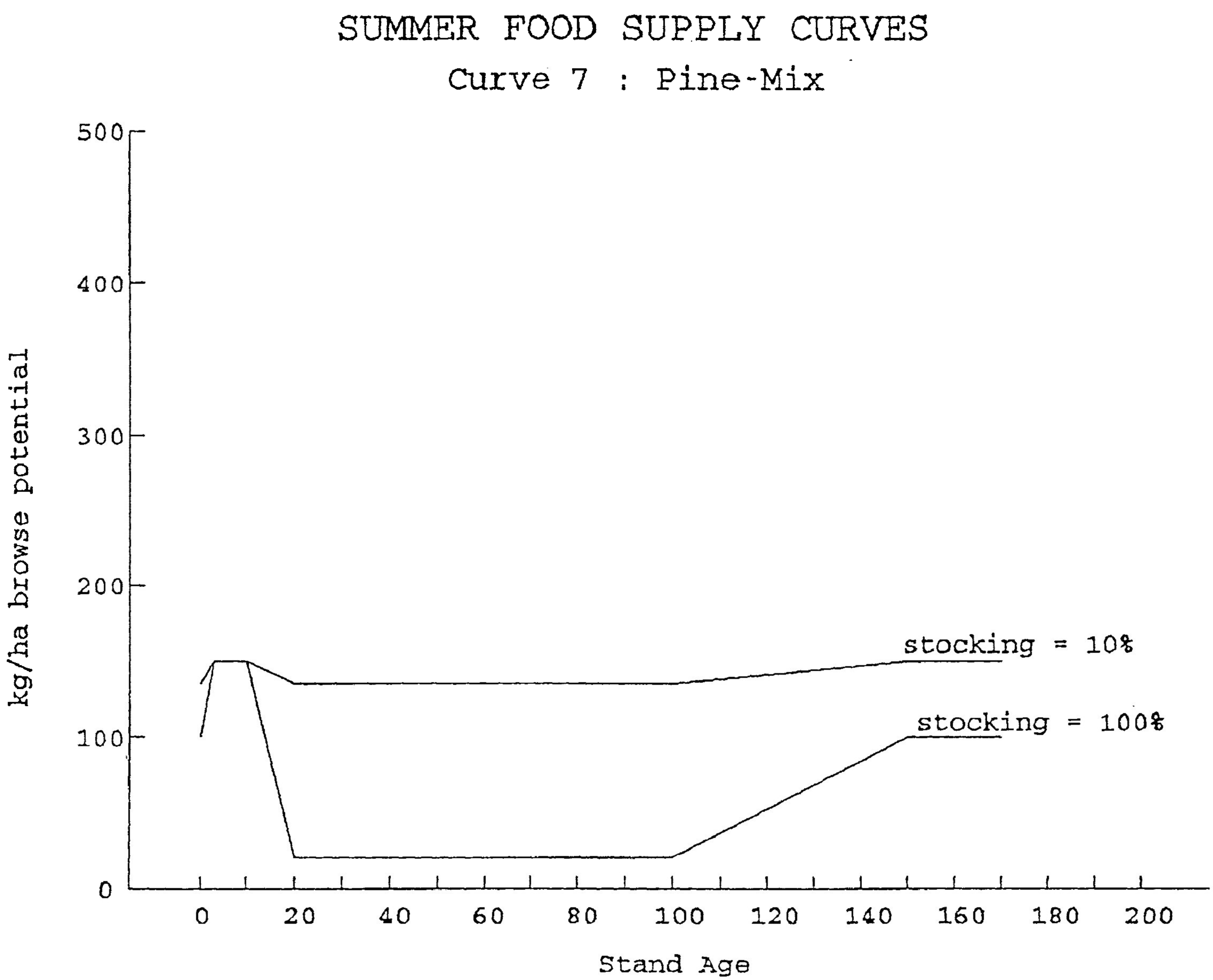


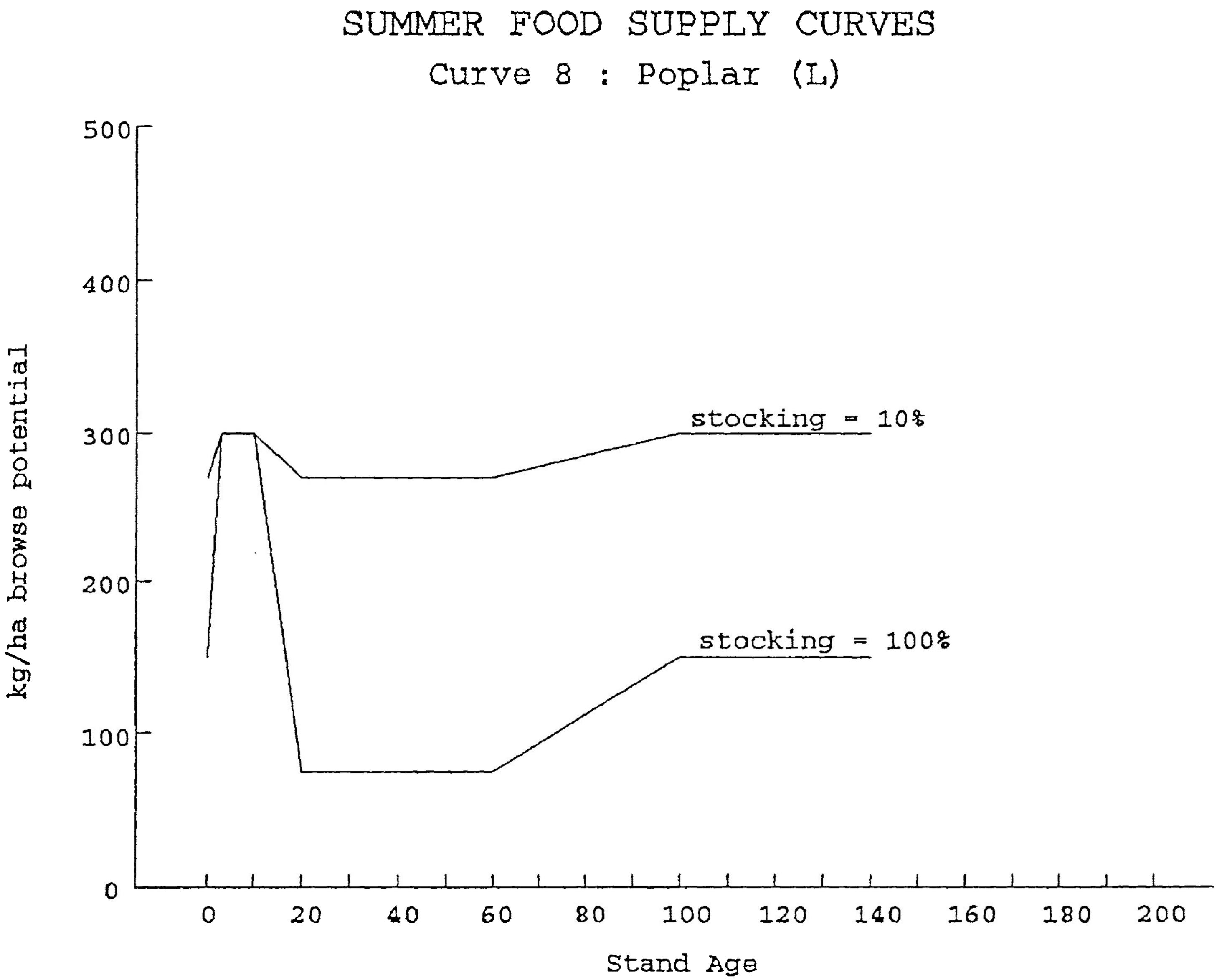
SUMMER FOOD SUPPLY CURVES

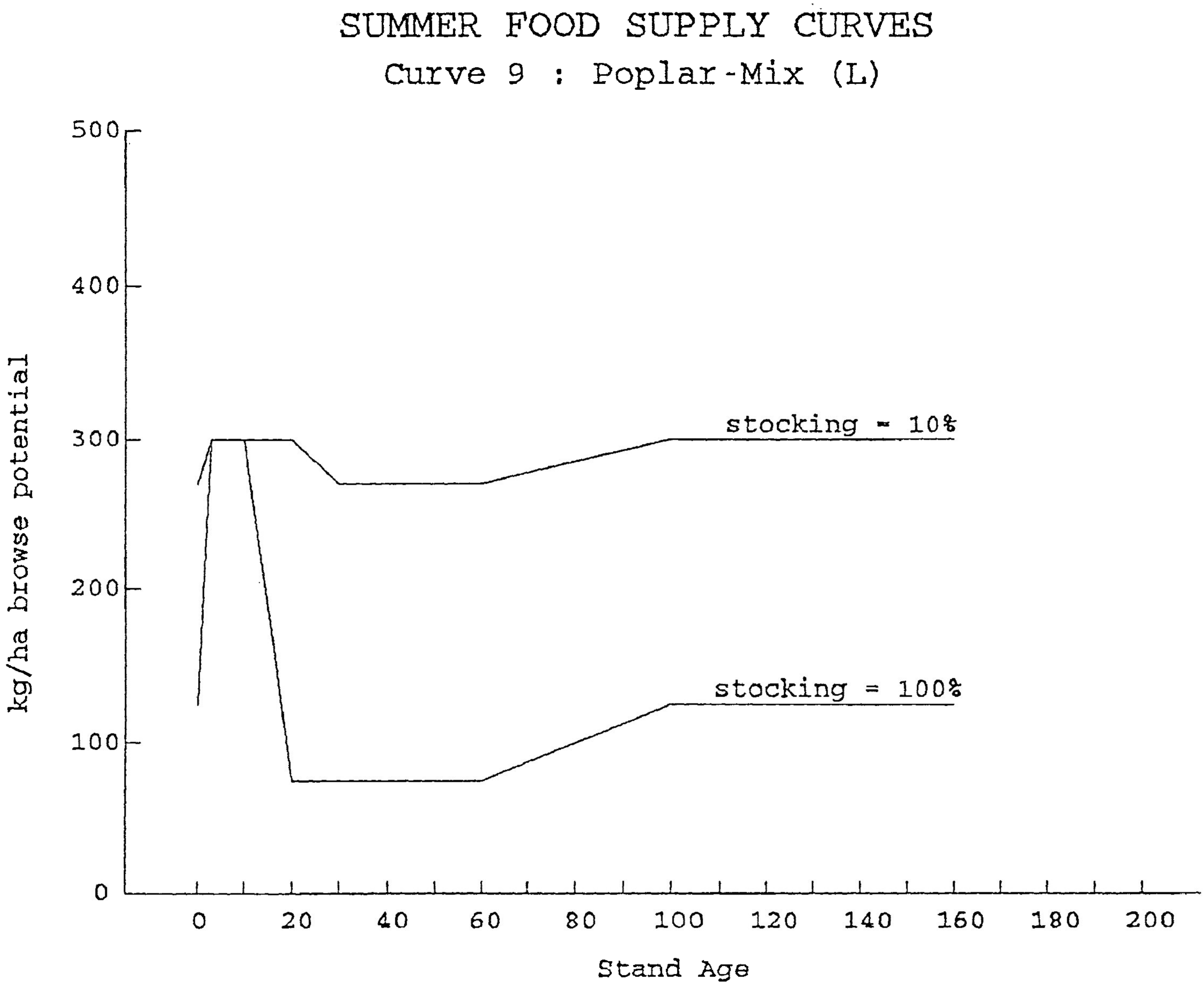
Curve 5 : Sb (lowland), Ce, L




SUMMER FOOD SUPPLY CURVES
Curve 6 : Spruce (upland)
kg/ha browse potential
500
400
300
200
100
0
stocking = 10%
stocking = 100%
0
20
40
60
80
100
120
140
160
180
200
Stand Age

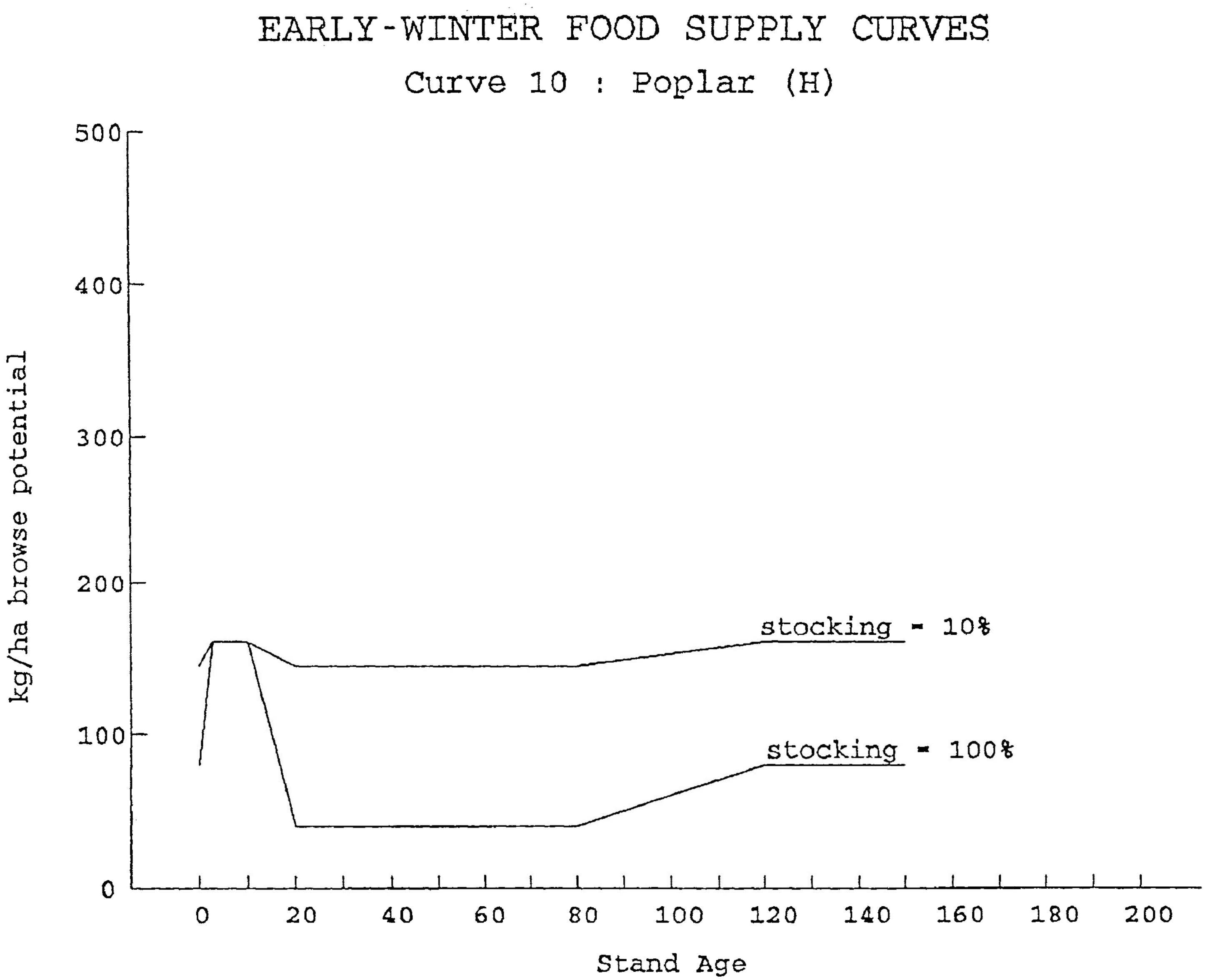

SUMMER FOOD SUPPLY CURVES
Curve 7 : Pine-Mix
kg/ha browse potential
500
400
300
200
100
0
stocking = 10%
stocking = 100%
0
20
40
60
80
100
120
140
160
180
200
Stand Age

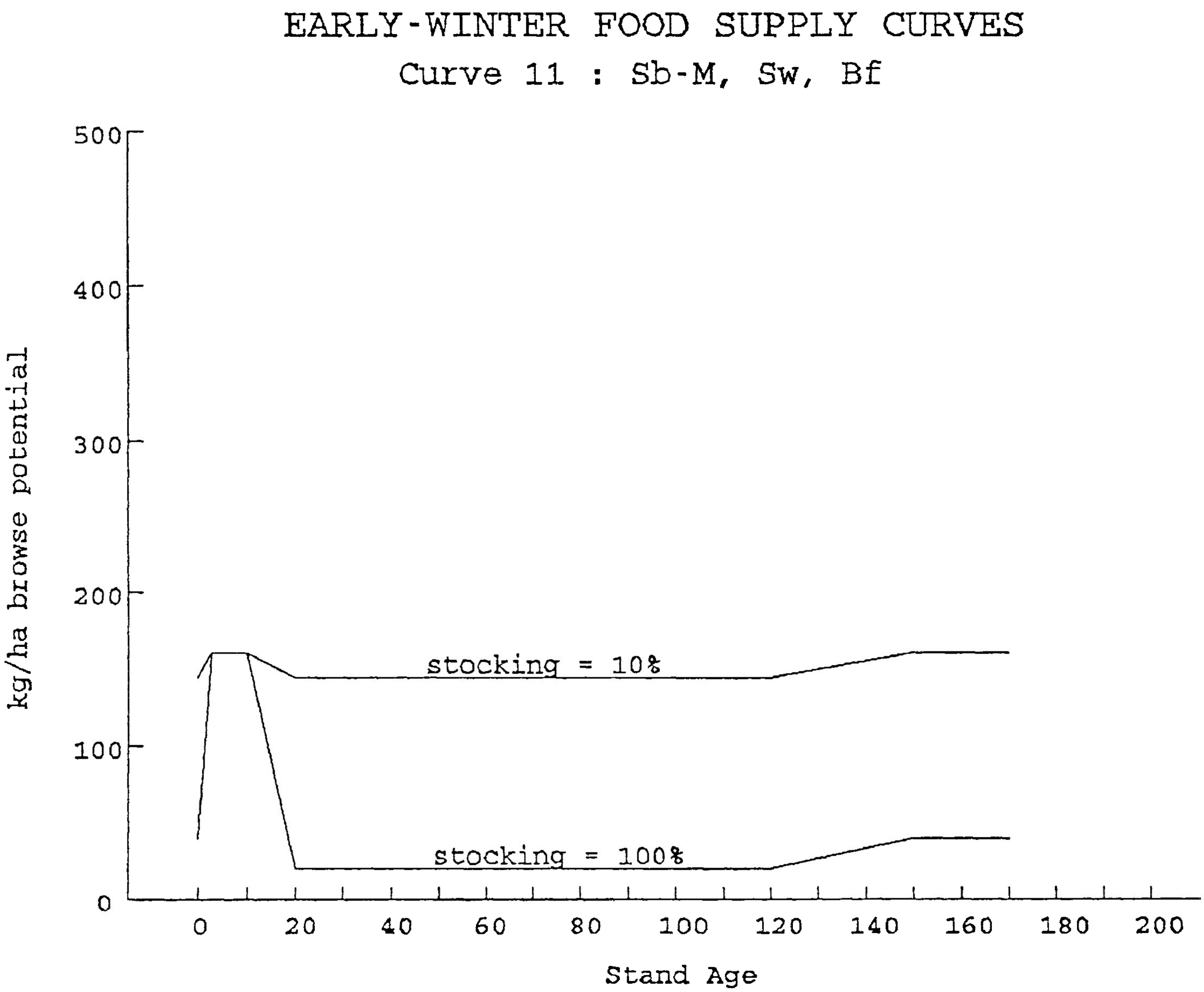

SUMMER FOOD SUPPLY CURVES
Curve 8 : Poplar (L)
kg/ha browse potential
500
400
300
200
100
0
stocking = 10%
stocking = 100%
0
20
40
60
80
100
120
140
160
180
200
Stand Age

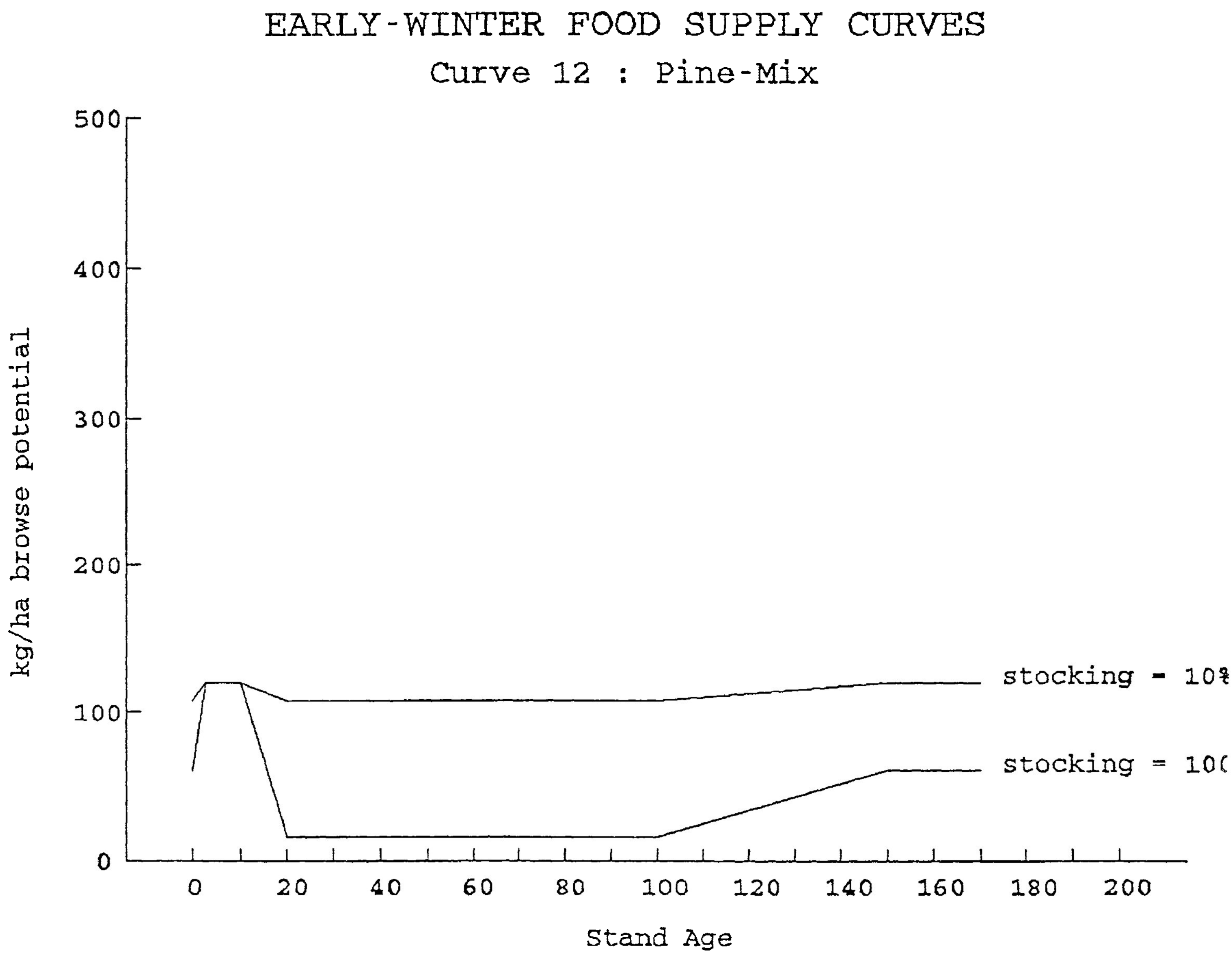

SUMMER FOOD SUPPLY CURVES
Curve 9 : Poplar-Mix (L)
kg/ha browse potential
500
400
300
200
100
0
stocking = 10%
stocking = 100%
0
20
40
60
80
100
120
140
160
180
200
Stand Age

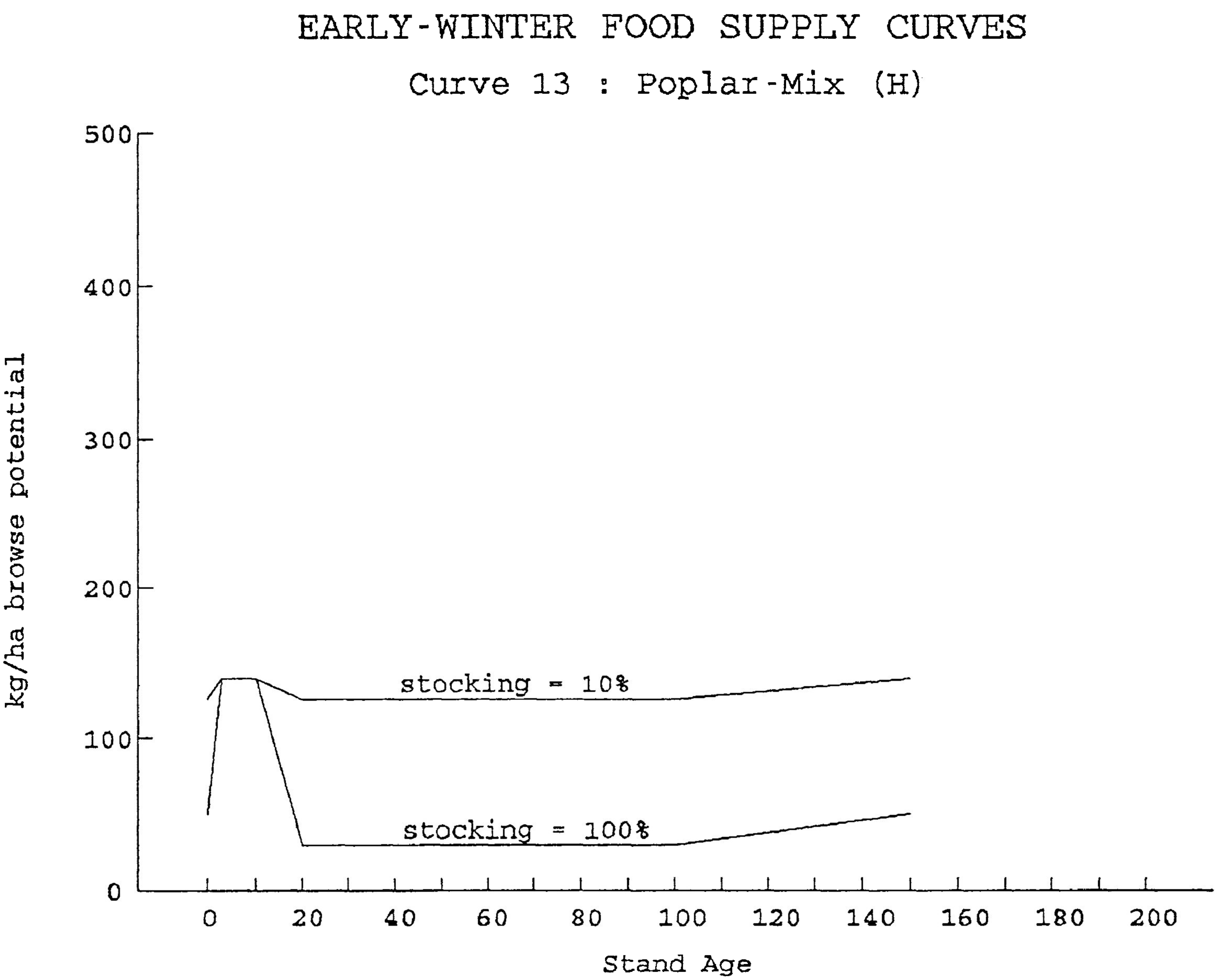
APPENDIX V

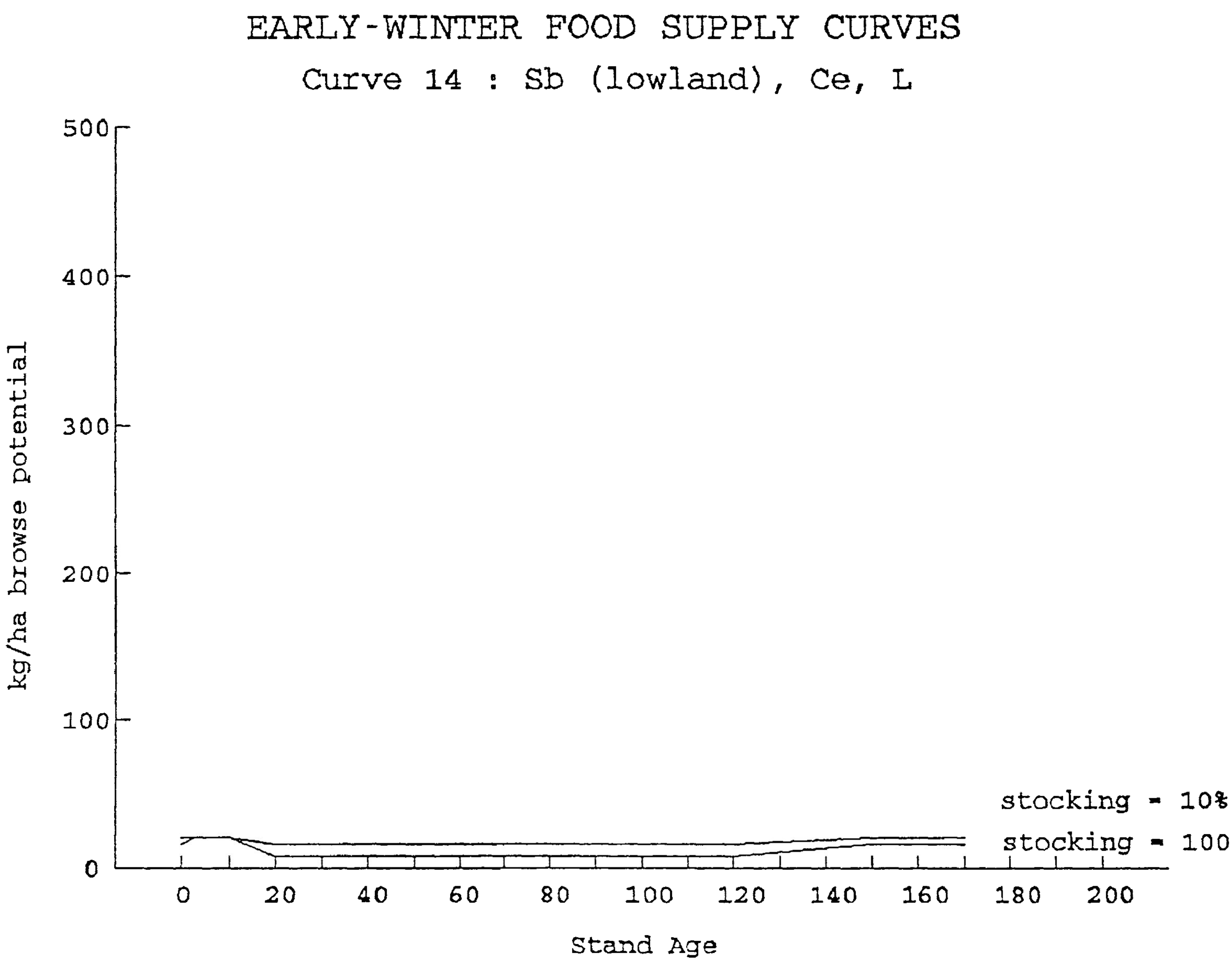
EARLY WINTER FOOD SUPPLY CURVES

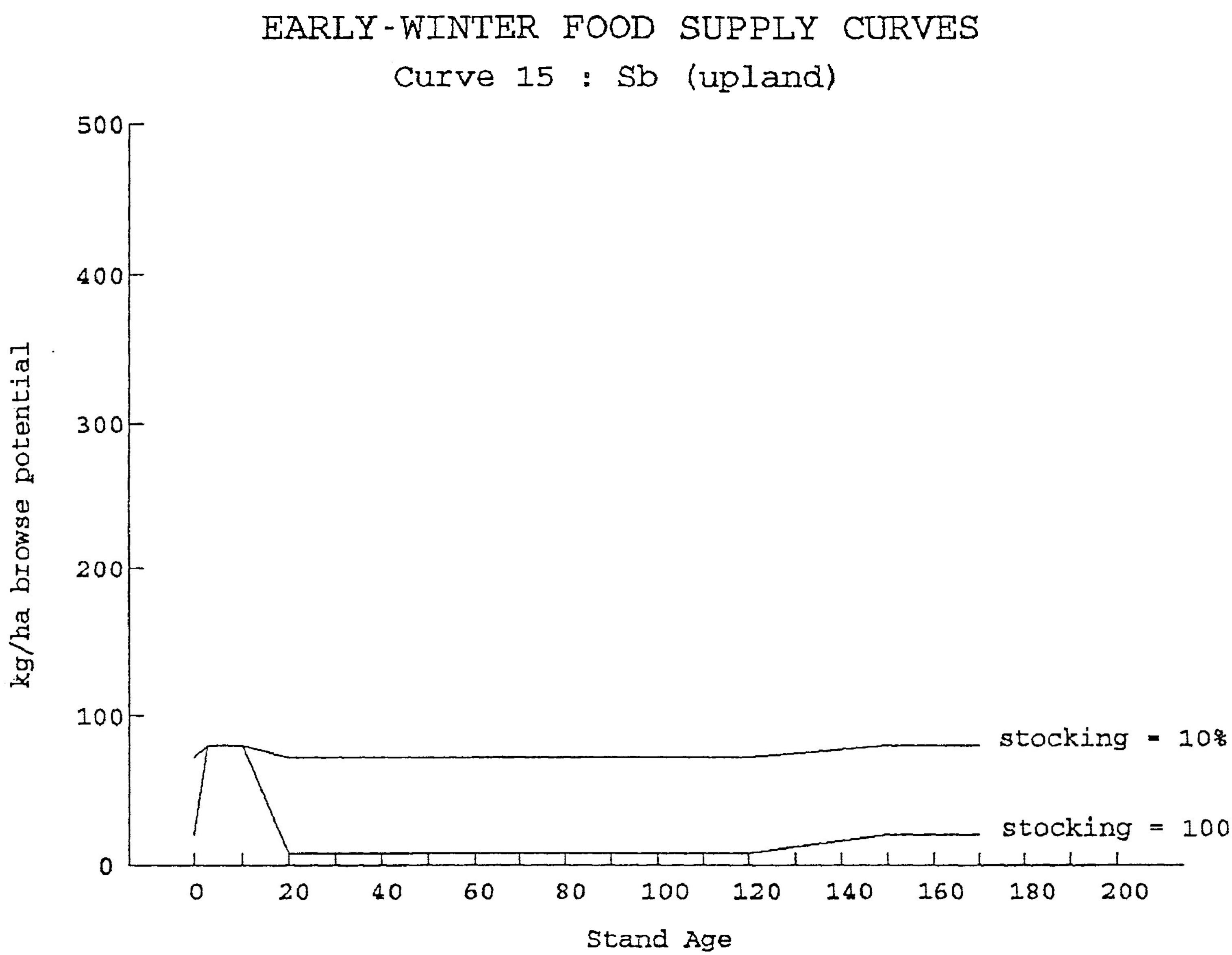

EARLY-WINTER FOOD SUPPLY CURVES
Curve 10 : Poplar (H)
kg/ha browse potential
500
400
300
200
100
0
0
20
40
60
80
100
120
140
160
180
200
Stand Age
stocking = 10%
stocking = 100%

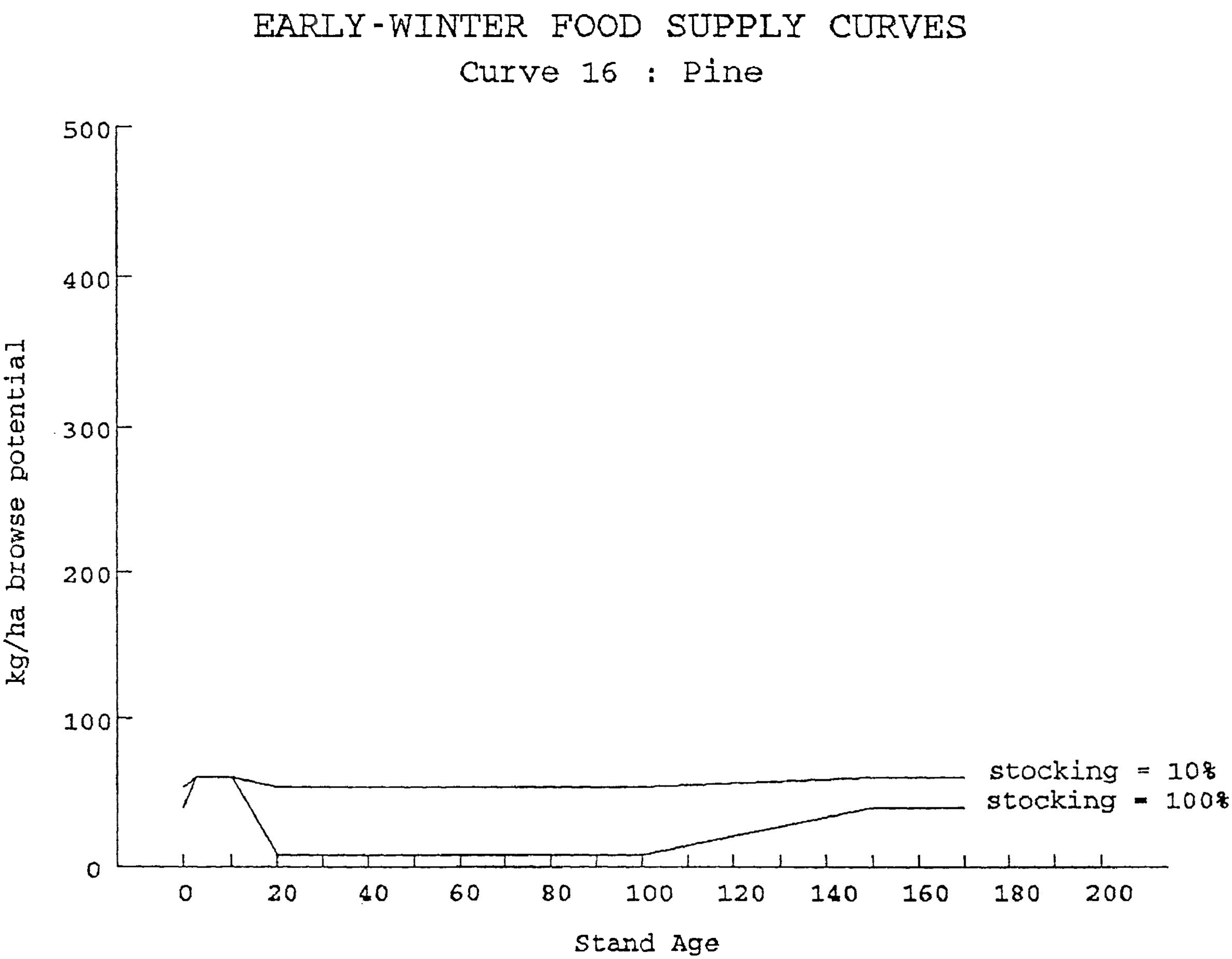

EARLY-WINTER FOOD SUPPLY CURVES
Curve 11 : Sb-M, Sw, Bf
kg/ha browse potential
500
400
300
200
100
0
stocking = 10%
stocking = 100%
0
20
40
60
80
100
120
140
160
180
200
Stand Age


EARLY-WINTER FOOD SUPPLY CURVES
Curve 12 : Pine-Mix
kg/ha browse potential
500
400
300
200
100
0
stocking = 10%
stocking = 10(
0
20
40
60
80
100
120
140
160
180
200
Stand Age

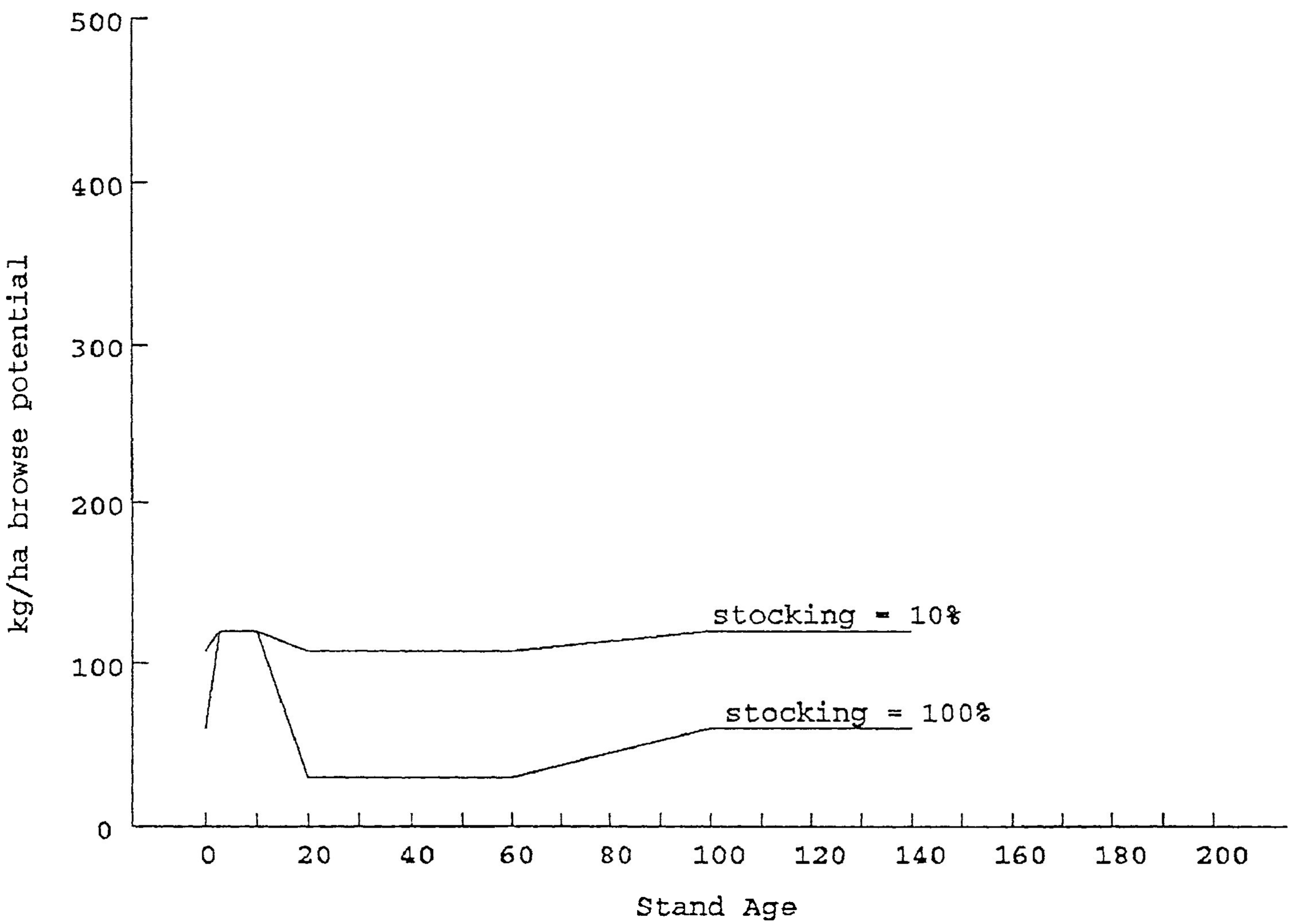

EARLY-WINTER FOOD SUPPLY CURVES
Curve 13 : Poplar-Mix (H)
500
400
300
200
100
0
kg/ha browse potential
stocking = 10%
stocking = 100%
0
20
40
60
80
100
120
140
160
180
200
Stand Age

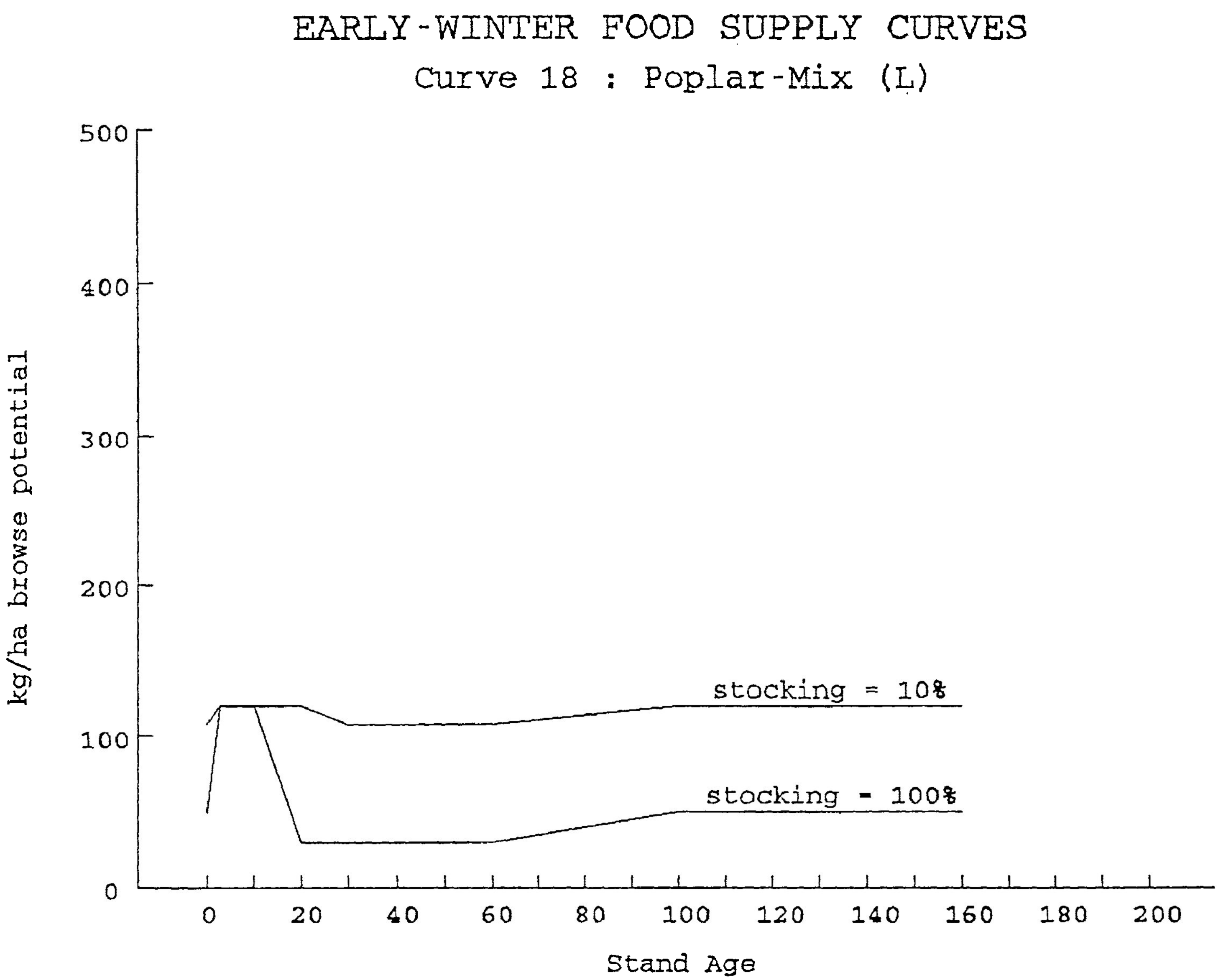

EARLY-WINTER FOOD SUPPLY CURVES
Curve 14 : Sb (lowland), Ce, L
kg/ha browse potential
0
100
200
300
400
500
0
20
40
60
80
100
120
140
160
180
200
Stand Age
stocking = 10%
stocking = 100


EARLY-WINTER FOOD SUPPLY CURVES
Curve 15 : Sb (upland)
kg/ha browse potential
500
400
300
200
100
0
stocking = 10%
stocking = 100
0
20
40
60
80
100
120
140
160
180
200
Stand Age


EARLY-WINTER FOOD SUPPLY CURVES
Curve 16 : Pine
kg/ha browse potential
500
400
300
200
100
0
0
20
40
60
80
100
120
140
160
180
200
Stand Age
stocking = 10%
stocking = 100%

EARLY-WINTER FOOD SUPPLY CURVES
Curve 17 : Poplar (L)



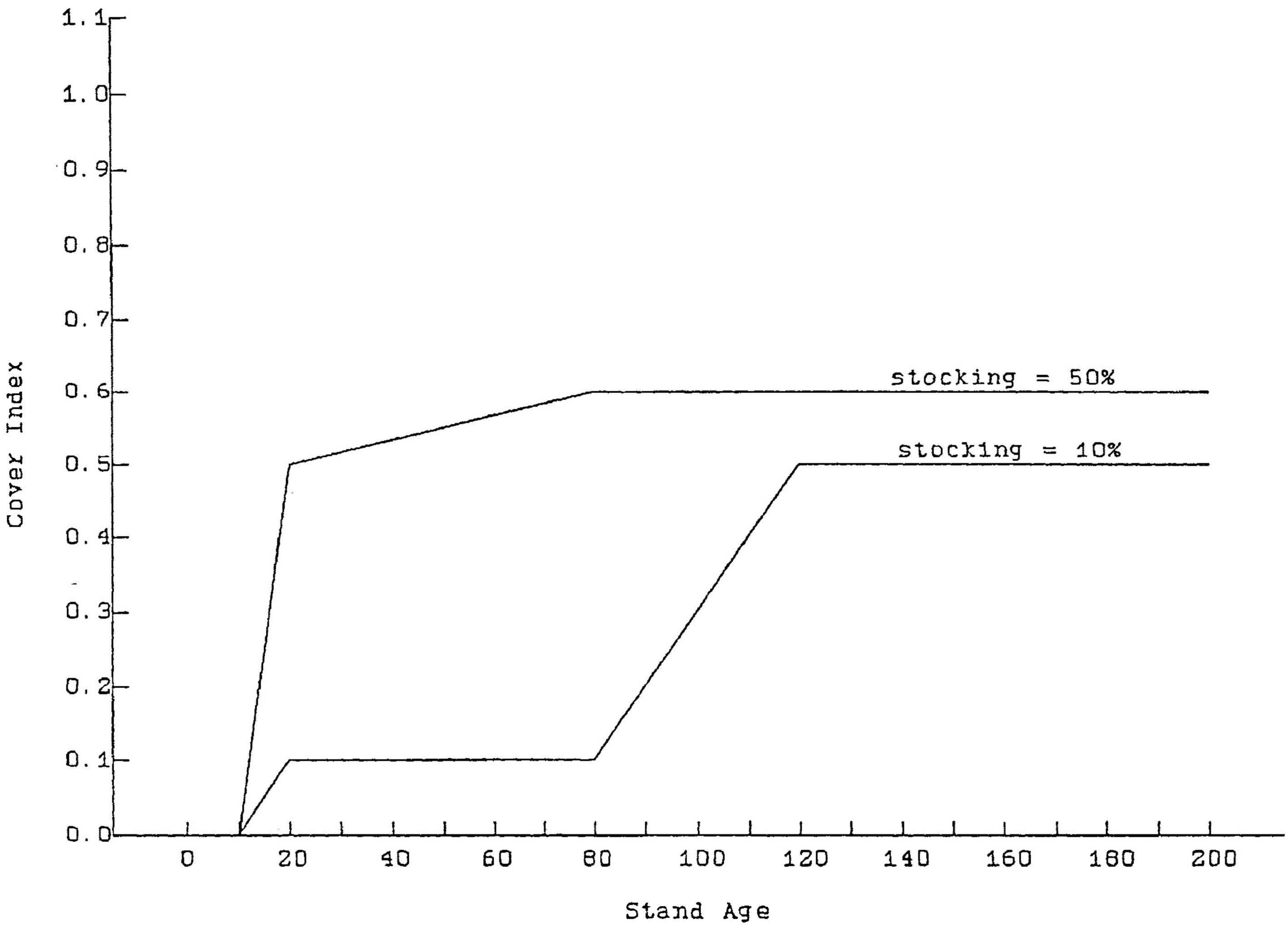

EARLY-WINTER FOOD SUPPLY CURVES
Curve 18 : Poplar-Mix (L)
kg/ha browse potential
500
400
300
200
100
0
stocking = 10%
stocking = 100%
0
20
40
60
80
100
120
140
160
180
200
Stand Age

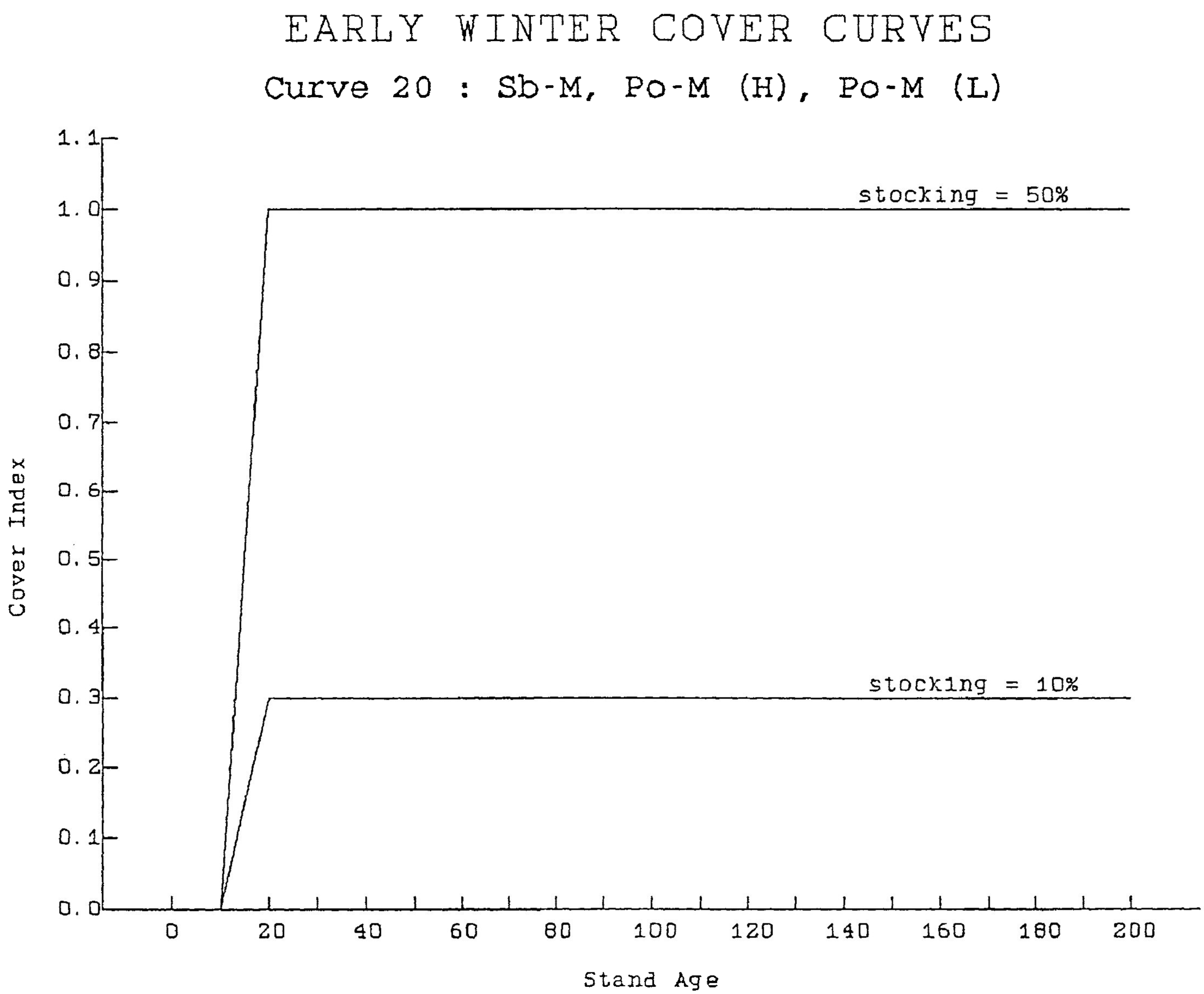
APPENDIX VI

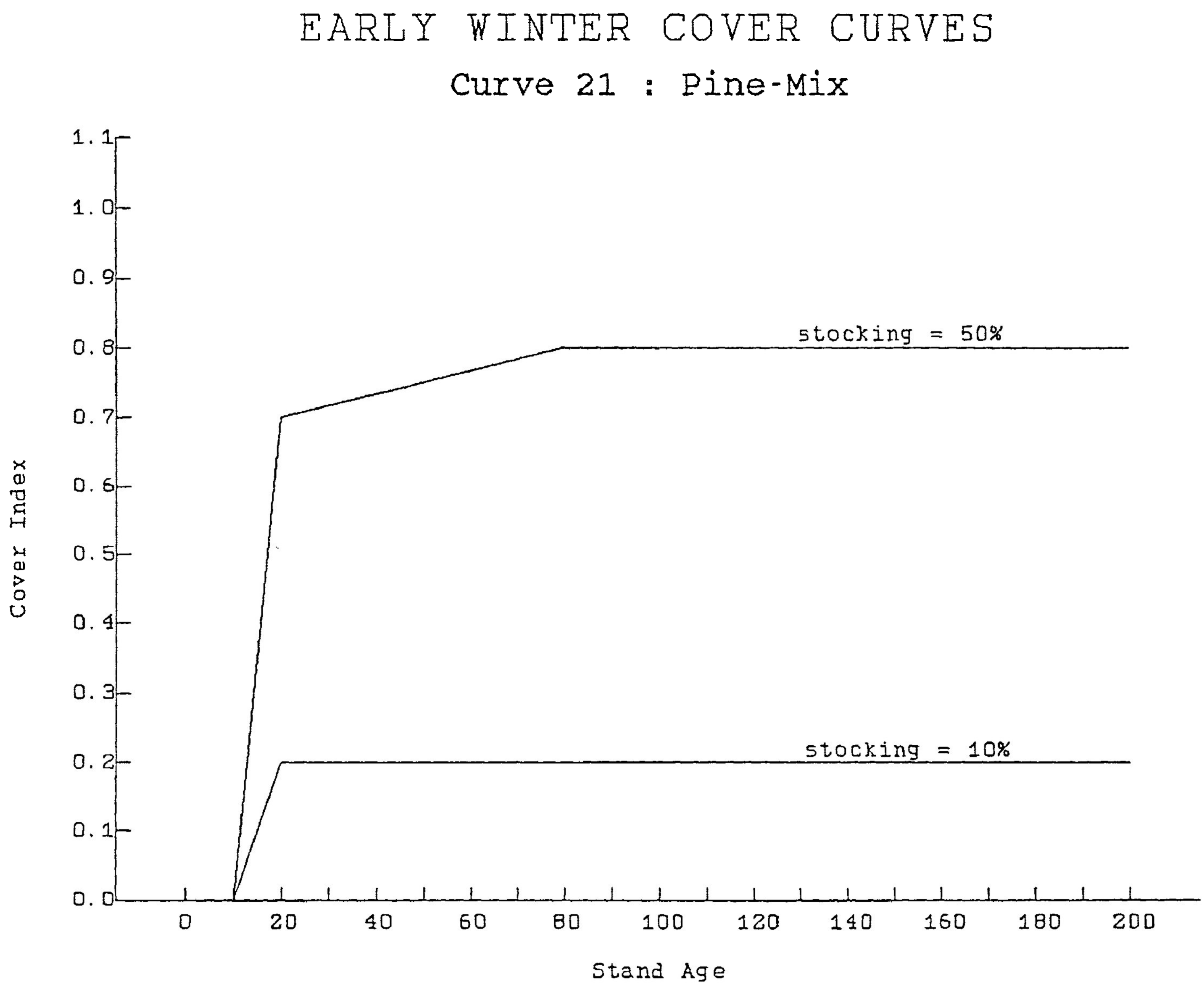
EARLY WINTER COVER CURVES

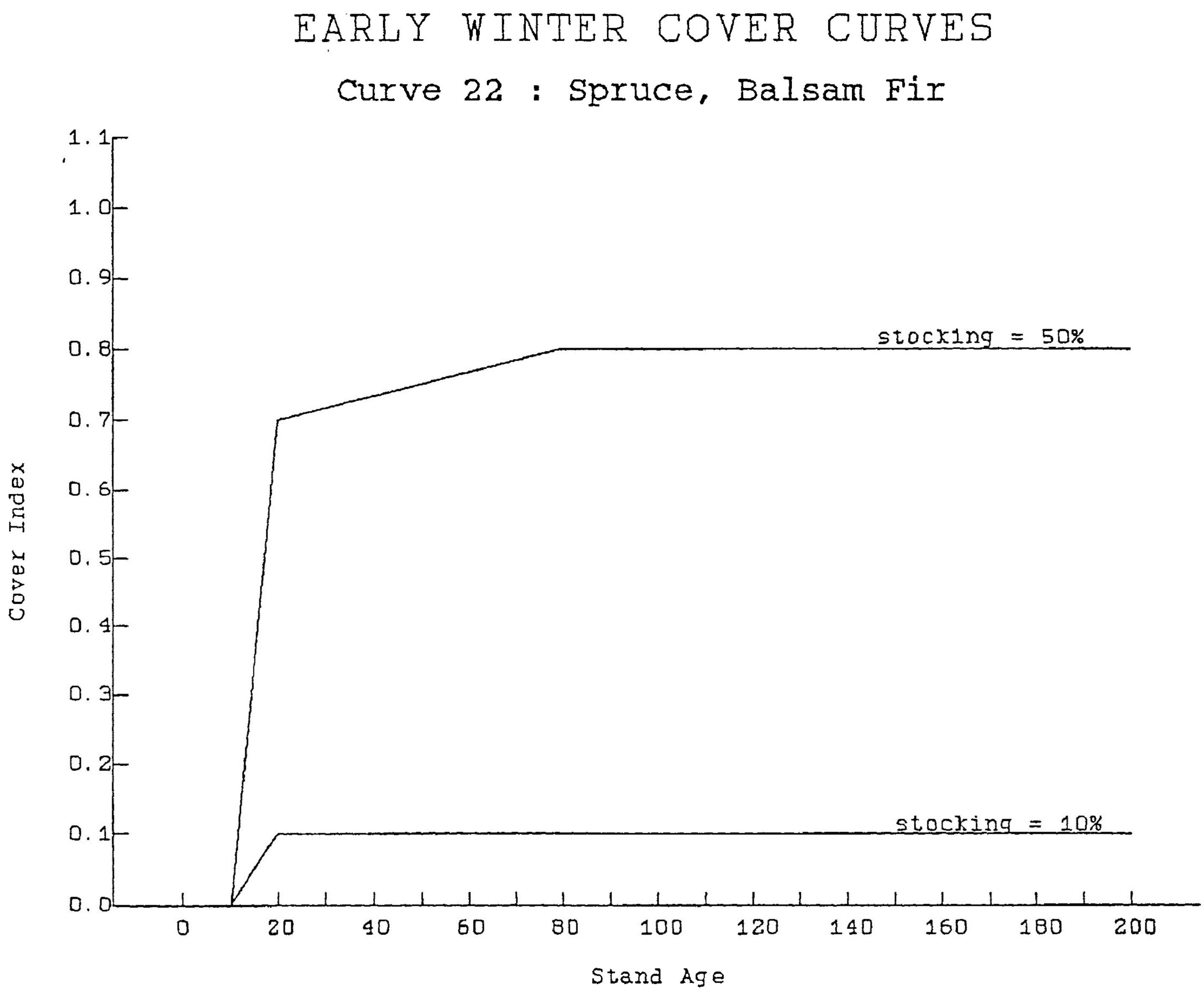
EARLY WINTER COVER CURVES

Curve 19 : Poplar (H), Poplar (L), Larch




EARLY WINTER COVER CURVES
Curve 20 : Sb-M, Po-M (H), Po-M (L)
stocking = 50%
stocking = 10%
Cover Index
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Stand Age


EARLY WINTER COVER CURVES
Curve 21 : Pine-Mix
Cover Index
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
stocking = 50%
stocking = 10%
0
20
40
60
80
100
120
140
160
180
200
Stand Age


EARLY WINTER COVER CURVES
Curve 22 : Spruce, Balsam Fir
Cover Index
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
stocking = 50%
stocking = 10%
0
20
40
60
80
100
120
140
160
180
200
Stand Age

EARLY WINTER COVER CURVES

Curve 23 : Pine