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An Economic Analysis of Protecting Woodland Caribou Habitat in Northwestern Ontario

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This file report is an unedited, unpublished report submitted as partial fulfilment of NODA/NFP Project #4051, "Trade-off analysis in protecting caribou in multiple-use forestry in Northwestern Ontario".

The views, conclusions, and recommendations contained herein are those of the authors and should be construed neither as policy nor endorsement by Natural Resources Canada or the Ontario Ministry of Natural Resources.

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carbon in multiple-use forestry
in Northwestern Ontario"*

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An Economic Analysis of Protecting Woodland Caribou Habitat in Northwestern Ontario

NODA Technical Report

Prepared Under NODA/NFP Project # 4051

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Abstract

The Wildlife Policy Branch of the Ontario Ministry of Natural Resources has drafted a proposal for Timber Management Guidelines to enhance Woodland Caribou habitat in Northwestern Ontario. This report summarizes the findings of an economic analysis of these proposed Guidelines. An economic model of multiple-use forestry is constructed based on the Hartman rotation model. The model is used to estimate the present value of forest management on a representative hectare of boreal forest under scenarios representing the Moose Guidelines and the Woodland Caribou Guidelines. The forest values affected by the Woodland Caribou Guidelines are identified as fibre, Moose, and wilderness recreation. The difference in net present value for a representative hectare of boreal forest between the Moose and the Woodland Caribou scenario represents the shadow value of Woodland Caribou. The shadow value of Woodland Caribou is estimated at between \$503.64/ha and \$1456.38/ha. The shadow value is largely determined by the increase in fibre transportation costs under the Woodland Caribou Management Guidelines. Depending on how the Woodland Caribou Guidelines might be introduced over the land base, the present value of the per hectare shadow values would amount to over \$500 million. This estimate should be interpreted with caution given the level of uncertainty associated with important parameters and relationships used in the analysis. A spatial modelling approach that is capable of imposing adjoining constraints on the harvest pattern under the Guidelines is an important area for further research. Nevertheless, this study provides a benchmark set of results as an input into the policy development process.

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I Introduction

The southern limit of continuous forest dwelling Woodland Caribou distribution in Ontario has shifted northward over the past century (Darby et al, 1989). Cumming and Beange's (1993, Table 1) survey of OMNR biologists and conservation officers, conducted in 1990, indicated that about 800 Woodland Caribou were present in the 38 million ha of commercial forest in northwestern Ontario. An additional 400 animals were located in an area of potentially commercial forest in the Sioux Lookout district and 600 more were estimated to be located in parks in the region. This results in an overall estimate of forest dwelling Woodland Caribou in the region that is the focus of this study of about 1800 animals.¹ A number of factors have been identified as the cause of the northward shift, including predation, disease, fire, overhunting, and habitat loss (Darby et. al., 1989).

Harvesting operations in Northern Ontario typically use cutovers 100-250 ha in size. Regrowth in these cutovers varies widely among stands, but cutovers frequently regrow partially in hardwood species such as white birch (Betula papyrifera) and poplar (Populus spp.). Cleared areas which regrow in hardwood browse species tend to reduce the quality of Woodland Caribou habitat, but enhance Moose habitat, and increase Moose populations. Harvested areas have thus become more suitable for Moose than Woodland Caribou. The increase in the population of Moose in former Woodland Caribou areas has been accompanied by an increase in wolf numbers. This increase in the number of wolves in Woodland Caribou range has decreased the number of forest dwelling Woodland Caribou through predation.

A Synopsis of Caribou Ecology

Woodland caribou (*Rangifer tarandus caribou*) are an ungulate species native to every

¹ This estimate excludes Woodland Caribou located on the islands of Lake Superior.

province in Canada with the exception of Prince Edward Island. Caribou have disappeared from New Brunswick and Nova Scotia, but are currently present in varying numbers in the remaining provinces and territories (Bergerud, 1979, Cumming, 1992). In Ontario, woodland caribou are present in northwestern regions of the province, with some remnant caribou herds on coastal islands along the north shore of Lake Superior. Estimates put the Ontario population of woodland caribou at about 15,000 animals (Darby *et al.*, 1989), with most of these located in the Hudson's Bay Lowlands. Caribou numbers in the commercially harvested portion boreal forest have been estimated at about 1800 animals (Cumming, 1993).

Woodland caribou are one of two species of caribou found in Ontario. Adult woodland caribou bulls typically have a mass between 180-270 kg; adult cows have a mass between 90-140 kg. Woodland caribou have an average range of 250 km² (OMNR, Wildlife Policy Branch, 1991). Caribou are the only cervids in which both male and female grow antlers. Woodland caribou are somewhat larger than white-tailed deer (*Odocoileus virginianus*). They are not as large as either moose (*Alces alces*) or elk (*Cervus elaphis*) (Cumming, 1992).

Woodland caribou become increasingly gregarious in September and October with the onset of the rut. Rutting typically takes place in swamps, bogs, or fens which facilitate predator avoidance. Bulls maintain harems in these areas; one bull may breed multiple cows. Cows are typically 2 and 1/2 years of age before they breed. With the onset of winter, caribou travel to traditional wintering areas. These areas may be upwards of 50 km from the rutting areas. Wintering areas are characterized by the presence of mature jack pine (*Pinus banksiana*), black spruce (*Picea mariana*), and balsam fir (*Abies balsamifera*) at low stocking rates. These conditions favour the growth of lichens, upon which caribou are dependent as a major source of food. Terrestrial lichens of the *Cladonia* genus and

arboreal lichens of the *Usnea*, *Evernia*, and *Alectoria* genus are of major importance in the caribou diet (Cumming, 1992). Caribou are not as gregarious in the wintering areas as they are during the rut.

In late winter, caribou begin to leave the wintering areas for calving areas and summer habitat. The animals travel the ice of creeks and lakes, and other corridors of movement, and disperse upon reaching their summer range. Calving sites are typically small islands in lakes dominated by mature and over-mature conifer and abundant sources of lichens and aquatic foodstuffs. Isolated ridges are occasionally used as calving sites. Cows rarely have more than one calf in a given year, and may return to calve at the same location repeatedly over a number of years (Darby *et al.*, 1989). Cows remain sedentary on calving islands during spring and summer.

The major constraint on woodland caribou numbers appears to be predation. Wolves (*Canis lupus*) are the major predators of adult woodland caribou, although Cumming (1992) suggests that black bears (*Ursus americanus*) and lynx (*Lynx lynx*) are probably also caribou predators since they are predators of moose calves. Starvation due to insufficient or unreachable sources of food as a result of snow depth may also be a limiting factor in caribou populations. Another factor may be the meningeal worm parasite (*Paralephostrongylus tenuis*). The meningeal worm is harmlessly carried by white tailed deer, but infection of caribou by the brain worm may prove lethal (Cumming, 1992).

The southern limit of continuous woodland caribou distribution in Ontario has been experiencing a northward shift. A number of factors have been identified as the cause of this shift. Predation, disease, fire, overhunting, and habitat loss have probably each played a role in the northward movement of caribou (Darby *et al.*, 1989). Human activities, particularly commercial logging, may have had the largest effect on caribou.

Commercial logging has been undertaken in the boreal forests of Northern Ontario for about a century. With timer harvest, roads and communities sprang up which serviced the timber industry. This provided access to wilderness areas for hunters and trappers, and with little regulation until the 1920's, there was substantial overharvesting of caribou (Darby *et al.*, 1989). Hunting of caribou was restricted to natives in 1929.

Timber harvesting methods may also have been damaging to caribou. Timber harvesting operations in northern Ontario typically use cutovers 150 ha in size. Regrowth in these cutovers varies widely among stands, but frequently cutovers regrow partially in hardwood species such as white birch (*Betula papyrifera*) and poplar (*Populus spp.*). Cleared areas which regrow in hardwood browse species tend to provide excellent moose habitat. As a result, moose have absorbed former caribou habitat due to logging operations. The increase in moose in former caribou areas has been accompanied by an increase in wolf numbers. The increase in the number of wolves in caribou range has decreased caribou numbers through predation. The substitution of moose for caribou through logging has thus increased wolf predation of caribou.

Proposed Habitat Management Strategy for Woodland Caribou

The Caribou Task Team of the Ontario Ministry of Natural Resources (OMNR) has proposed Timber Management Guidelines to conserve forest dwelling Woodland Caribou. The OMNR has indicated that it hopes to achieve its objectives with respect to Woodland Caribou by the year 2010. These include the maintenance of forest dwelling Woodland Caribou populations at current levels, the maintenance of viable Woodland Caribou habitat in the boreal forest, tundra, and coastal islands, the provision of limited sport hunting and aboriginal harvest, and the provision of increased viewing

opportunities (OMNR, 1991). The planning strategy for Woodland Caribou conservation is to minimize the degree of improvement in Moose habitat and to create a forest structure resembling that which emerges from wildfire through timber management (OMNR, 1994). Woodland Caribou winter habitat is characterized by coniferous forest that supports a lichen understory. Woodland Caribou require large blocks of these areas for winter habitat. They also rely on large blocks of old, undisturbed forest as a defense against predators and man.

Table 1 indicates how the Timber Management Guidelines for Woodland Caribou are designed to approximate the characteristics of natural habitat.² Large areas of uniform age class conifer would be created using large clearcut harvests. This practice is intended to mimic the effect of fire and to allow for the development of lichen-supporting coniferous stands. Harvested areas would be regenerated into coniferous species, especially jack pine and black spruce. Harvest operations would bypass known winter habitat and calving areas. Currently used habitat would not be harvested until older age class habitat became suitable for use in adjacent or nearby areas. This would create a mosaic of large cut blocks suitable for Woodland Caribou habitat. In order to maintain the desired level of protection from predators and man, access into winter habitat blocks would be restricted. Figures 1 and 2 provide a comparison of the Timber Management Guidelines for the Provision of Moose Habitat and the Timber Management Guidelines for Woodland Caribou³. Figure 1 illustrates the harvest pattern under the Moose Guidelines. Moose Guidelines prescribe a progressive harvest pattern in which there is a small distance between cutover blocks. The cuts

² The degree to which the proposed Guidelines actually correspond to natural habitat characteristics continues to be debated (Biehn, 1995, Cumming (personal communication, 1996)).

³ Throughout this report, "Moose Guidelines" and "Woodland Caribou Guidelines" are used in place of "Timber Management Guidelines for the Provision of Moose Habitat" and "Timber Management Guidelines for Woodland Caribou", respectively.

Table 1 Correspondence Between the Attributes of Natural Woodland Caribou Habitat and the Provisions of the Timber Management Guidelines for Woodland Caribou

Natural Habitat Characteristic	Timber Management Guidelines for Woodland Caribou
Large blocks of winter habitat (Average 66 km ² , Cumming and Beange, 1987)	Protection of currently used habitat from harvest Develop habitat mosaic by bypassing currently used winter habitat and calving areas to harvest other areas
Large areas of lichen-supporting coniferous forest for winter habitat	Large clearcut harvest (100 km ²) Regeneration to coniferous species
Older age class conifer	Protection of existing habitat from harvest until adjacent stands become suitable as habitat
Isolation from predators and man	Restrictions on access to winter habitat areas

Figure 1 Schematic Representation of Moose Guidelines

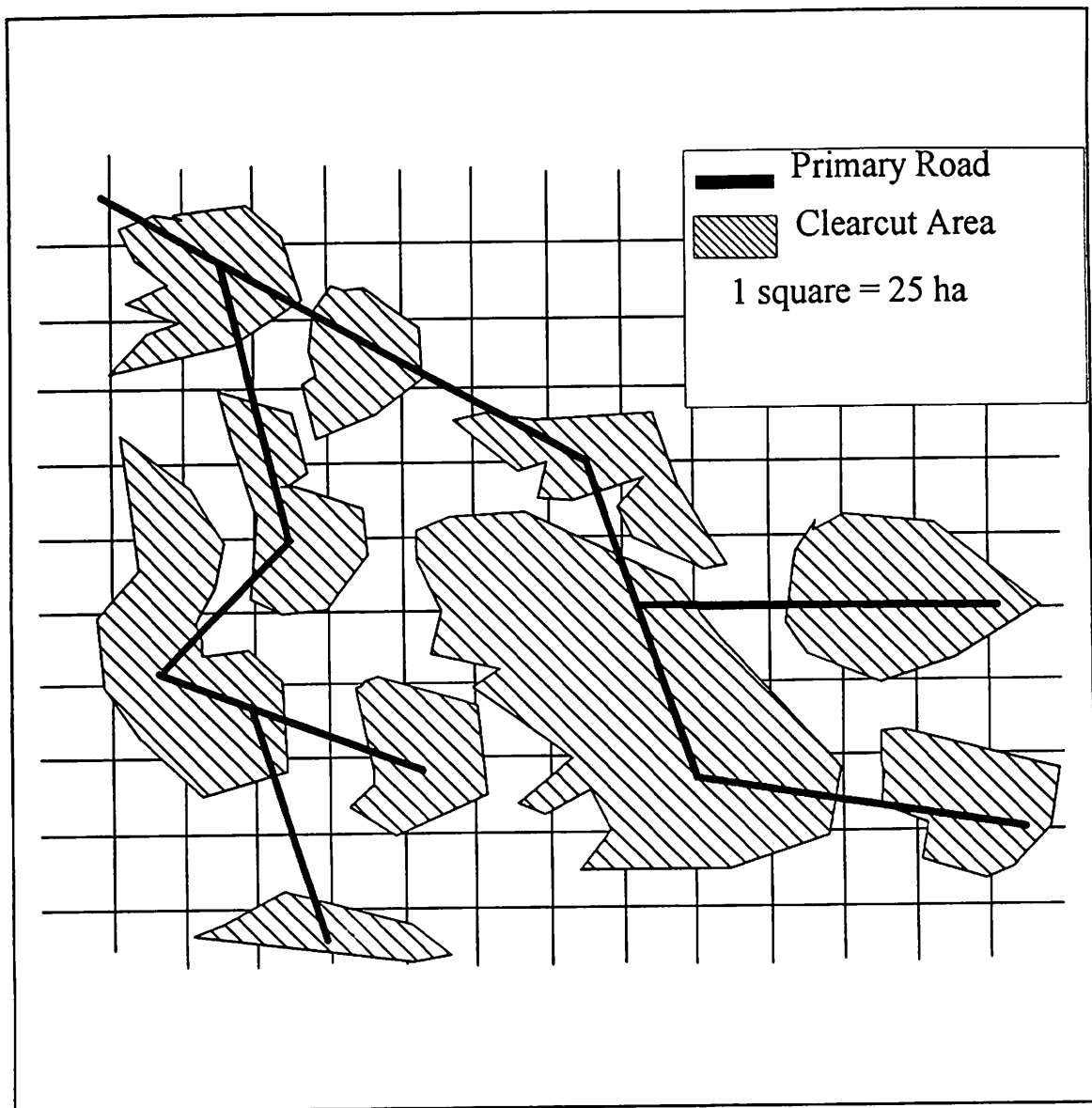
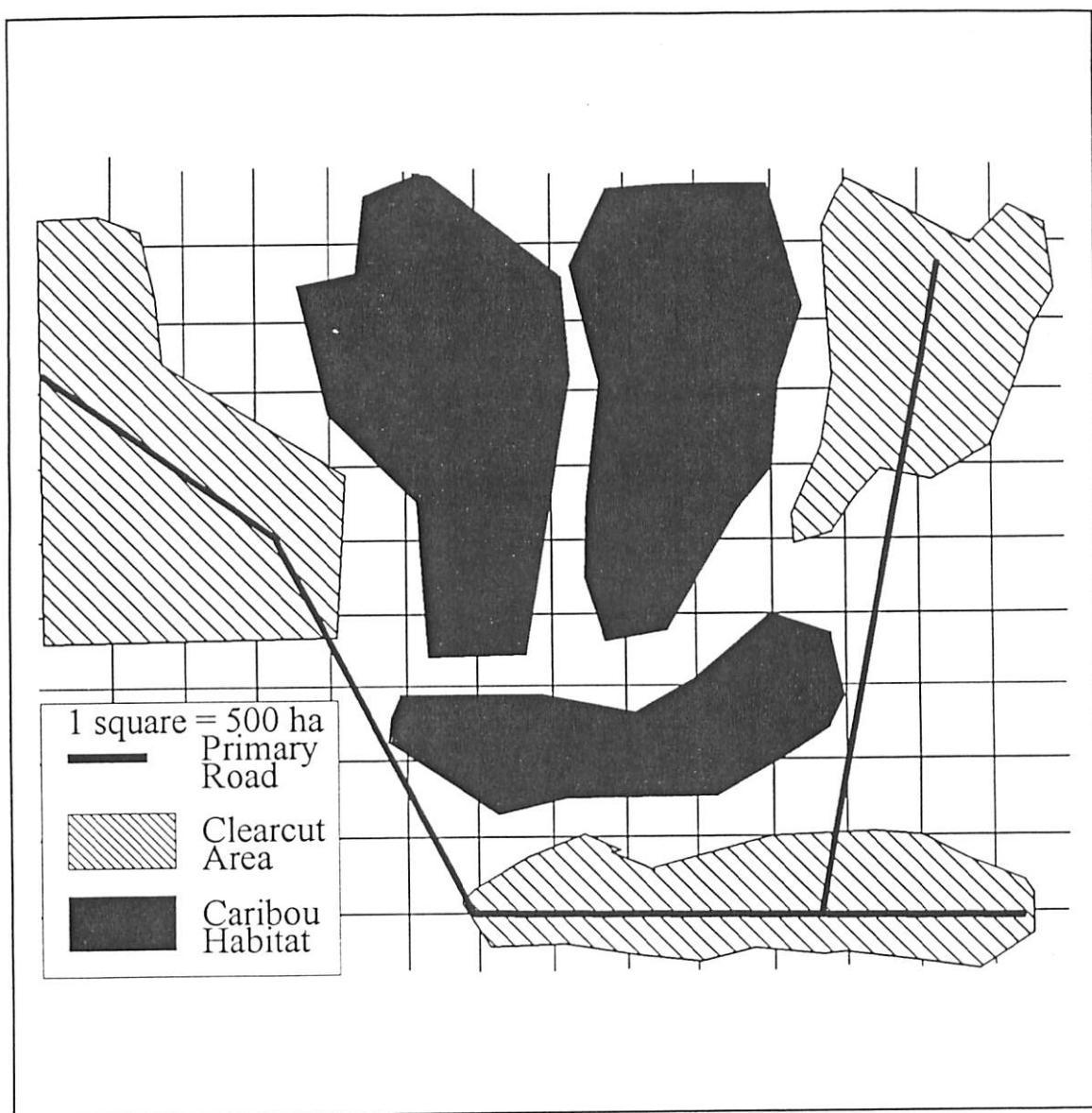


Figure 2 Schematic Representation of Woodland Caribou Guidelines



themselves are relatively small; they range between approximately 50 and 300 ha (OMNR, 1988). The cutovers are irregularly shaped to increase the amount of forest edge. The primary road network follows the harvest pattern.

Figure 2 illustrates harvesting patterns under the Woodland Caribou Guidelines. The size of individual cutovers is much greater than under Moose Guidelines. Figure 2 shows harvest blocks greater than 7000 ha in area. Under the Timber Management Guidelines for Woodland Caribou, individual cutovers could exceed 22,000 ha in area. The cuts lack the irregular shape characterized by the Moose Guidelines. The Timber Management Guidelines for Woodland Caribou prescribe cutovers that are distributed over a larger area than under the Moose Guidelines. The harvest pattern is structured to circumvent currently used Woodland Caribou winter habitat. This results in a larger primary road network than that under the Moose guidelines.

During the first phase of this project, stakeholder interviews were conducted as a means of enumerating the anticipated impacts of the Woodland Caribou Guidelines. These anticipated effects of the Timber Management Guidelines for Woodland Caribou are summarized in Table 2. The Woodland Caribou Guidelines are expected to create an increase in the size of the road network for timber harvesting. This is due to the requirement to bypass stands of merchantable timber that would be harvested under the Moose Guidelines. The impact of the Guidelines on roadbuilding and transportation costs depends on the spatial distribution and size of protected habitat areas. The larger road network is expected to result in greater per unit transportation costs for fibre harvested under Woodland Caribou Guidelines. The bypass of merchantable stands would likely result in an increased loss of timber to natural factors such as fire and windthrow. Bypassed stands may not be available to harvest by the time the availability of adjacent habitat would permit harvest under the guidelines.

Table 2 Anticipated Effects of the Provisions of the Woodland Caribou Guidelines

Provision of Timber Management Guidelines for Woodland Caribou	Anticipated Implications
Bypass of currently used Woodland Caribou habitat by timber harvesting operations; harvest directed to other areas	Increase in loss of standing timber to fire and windthrow Increase in size of primary road network; increase in fibre transportation costs
Increase in the size of individual clearcuts	Negative public perception Potential decrease in unit harvesting costs
Restriction of access	Reduction in human impact in habitat areas Increase in the quality of wilderness canoeing and camping
Decrease in forest edge, regeneration to conifer species	Decrease in the Moose population and Moose hunting opportunities

This would represent a loss of standing timber to the forest products industry and a potential loss of stumpage revenue to the Crown.⁴

The size of clearcut areas under the Timber Management Guidelines for Woodland Caribou would increase over that under the Moose Guidelines⁵. The increased scale of harvesting could be perceived negatively by the public. There is some speculation that there might be a cost saving advantages to larger scale harvesting. The cost advantages of harvesting under the Woodland Caribou Guidelines depend on any requirements to cut unmerchantable wood.

Logging in more northerly areas will tend to create more access to wilderness areas. Under the Woodland Caribou Guidelines, access to harvested areas would be more rigorously controlled than under the Moose Guidelines. The Woodland Caribou Guidelines would also maintain larger areas of undisturbed old growth boreal forest. This may provide benefits in terms of wilderness canoeing and camping.

II Methods

Problems associated with tradeoffs between fibre production and wildlife species management have been addressed by a number of authors. Hyde (1989) used a modified Faustmann model to study the tradeoffs between forest management and preservation of the Red-Cockaded Woodpecker in North Carolina, and to search for the least-cost management solution. His results showed that

⁴ Because of the stochastic and spatial nature of natural catastrophic factors, these effects are not considered here.

⁵ The total area harvested under the Woodland Caribou Guidelines is expected to be similar that under the Moose Guidelines. The size of individual cutovers would be larger under the Timber Management Guidelines for Woodland Caribou.

preservation of current habitat was a less costly means of ensuring the survival of the Red-Cockaded Woodpecker than management over an infinite series of rotations. This study is important in its use of a rotation model in cost-benefit analysis and its estimation of a least-cost means to species preservation.

Rubin *et al.* (1993) used cost-benefit analysis to compare the costs of Northern Spotted Owl preservation in the Pacific Northwest region of the United States with the benefits. Contingent Value surveys were used to measure the value of the Northern Spotted Owl. The results gave an estimated willingness to pay of \$34.84 U.S. per year within the Pacific Northwest region. This result was extrapolated to the entire United States under the assumption that willingness to pay decreases by 10% for every 1000 miles from the site, to give a national willingness to pay of almost \$1.5 billion U.S. per year. The study gives an indication of people's value for the Northern Spotted Owl, and illustrates the use of contingent value techniques to measuring net benefits.

Montgomery *et al.* (1994) also studied the Northern Spotted Owl and old-growth forest protection in the Pacific Northwestern United States. Their study used Marshallian surpluses as a measure of the costs and benefits of owl preservation, given different probabilities of species survival. The results showed that the loss in annual stumpage revenue per owl pair was approximately \$45,000,000 (U.S.), with the lowest proposed level of Northern Spotted Owl protection at 1600 pairs. The contribution by Montgomery *et al.* is important in its comparison of scenarios representing probabilities of species preservation and the use of Marshallian surplus as a measure of value.

A study by McKenney and Lindenmayer (1994) examined the conservation of Leadbeater's Possum in central Victoria, in southeastern Australia. The purpose of the study was to provide an economic analysis of a proposal to install nest boxes, and to suggest a least-cost means for the

conservation of Leadbeater's Possum. A scenario representing a ban on logging was compared with a scenario in which nest boxes were installed. The Faustmann model was used to compare the two scenarios. The results showed that the logging ban was the lower cost option for species protection. The McKenney and Lindenmayer study provides an example of the use of a rotation model to characterize the management problem and to estimate the net present value.

A study by van Kooten *et al.* (1995) investigated the effect of carbon taxes and subsidies on the optimal rotation age of British Columbia coastal forests and Alberta boreal forests. The purpose of the study was to examine the changes required in forest management to reduce the release of carbon dioxide into the atmosphere. The study used a generalized Hartman rotation model to select the optimal fibre and carbon sequestration age. In all scenarios in which carbon removal service had value, the optimal harvest age exceeded the fibre-only harvest age. The van Kooten *et al.* study is an important contribution in multiple-use management through its consideration of values other than fibre. The study demonstrates the use of the Hartman model as a means to determine an optimal rotation over priced and unpriced goods.

The Extended Hartman Model

An extension of the Hartman model is used to investigate the tradeoffs among fibre, Moose, and wilderness canoeing and camping⁶.

⁶ Other potential impacts of the Timber Management Guidelines for Woodland Caribou have been identified that lie beyond the scope of this study. The effect of an increased loss to natural factors and/or an increase in fire protection effort to protect winter habitat stands is a complex, spatially dependent issue. It is not investigated here. Any decrease in harvesting costs due to larger cutover areas is a source of uncertainty. The economies of size available with larger clearcut areas would depend on any requirements to cut unmerchantable material. An investigation of economies of size in harvesting are beyond the scope of this study. Negative public perception of large clearcuts has the potential to negatively impact harvesters through public protest or product boycotts. These potential results are strictly speculative, however, and the issue of negative public perception is not addressed in modelling.

The model used in this study is given in Equation 1.

$$\underset{[T]}{Max} \beta = P_{\pi} V(T_0) + \frac{[P_{\pi} V(T)]e^{-iT} - C + \sum_j \int_{t=0}^T a_j(t) e^{-it} dt}{(1 - e^{-iT})} \quad (1)$$

Where

β = Present value of the streams of values derived from a representative hectare of forest land, in \$/ha

P_{π} = Marginal value product of standing timber, net of harvesting and transportation costs, in \$/m³

$V(T_0)$ = Gross merchantable fibre volume initially present, in m³/ha

$V(T)$ = Merchantable timber volume at age T, in m³/ha

i = Real discount rate

T = Rotation age, in years

C = Regeneration costs, in \$/ha

$a_j(t)$ = Value of the j th forest amenity at age t , in \$/ha

The first term in Equation 1 gives the value of the volume of fibre harvested in the initial period. In the initial period, it is assumed that a 100 year old stand is present. It is cut and regenerated in the initial period yielding fibre benefit $P_{\pi} V(T_0)$ and regeneration cost C . Fibre values $P_{\pi} V(T)$ and amenity values $a_j(t)$ vary with stand age. Fibre values are a point benefit received when a stand is harvested at age T . Amenity values are conceived as a flow of benefits received from age 0 up to harvest age T , summed across the j amenities. Fibre and amenity values vary on an interval between stand age 0 and harvest age T . The discount factor converts benefits that do not occur until age $t \leq T$ back to the present. The numerator of Equation 1 thus expresses the net present value of a single rotation at age T . The denominator of the criterion function converts the net present value of a single rotation at age T into the net present value of the sum of an infinite number of rotations at age T . The value of forestland, β , is equal to the sum of the net present value of an infinite number of rotations at age T .

Context of the Model

The model described by Equation 1 is based on a representative hectare of boreal forest. Harvesting and regeneration decisions are undertaken at the level of the whole hectare. The representative hectare is located in a spatially representative position within a sustainable land base. The sustainable land base is defined here as the area required to harvest a fibre volume equal to the mean annual increment each year. The distance from the representative hectare to processing facilities is the average of that for the sustainable land base. Equation 1 is used as a tool to calculate the net present value of forest management given a rotation age for a representative hectare. Rotation ages are substituted into the criterion function that correspond to different forest management strategies.

Equation 1 is used to compare the net present value under the Moose Guidelines with the corresponding net present value under Woodland Caribou Guidelines. Under the Moose Guidelines, timber is cut at the maximal sustained yield age T , yielding fibre benefits and a flow of Moose and wilderness canoeing and camping benefits. Under the Woodland Caribou Guidelines, timber is cut at an age that exceeds the maximal sustained yield age under the Moose Guidelines, yielding fibre benefits along with a flow of wilderness canoeing and camping benefits. Under the Woodland Caribou Guidelines, Moose habitat is less favourable, and Moose values are assumed to fall to zero.⁷ Wilderness camping and canoeing benefits increase relative to the Moose Guidelines because of

⁷ We acknowledge that this assumption does not accurately reflect the findings reported in the literature on the suitability of cutover areas as moose habitat. For example Welsh *et al.* (1980) found that large clear cut areas of forest land, prior to 1980 when larger clear cuts were used, did support moose. It turns out, however, that the assumptions about the effect of the Woodland Caribou Guidelines on Moose habitat and subsequently on Moose values have negligible effects on the results obtained with the extended Hartman model used in this study. These results are dominated by the effects of the Guidelines on wood transportation costs. This is true even for a set assumption that in all likelihood overstates the adverse effects of the Woodland Caribou Guidelines on Moose values.

greater areas of old growth forest.

The Moose Guidelines employ a progressive type of harvest pattern. It is assumed for simplicity that there are no lakes, swamps, or unharvestable areas. This representation of the Moose Guidelines is illustrated in Figure 3. Small cutovers are spread throughout a management area. Over time, the harvest and accompanying road network move progressively further into the forest.

The way in which the Woodland Caribou Guidelines are modelled is illustrated in Figure 4. The cutovers used under the Woodland Caribou Guidelines are larger and lack the irregular shape of cutovers under Moose Guidelines. Individual cutovers are more dispersed under the Woodland Caribou Guidelines than under the Moose Guidelines. The annual area cutover in Figure 4 is equal to that in Figure 3. The Timber Management Guidelines for Woodland Caribou prohibit adjacent cutovers until harvested areas can provide winter habitat for Woodland Caribou. This creates a dispersion in the harvest pattern. In Figure 4, cutovers are illustrated as being at least 10 km apart.

Figures 5 and 6 illustrate the differences between the Moose Guidelines and the Woodland Caribou Guidelines at a more extended spatial scale. Figure 5 illustrates a hypothetical forest area managed under the Moose Guidelines. Under the Moose Guidelines, the rotation age is the sustained yield rotation age. The growth function used in this analysis gives a maximal sustained yield rotation age of 93 years⁸. The management areas in each 10 year period are illustrated as being somewhat larger than 100 km². The cutovers are small and irregularly shaped. Over time, the harvest and its corresponding road network move progressively further from the mill. After harvest in year 93, the block originally harvested in the first 10 year period is reharvested.

Figure 6 illustrates the spatial distribution of harvest under the Woodland Caribou Guidelines.

⁸ See Appendix A.

Figure 3 Characteristics of Harvest Under Moose Guidelines

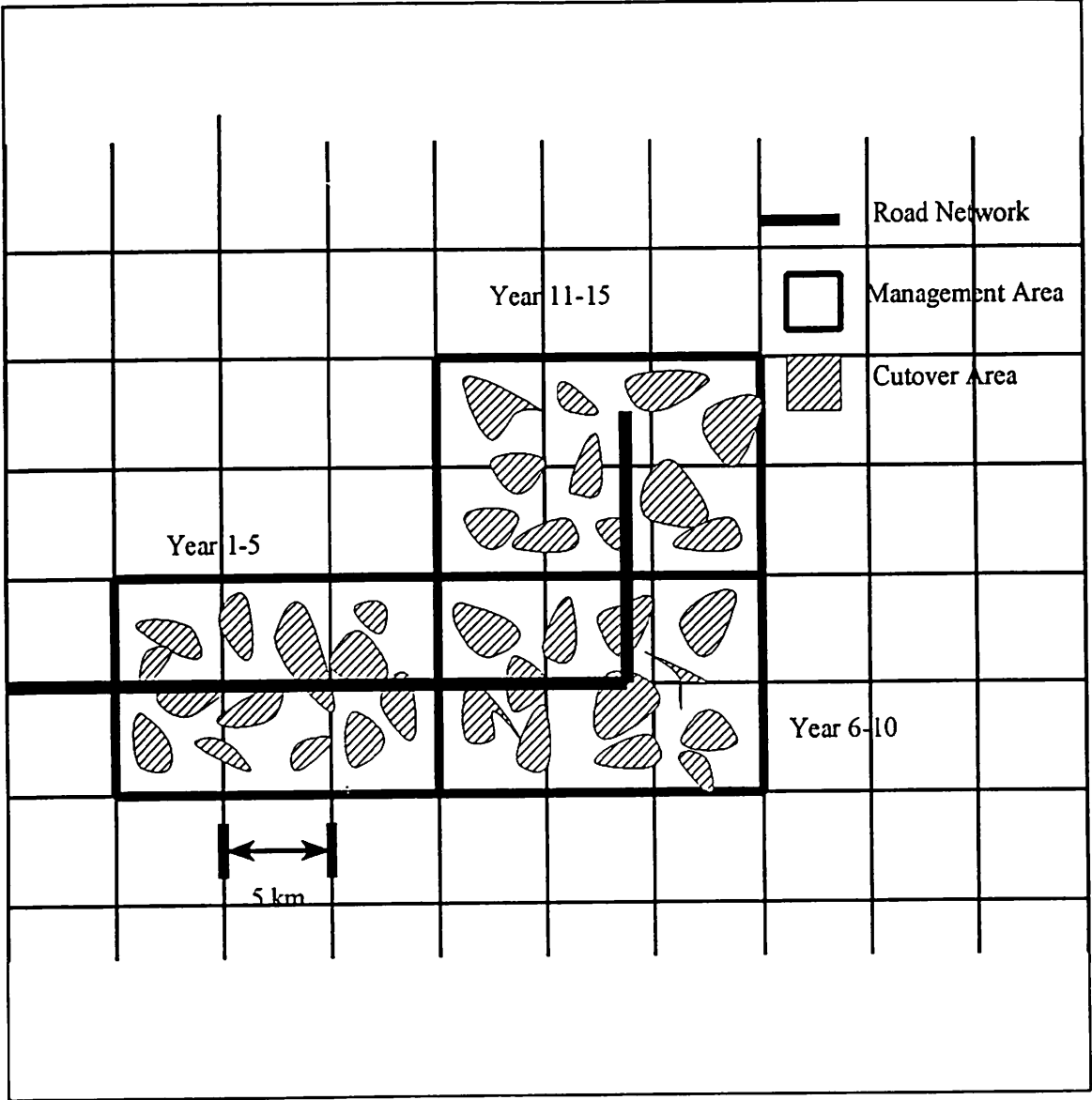


Figure 4 Characteristics of Harvest Under Woodland Caribou Guidelines

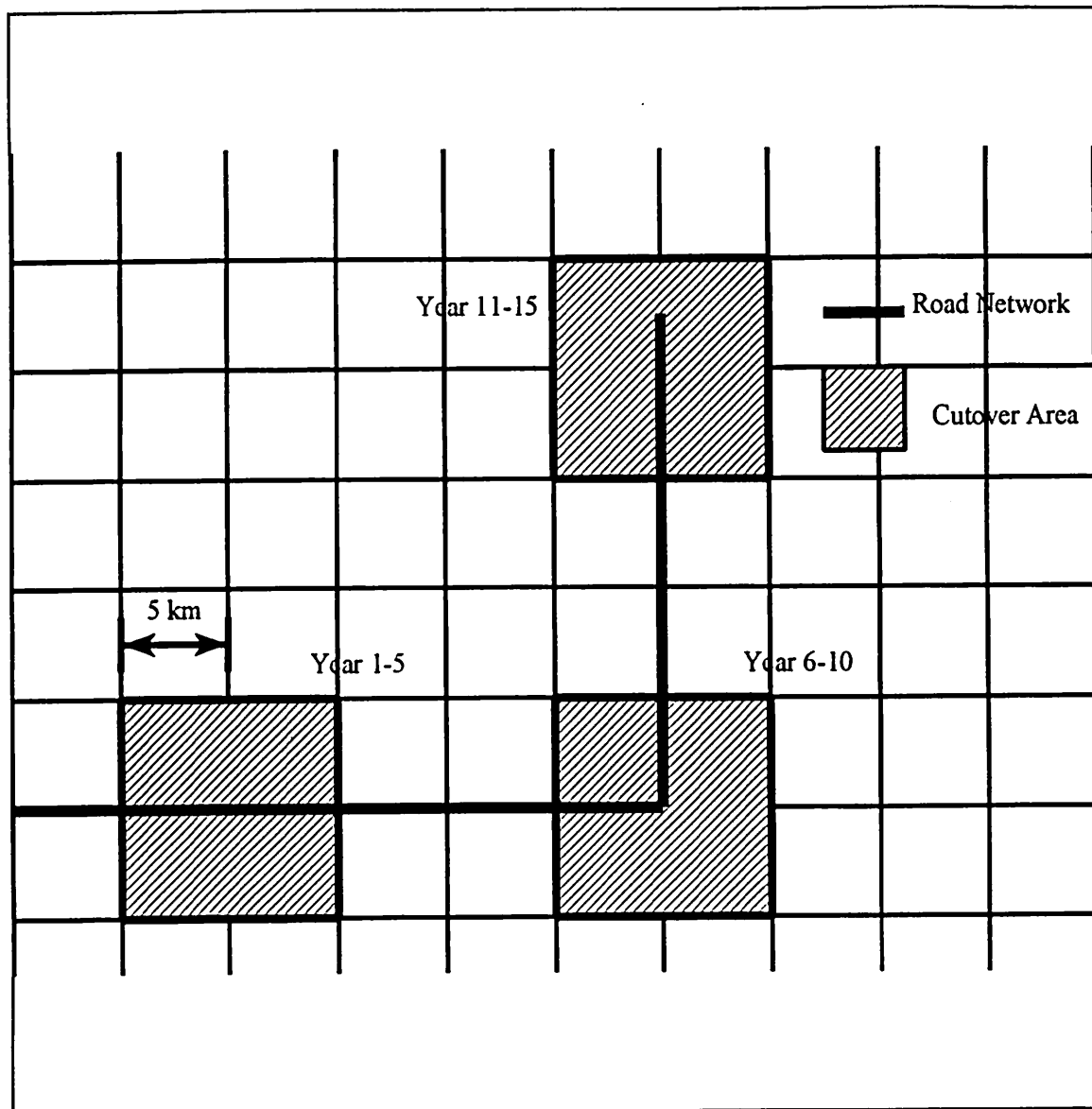


Figure 5 Spatial Distribution of Harvest Under Moose Guidelines

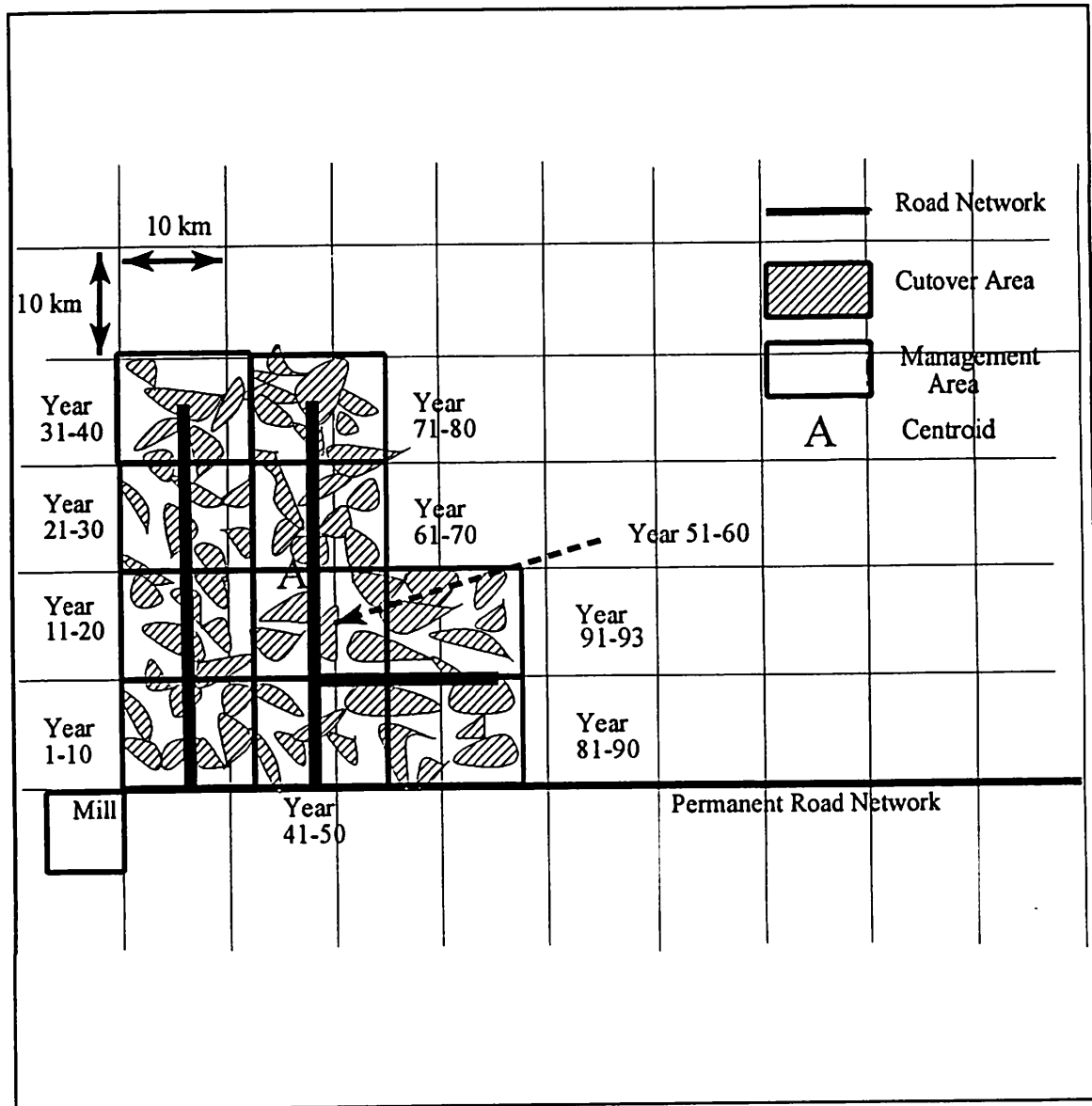
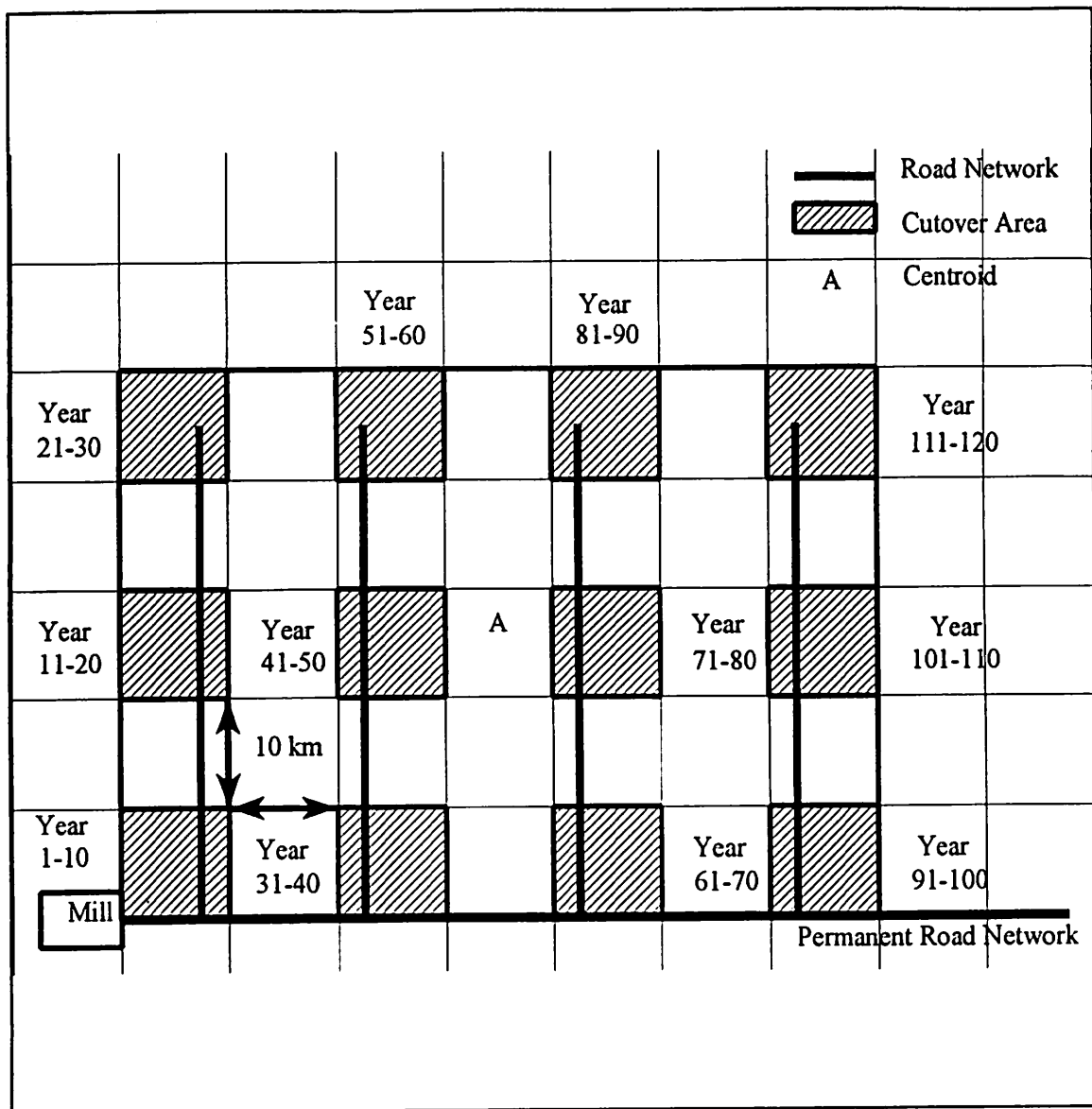


Figure 6 Spatial Distribution of Harvest Under the Woodland Caribou Guidelines



It is assumed that at least a 100 km² (10 km x 10 km) block of forest suitable as Woodland Caribou winter habitat is left unharvested around all cutover blocks. The rotation age under Woodland Caribou Guidelines is assumed to be 120 years. Each column of harvest blocks has its own road network. This results from a requirement to abandon roads as previously cutover areas become useable as winter habitat. Thus, after harvest in year 30, the road network running down the first column of harvests (year 1-30) is abandoned. In year 40, a new road network is laid out to access the second column of harvests.

The average transportation distances under Moose and Woodland Caribou Guidelines correspond to the centroid of the area required for a sustainable harvest. This centroid is labelled as point A in Figures 5 and 6. The distance from the centroid to the mill is the average transportation cost over the rotation. In the hypothetical Moose scenario in Figure 5, the average distance to the mill is about 35 km. In Figure 6, the average distance to the mill over the rotation period is 60 km. Thus, the average distance from the mill is greater under the Woodland Caribou Guidelines than the under the Moose Guidelines. The differences between the Moose and Woodland Caribou scenarios are summarized in Table 3.

The relative difference in the distance to the mill under Moose and Woodland Caribou Guidelines is determined largely by the required separation between harvest blocks. The 10 km separation between cuts in Figure 6 is derived from a prohibition on adjacent harvests until previously cut blocks can provide winter habitat. If a greater dispersion of cuts were required, the average distance to the mill would increase. Under the Woodland Caribou Guidelines, the average transportation cost is taken as the vertical distance from the centroid to the permanent road network plus the horizontal distance from the centroid to the mill along the permanent road network. The

Table 3 Operational Characteristics Under Moose and Woodland Caribou Guidelines

Operational Characteristics	Scenario	
	Moose Guidelines	Woodland Caribou Guidelines
Harvest Pattern	Progressive	Dispersed
Cutover Size (ha)	120-250	> 10,000
Wildlife Management Goal	Enhance Moose habitat	Renew Woodland habitat/discourage proliferation of Moose
Rotation Age (years)	93	120

distance to the mill cannot be approximated "as the crow flies" because of the requirement to abandon roads from cutover areas after they have been accessed. Using the harvest pattern illustrated in Figure 6 with a rotation age of 120 years, the average distance to the mill is 3.5 "blocks" along the permanent road network, and 2.5 blocks from the centroid to the permanent road network, for a distance covering 6 blocks, or 60 km. This harvesting pattern gives an average distance to the mill from the centroid under the Woodland Caribou Guidelines of:

$$D = 6\delta \quad (2)$$

Where: D = Distance to the mill, in km
 δ = Separation between cutovers, in km

Under the Moose Guidelines, the distance from the centroid to the mill is approximately two 100 km² blocks down to the permanent road network, and 1.5 blocks horizontally along the permanent road network to the mill. This gives an average distance of 35 km.

Because of the spatial nature of the model in Equation 1, transportation costs are measured strictly on a per cubic metre basis, rather than in terms of the haul distance. This requires an assumption with respect to the distance from the stand to the mill. The study of residual values undertaken by the OMNR (OMNR, Forest Values Project, 1993) calculated transportation costs as a function of highway and off-highway distance to the mill. The formula for transportation cost developed in the OMNR study is given in Equation 3.

$$C_T = (D_H + D_{OH} * 1.5) * \sigma * \frac{CPI_{92}}{CPI_{88}} \quad (3)$$

Where: C_T = Transportation cost, in $\$/m^3$
 D_H = Highway distance, in km
 D_{OH} = Off-highway distance, in km
 σ = Base transport cost (1988)
 CPI_{92} = Consumers' Price Index, all goods, 1992 (1981=100)
 CPI_{88} = Consumers' Price Index, all goods, 1988

Because the off-highway transportation cost data were not available, in the OMNR study off-highway transportation costs were assumed to be 50% greater than the highway transportation costs. In the study area, it is assumed that the average highway distance from the stand to the mill under both Moose and Woodland Caribou Guidelines is 120 km. In the illustration of average transportation costs under Moose Guidelines above, the average off-highway distance is 35 km. Equation 4 uses the parameters estimated in the OMNR study to calculate the average transportation cost under the Moose Guidelines.

$$C_T = (120 + 35 * 1.5) * .0945 * \frac{169.558}{143.825} \quad (4)$$

Based on Equation 4, the average transportation cost under Moose Guidelines is calculated as $\$19.24/m^3$. Under the Woodland Caribou guidelines, the average off-highway distance from cutover areas was estimated to be 60 km using a 10 km spread between harvests. Substituting an off-highway distance of 60 km for the 35 km distance under the Moose scenario and maintaining a 120 km on-highway distance into Equation 4 gives an average transportation cost of $\$23.42/m^3$. The difference in transportation costs between the two scenarios is rounded off to $\$4.20/m^3$. Thus, under Woodland Caribou Guidelines, the price of standing timber net of harvest and transportation costs, P_π , decreases by $\$4.20/m^3$.

Fibre Values

The growth function $V(T)$ gives merchantable timber volume as a function of stand age. The growth function is taken as a weighted average of growth in black spruce, jack pine, aspen, and white birch based on the composition of the Lac Seul Forest in the study region. The form of the growth function and its summary statistics are given in the Appendix. The values used in the growth function are based on Plonski (1981). Regeneration costs, C , consist of mechanical site preparation and planting. In Ontario, both natural and artificial means of regeneration are used. Approximately 50% of logged areas are planted or seeded (Koven *et al.*, 1994). The costs of natural and artificial regeneration vary greatly. In this study, it is assumed that regeneration costs are \$100/ha. The model implicitly assumes there are no tending or silvicultural costs as the stand grows. No costs of fire protection are assessed to the management of the representative hectare of forest.

Estimation of Fibre Values

Timber is cut from Crown land by private harvesters for an administratively set stumpage fee and is sold or used as an input in the production of wood products. One approach to valuing timber equates the stumpage fee with timber value. Since this price is set administratively by the OMNR, it does not reflect the interaction of supply and demand. It is not an equilibrium price. The alternative means to value timber is to derive the residual value of standing timber in the production of finished products FOB the mill net of harvesting and transportation costs. That is;

$$P_{\pi} = P_F \frac{\partial Q_F}{\partial Q_W} - C_T - C_H \quad (5)$$

Where:

- P_{π} = Value of the marginal product of standing timber, in $\$/m^3$
- P_F = Price of finished products net of processing costs FOB the mill, in $\$/m^3$
- Q_F = Quantity of finished products, in m^3
- Q_w = Quantity of standing timber harvested, in m^3
- C_T = Cost of transporting timber to the mill, in $\$/m^3$
- C_H = Cost of harvesting timber, in $\$/m^3$

According to Equation 5, the residual value of standing timber is equal to the productivity of timber in terms of finished products times the price of finished products net of processing costs FOB the mill less the costs of transportation and harvesting.

Problems arise in executing this calculation, however. Due to variations in processing plant technology, and in harvesting and transportation costs, the nature of costs is extremely variable. Other difficulties arise because timber delivered to the mill may be used to produce multiple products. For example, the chips resulting from the production of lumber may be used in the production of pulp. The relative allocation of timber to different wood products varies by processing facility. These complications make it impossible to use this technique directly in this study.

A study conducted by the OMNR Forest Values Project (1993) estimated residual values for a variety of fibre products in Ontario. The residual value was defined as the price of finished products FOB the mill less all manufacturing, transportation, harvesting costs and allowance for profit and risk. The study found great variation in residual values across regions and fibre products. Veneer and plywood were found to have the greatest residual value. Lumber had the lowest residual value. For 1990, veneer and plywood were found to have an average residual value of $\$514.86/m^3$; the average residual value of lumber was estimated as $-\$39/m^3$. The authors of the study cautioned that the residual values calculated were intended to illustrate relative values by finished product type. The use of the absolute results were regarded to have little meaning out of context. Thus, the results of the

study are not directly useable here.

Other studies have estimated the value of standing timber. Quirin and Waters (1989) estimated the residual value of standing timber in Ontario at between \$6.93/m³ and \$7.45/m³ for the period 1985-1986, or \$8.87/m³-\$9.53/m³ in 1992 terms. The residual value is the value of timber in excess of all costs. It is thus equivalent to the value of the marginal product of timber net of costs. van Kooten *et al.* (1995) used standing timber values of between \$15/m³ and \$50/m³ in their study of the optimal forest rotation for carbon benefits. The study was partially undertaken in the boreal forest of northern Alberta, which is a region similar to the study area in terms of growth, tree species, and distance to markets for wood products. A fibre value of \$15/m³ was considered the most likely value for standing timber. Since a direct estimation of the value of standing timber is beyond the scope of this study, a value of \$15/m³ is used here.

Amenity Values

The non-fibre portion of the Equation 1 is presented in Equation 6.

$$\frac{\sum_j \int_{t=0}^T a_j(t) e^{-it} dt}{(1 - e^{-iT})} \quad (6)$$

Equation 6 is a cumulative function in that amenity benefits are enjoyed on an annual basis from the period of establishment of a stand to harvest. The amenity values relevant to Equation 6 are Woodland Caribou, Moose, and wilderness.

Woodland Caribou

Economic research related to Woodland Caribou in Canada (for example Tanguay *et al.*, 1993), has not yet produced estimates of individuals' value of Woodland Caribou. Estimating the value of Woodland Caribou directly using techniques such as contingent valuation, hedonic pricing, or travel-cost methods was considered to be inappropriate. Woodland caribou are not a game species, so travel cost or license-fee based approaches are inapplicable. Familiarity with the Woodland Caribou by and with the proposed Guidelines by the general public would make estimates derived from contingent evaluation or conjoint analysis of limited relevance. Another means is thus required to take account of Woodland Caribou values. Shadow pricing (Mishan, 1988) was identified as an option to estimate Woodland Caribou value. Shadow pricing attempts to quantify the net costs associated with the implementation of a project or policy. If that policy or project is socially beneficial, the unestimated and often intangible benefits must be judged to be larger than this net cost.

The shadow value of Woodland Caribou is estimated by comparing the net present value per hectare under the Woodland Caribou Guidelines to the Moose Guidelines. The Moose Guidelines are expected to give a greater net present value than the Woodland Caribou Guidelines, because no value is imputed to Woodland Caribou. The difference in present value between the Moose scenario and the Woodland Caribou scenario is an estimate of the minimum value that must be attached to Woodland Caribou for the Woodland Caribou Guidelines to have a net present value equal to the Moose Guidelines. This is the essence of the shadow value approach.

Moose

Moose values, as defined in this study, refer to value associated with Moose hunting. According to Allen *et al.* (1987), Moose density in the region north of Lake Superior is about 2 Moose/km² or .02 Moose/ha on a year-round basis. Allen *et al.* describe this Moose density as "both conservative and practical", and, as such, it is used as the maximum moose density in the study region.

The Hartman model relates Moose value to stand age. The area north of Lake Superior described by Allen *et al.* is characterized by large scale commercial logging. For the purposes of this study, the average rotation age in the area north of Lake Superior is 93 years, the maximal sustained yield age calculated for the study area. The Moose density and average rotation age serve as the basis to generate an expression for Moose density in this study.

The functional form of the Moose density-stand age relationship is unknown. A linear function with a zero intercept is assumed⁹. The Moose density is conceived as increasing in stand age up to a peak of 0.2 Moose/ha at 93 years. Beyond age 93, Moose density is assumed constant.¹⁰ Equation 7 gives the form of the Moose density function.

$$M(t) = \min (.0002t, .02) \quad (7)$$

⁹ Although this aspect of model structure is potentially controversial, it has relatively little impact on the results of this study.

¹⁰ Data presented by Welsh *et al.* (1980, Table 4) indicate a time profile of moose density against stand age that resembles an inverted V, reaching a peak at about 20 years, more closely than the von Liebig function that we have assumed. Our model, as we indicated above, likely over-states the significance of the losses of moose values under the Woodland Caribou Guidelines. Our assumptions are conservative in the following sense: if losses in moose values are dominated by other values when moose values are likely over-stated, then the impacts of a more biologically realistic time profile would be to make lost moose values even less influential in the results that we report below. Given that losses of moose values were mentioned frequently in some stakeholder interviews in the first phase of this project, we elected to adapt the modelling strategy described in the text of this report.

Where: $M(t)$ = Moose density, in Moose/ha

Equation 7 corresponds to a von Leibig, or linear response plateau functional form shown in Figure 7. The upper curve in Figure 7 gives the density of Moose as a function of stand age. The lower curve is the density of Moose eligible for harvest. The harvest quota is set at approximately 12% of the total estimated winter population (G. Umali, pers. comm.). The relevant Moose population for hunting value is thus the quota level, or 12% of the total population.

The estimate of Moose value in this study is derived from the results of an OMNR Moose values study in Northwestern Ontario (OMNR Forest Values Project, 1995). The area studied by the OMNR was Wildlife Management Unit 21A located east of Lake Nipigon. It is a boreal forest region in which substantial timber operations under Moose Guidelines have been undertaken, and a popular Moose hunting area. The purpose of the OMNR study was to determine hunters' consumer surplus. The study used the travel-cost method to estimate aggregate annual consumers' surplus for Moose hunting in the Wildlife Management Unit. The results from the study were converted to value per harvestable moose according to the data presented in Table 4. These values were incorporated with Equation 7 to give a Moose value function.

$$\alpha_M(t) = 96.09 \cdot 0.12 \cdot \min (.00022t, .02) \quad (8)$$

Where: $\alpha_M(t)$ = Moose value, \$/ha

Figure 7 Moose Density as a Function of Stand Age

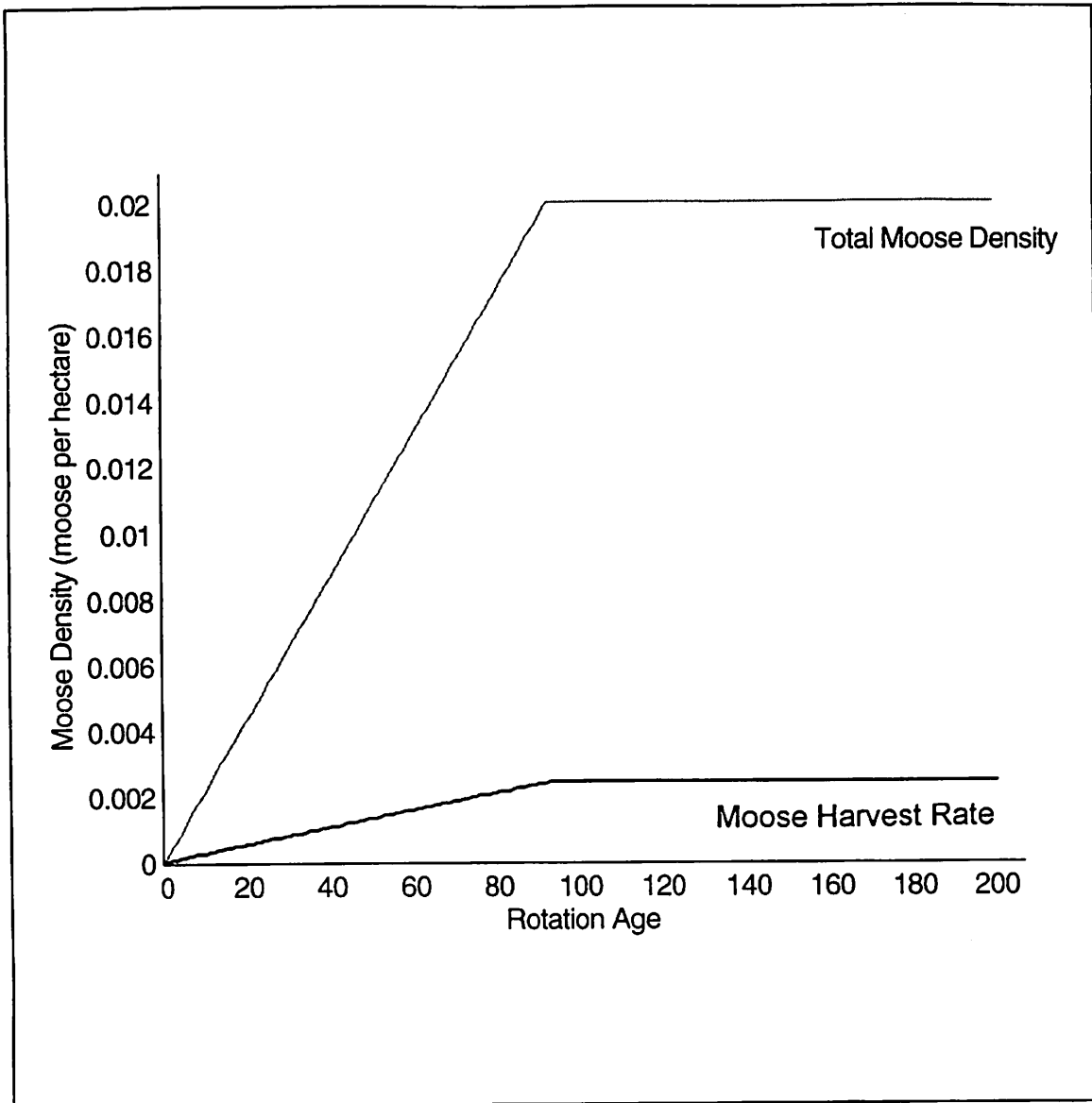


Table 4 Data Used in Computing Moose Value

Aggregate consumers' surplus (\$/year)	106,179
Moose harvest quota (number of moose)	1105*
Consumers' surplus/moose (\$/moose/year)	96.09

***Source: Moose Hunter's Fact Sheet-1993 (OMNR, 1993)**

Wilderness Canoeing and Camping

The value of wilderness canoeing and camping is taken as a proxy for wilderness value in this study. The value of summer remote recreation is thus measured as a lower bound for all wilderness values. For the purposes of this study, summer recreation value in the study area is assumed to vary with stand age.

In this study, wilderness canoeing and camping value is conceived as increasing in stand age up to age 120 at which point a stand is recognized as "old growth". Beyond this age, remote recreation value does not vary as a function of stand age. This corresponds to a linear response plateau functional form similar to that described in the Moose density function. The recreation value at stand age zero is assumed to be zero.

The value of summer remote recreation is based on Wistowsky (1995). Wistowsky's study investigated the willingness to pay for canoeing and camping in provincial wilderness parks, including Quetico Park in Northwestern Ontario, using a contingent value approach. Two estimates of willingness to pay were observed. An estimate of \$65.82/person/day was made based on respondents' willingness to incur additional travel and equipment costs to visit Quetico Park. A second value of \$28.63/person/day was estimated based on respondents willingness to pay for an increase in user fees in Quetico Park. A willingness to pay of \$28.63/person/day converts to \$8/ha/year¹¹. A willingness to pay of \$65.82/person/day gives a value of \$18.42/ha/year.

¹¹ Using Wistowsky (1995) data, there were 130,261 person-days spent by visitors to Quetico Park. Multiplying the number of person-days by the value/person/day gives the annual value of Quetico Park to users. The area of Quetico Park is 465,500 ha. The annual value divided by the area of Quetico Park gives the value/ha/year.

The values estimated by Wistowsky in Quetico Park are used as a proxy¹² for those in Wabakimi Park, a wilderness park located within the study region, to develop wilderness canoeing and camping value function. The Wistowsky values are assumed to be associated with a stand of age 120 years. Thus a conservative approach would be to associate a wilderness canoeing and camping value function of \$18.42/ha/year as in Equation 9.

$$\alpha_w(t) = \min \left(\frac{18.42}{120}t, 18.42 \right) \quad (9)$$

Where: $\alpha_w(t)$ = Remote recreation value, in \$/ha/year

Figure 8 illustrates the form of the remote recreation value function evaluated for a value of \$8.00/ha/year and \$18.42/ha/year.

Application of Model

The parameter values associated with the Moose and the Woodland Caribou scenarios are presented in Table 5. Under the Moose Guidelines, harvest occurs at 93 years. Under the Moose scenario, the value of fibre net of harvesting and transportation costs is \$15/m³. Moose values are \$.2306/ha/year, and remote recreation values are \$18.42/ha/year. The Woodland Caribou scenario is assumed to have a rotation age of 120 years. It is assumed here that the Woodland Caribou

¹² Wabakimi is a new remote wilderness park that is not nearly as well known nor as intensively used as Quetico. Because of the limited public use of or even familiarity with Wabakimi, a survey based method of estimating recreation values would not be appropriate. This study characterizes the potential impacts of the Woodland Caribou Guidelines for an extended period of time. By using the recreation values estimated for Quetico park, we are implicitly assuming that the growth in demand for wilderness recreation anticipated by Wistowsky will be realized during the time period considered in this analysis. Like our treatment of moose values, this assumption likely over-states the significance of wilderness recreation values in the results reported below, and even with assumptions that are conservative in this sense, wilderness recreation values are dominated by the effects of transportation costs.

Guidelines would substantially reduce the Moose population. Under the Woodland Caribou Guidelines, it is assumed that the Moose population would be reduced to the point that Moose hunting value would be zero. The Woodland Caribou Guidelines would introduce a more dispersed harvest pattern than the Moose Guidelines. Consequently, transportation costs would increase. Transportation costs increase by an estimated \$4.20/m³ relative to the Moose Guidelines. The larger areas of old growth forest under the Woodland Caribou Guidelines are assumed to provide more value to wilderness canoeists and campers than that available under the Moose Guidelines. We have assumed that wilderness canoeing and camping value would increase by 10% under the Woodland Caribou Guidelines.

The rotation age and parameter changes under the Woodland Caribou Guidelines are substituted into Equation 1. The extended Hartman model in Equation 1 is used to calculate the net present value of fibre and amenity values under the Woodland Caribou Guidelines. The net present value is compared with the present value under the Moose Guidelines to give the shadow value of the Timber Management Guidelines for Woodland Caribou.

Sensitivity analysis is used to test the effect of alternate parameter values on the results. The parameter values tested in sensitivity analysis are presented in Table 6. The discount rate is initially 5%. It is varied by 3 percentage points upward and downward. Lower discount rates are expected to give higher net present values; higher rates of discount tend to give lower net present values. Increasing the transportation cost differential has the effect of reducing the net value of fibre under the Woodland Caribou scenario relative to the Moose scenario. The increase in transportation costs under the Woodland Caribou Guidelines is initially \$4.20. This corresponds to a 10 km distance between cutover areas.

Figure 8 Remote Recreation Value as a Function of Stand Age

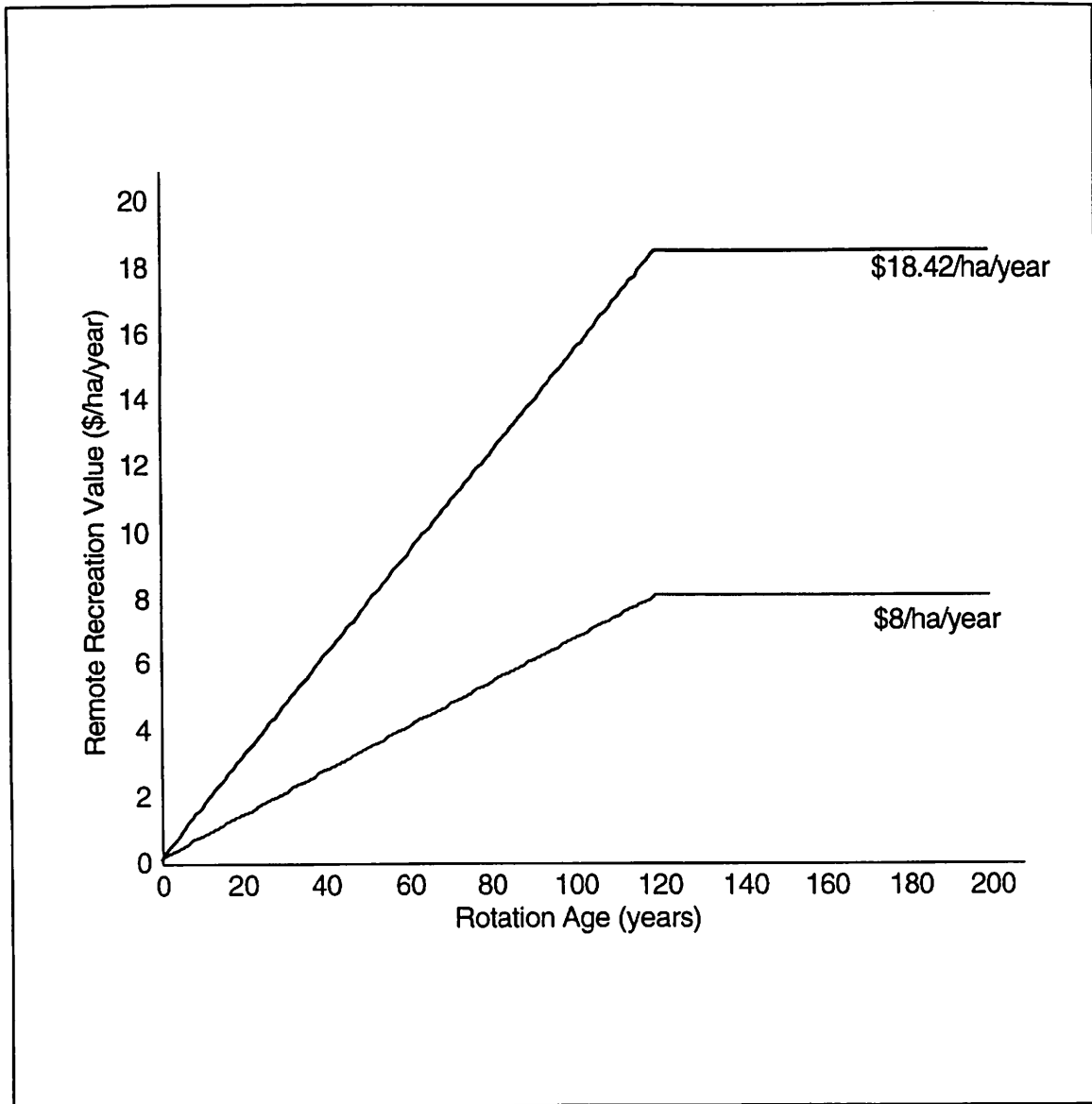


Table 5 Base Scenarios Compared Using Theoretical Model

Scenario	Modelling Parameters	
<u>Moose Guidelines</u>	Rotation Age (years)	93
	Residual Fibre Value (\$/m ³)	15*
	Moose Value (\$/ha/year)	.2306**
	Wilderness Canoeing and Camping Value (\$/ha/year)	18.42
<u>Woodland Caribou Guidelines</u>	Rotation Age (years)	120
	Residual Fibre Value (\$/m ³)	10.80*
	Moose Value (\$/ha/year)	0
	Wilderness Canoeing and Camping Value (\$/ha/year)	20.26

* The residual value of fibre is the VMP of timber delivered to the mill net of harvesting and transportation costs. The residual value of fibre under the Moose Guidelines exceeds that of the Woodland Caribou Guidelines because of the greater transportation costs under the Woodland Caribou Guidelines.

** Equation 7 evaluated at a rotation age of 93 years.

Table 6 Parameter Values Used in Calculating Base Results

Parameter	Initial Value	Range Tested in Sensitivity Analysis
Discount rate, I	5%	2%, 8%
Transportation cost differential between Woodland Caribou and Moose Guidelines, \$/m ³	4.20	3.15, 9.20
Regeneration cost, C, \$/ha	100.00	200.00, 0
Moose Value, \$/ha/year	.23	.48, .12*
Wilderness Canoeing and Camping Value, \$/ha/year	18.42	40.00, 8.00

* Moose values of \$200/harvested Moose/year and \$50/harvested Moose/year, respectively.

Using Equation 3, a 15 km distance between cuts under the Woodland Caribou Guidelines would increase the transportation cost differential to \$9.20/m³. The larger cutovers under the Woodland Caribou Guidelines could allow some economies of size in assembly cost within the cutover. If a saving of 25% in transportation costs from the initial value were available through reduced assembly costs within the cutover, the transportation cost differential would fall to \$3.15/m³. Regeneration costs are initially set at \$100/ha. Regeneration costs of \$200/ha and \$0/ha are tested to examine the effect of more intensive regeneration and natural regeneration schemes.

The sensitivity of the model to Moose values is also tested. Increasing Moose value will tend to increase the net present value under the Moose Guidelines. Moose values of \$200/harvested Moose/year and \$50/harvested Moose/year are considered. Wilderness canoeing and camping values are substituted in the model under the Moose scenario at \$8/ha/year and \$40/ha/year. Under the Woodland Caribou scenario, values of \$8.80/ha/year and \$44/ha/year are substituted because wilderness camping and canoeing values are assumed 10% higher under the Woodland Caribou Guidelines. Increasing amenity values is expected to increase the net present value of forest management.

III Results

The net present value of fibre, Moose, and wilderness canoeing and camping were calculated using Equation 1 with the aid of a personal computer spreadsheet¹³. The net present value of fibre was calculated by evaluating the residual value of fibre times the fibre growth function in each year

¹³ Quattro Pro, version 5 by Borland International; run on 486, 33MHz hardware.

and discounting it back to year zero. The net present value of Moose and wilderness canoeing and camping amenities were calculated by evaluating the integral of the discounted amenity value functions in each year.

Table 7 presents the results calculated across three different discount rates. Using the base 5% discount rate, the net present value of forest management under the Woodland Caribou Guidelines is \$1667.04/ha, which is 29% less than the net present value of \$2336.04 under the Moose Guidelines. Most of the difference in net present value is accounted for by fibre values, which fall by \$675.77/ha. Moose values are \$1.11/ha higher under the Moose Guidelines. Wilderness canoeing and camping has a net present value \$7.89/ha greater under the Woodland Caribou Guidelines than the Moose Guidelines. The amenity values are more sensitive to the discount rate than fibre values. This occurs because a large proportion of fibre values occur in the initial period and are not discounted.

The difference in net present value between the Moose and Woodland Caribou Guidelines is the shadow value of Woodland Caribou as implied by the Timber Management Guidelines for Woodland Caribou. It is a measure of the minimum value people must place on Woodland Caribou for the Woodland Caribou Guidelines to give a net present value as high as the Moose Guidelines.

Sensitivity Analysis

Sensitivity analysis was performed to better understand the robustness of the results. Table 8 presents the results of the sensitivity analysis. The transportation cost differential between the Moose and Woodland Caribou Guidelines was found to have the greatest impact on the results. If transportation costs under the Woodland Caribou Guidelines were subject to economies of size, the

**Table 7 Present Value Under Moose and Woodland Caribou
Guidelines, by discount rate**

	Moose Guidelines			Woodland Caribou Guidelines		
Forest Value	2%	5%	8%	2%	5%	8%
All Forest Values (\$/ha)	2902.19	2336.04	2281.48	2088.06	1667.04	1622.74
Shadow Value of Woodland Caribou (\$/ha)				814.13	669.00	658.74
Fibre (\$/ha)	2644.96	2276.28	2257.15	1767.01	1600.51	1596.37
Moose (\$/ha)	5.08	1.11	.45	-	-	-
Wilderness Canoeing and Camping (\$/ha)	252.15	58.64	23.88	321.05	66.53	26.37
Timber Harvest (m ³ /ha)	147.34	147.34	147.34	167.73	167.73	167.73

Table 8 Effect of Changes in Parameter Values on Present Value of Forest Management Under Moose and Caribou Scenarios

	<u>Moose</u> <u>Guidelines</u> Present Value (\$/ha)	<u>Woodland</u> <u>Caribou</u> <u>Guidelines</u> Present Value (\$/ha)	Shadow Value of Woodland Caribou (\$/ha)	Sensitivity Factor (Moose Scenario)	Sensitivity Factor (Woodland Caribou Scenario)
Base Values	2336.04	1667.04	669.00	-	-.396
Transportation cost differential = \$3.15/m ³	2336.04	1832.40	503.64		
Transportation cost differential = \$9.20/m ³	2336.04	879.66	1456.38	-	-.397
Regeneration Cost = 0	2437.00	1767.29	669.71	-.0432	-.060
Regeneration Cost = \$200/ha	2235.07	1566.79	668.28	-.0432	-.060
Moose Value = \$.48/ha/year	2337.24	1541.06	796.18	.0005	-
Moose Value = \$.12/ha/year	2335.50	1541.06	794.44	.00048	-
Wilderness Canoeing and Camping Value = \$40/ha/year	2404.74	1744.99	659.75	.0247	.04
Wilderness Canoeing and Camping Value = \$8/ha/year	2302.86	1629.61	673.25	.0247	.04

results show that the shadow value of Woodland Caribou would be reduced to \$503.64/ha. If the required distance between harvest blocks illustrated in Figure 6 is increased to 15 km, the shadow value increases to \$1456.38/ha. Changes in regeneration costs caused relatively small changes to the net present value of the two scenarios. Doubling the regeneration cost decreased the net present value of the Moose scenario by 4% and decreased the present value of the Woodland Caribou scenario by 6%.

Changes in amenity values had only minor effects on the present value of forest management. Increasing the value of Moose to \$200/harvested Moose/year (\$.48/ha/year) left the net present value of forest management virtually unchanged. Reducing Moose value to \$50/harvested Moose/year (\$.12/ha/year) had similarly small effects. Increasing the wilderness canoeing and camping value to \$40/ha/year resulted in only a 3% increase in present value under the moose scenario. The impact increasing wilderness canoeing and camping values to \$44/ha/year caused a 5% increase in present value in the Woodland Caribou scenario¹⁴. Reducing wilderness canoeing and camping values to \$8/ha/year in the Moose scenario and \$8.80/ha/year in the Woodland Caribou scenario caused only small reductions in present value.

Sensitivity Factors were calculated to highlight the relative impact of changes in the value of the variables. Sensitivity Factors are the elasticity of the present value to a change in the value of a parameter, as shown in Equation 10.

$$\text{Sensitivity factor} = \frac{\% \Delta \text{ Present Value}}{\% \Delta \text{ Parameter}} \quad (10)$$

¹⁴ Under the Woodland Caribou Guidelines, it is assumed that the value of wilderness canoeing and camping would increase by 10% relative to the Moose Guidelines.

The Sensitivity Factors reveal that the increase in transportation costs under the caribou guidelines is the most important factor affecting the present value. The Sensitivity Factors for the amenity values are quite small relative to the transportation cost differential.

Summary of Results

Our estimates of the shadow value of forest dwelling Woodland Caribou in the boreal forest of Ontario are between \$658.74/ha and \$814/ha. The most important determinant of the shadow value of the Woodland Caribou Guidelines is the dispersion of harvest blocks and the accompanying increase in transportation costs. The principal effect of the Woodland Caribou Guidelines is the increase in the distance between cutover blocks. Increasing the required distance between cutovers increases transportation costs. The net present value of the Woodland Caribou scenario was very sensitive to transportation costs.

IV Discussion

Findings

The difference between the net present value of the Moose scenario and the Woodland Caribou scenario provides an estimate of the shadow value of Woodland Caribou as implied by the Timber Management Guidelines for Woodland Caribou. For the base scenario parameters the Woodland Caribou Guidelines have an estimated shadow value between \$658.74/ha and \$814.13/ha. Sensitivity analysis on important empirical parameters revealed a range of shadow values from \$503.64/ha to \$1456.38/ha. The largest component of the shadow value of Woodland Caribou was

fibre. Moose and wilderness canoeing and camping values had relatively minor impacts on the shadow value.

Aggregation

The shadow value of the Woodland Caribou Guidelines was estimated using a representative hectare model. The representative hectare results must be extrapolated to the area that would be affected by the Timber Management Guidelines for Woodland Caribou to fully interpret the shadow value. The aggregate shadow value of the Woodland Caribou Guidelines is estimated by extending the representative hectare results across the area to which the policy would be applied. The Woodland Caribou Guidelines are expected to be applied in all areas in which Woodland Caribou currently exist (OMNR, Wildlife Policy Branch, 1991). Precise data on the area of implementation are unavailable, but the current area of continuous Woodland Caribou distribution in Northwestern Ontario extends north and west from Lake Nipigon, encompassing a large proportion of the commercial boreal forest. If Woodland Caribou Guidelines were applied every year to 50% of the average area harvested annually in the Northwest region, they would effect approximately 38,184 ha annually¹⁵. If the Timber Management Guidelines for Woodland Caribou were applied to 38,184 ha every year ad infinitum, the aggregate shadow value would be \$510,901,920¹⁶ (see Table 9). On a per caput basis, the shadow value is \$50.66/person for the population of Ontario. This can also be

¹⁵ The average annual area harvested in Northwestern Ontario for the period 1988-1993 was 76,367 ha (John McCaugherty, OMNR, personal communication)

$$\frac{38,184 \text{ ha} \times \$669.00/\text{ha}}{.05} = \$510,901,920$$

¹⁶

Using a discount rate of 5%

expressed as an annuity of \$2.53 per person per year.

Implications

The shadow value of Woodland Caribou conservation estimated here should be placed in perspective. Montgomery *et al.* (1994) estimated that Northern Spotted Owl pairs in the Pacific Northwestern United States required a minimum of 3000 acres (1215 ha) of protected Douglas fir habitat, and that the average stumpage value per acre of this type of habitat was approximately \$15,000 (U.S.). The implied non-discounted cost of Northern Spotted Owl conservation is thus at least \$45,000,000 (U.S.) per pair. Hyde (1989) estimated the net present value of conserving Red Cockaded Woodpecker colonies in North Carolina to be between \$11,824 and \$145,404 (U.S.) per colony. Woodland Caribou conservation in Ontario falls between the value estimates for wildlife protection elsewhere but the range of values reported in studies of this type continues to be wide. The results of the present study suggest that fibre continues to dominate the economic values in forests in Northwestern Ontario. The amenity values were small relative to fibre. The net present value of forest management is relatively insensitive to changes in the discount rate. Net present value is very sensitive to changes in the residual value of fibre. These results are explained by the large proportion of the total present value that derives from harvest in the initial period. The initial period benefits are not directly affected by the discount rate. The value of the initial period harvest value varies directly with the net value of fibre.

The shadow values estimated here give a lower bound on the value of Woodland Caribou necessary for the Timber Management Guidelines for Woodland Caribou to be a beneficial policy.

Table 9 Shadow Value of Woodland Caribou Under Annual Implementation

Total loss in present value (\$)	\$510,901,920.00
Ontario population	10,084,885
Shadow value per caput (\$/person)	\$50.66
Annuity value per capita (\$/person/year)	\$2.53*

* Using a discount rate of 5%

A direct estimate of the value of Woodland Caribou was beyond the scope of the study. It is left to provincial decision makers to determine if the costs of the Woodland Caribou strategy are excessive. An estimate of individuals' value of Woodland Caribou, using contingent valuation or another valuation technique, is an option for the OMNR to compare the benefits of conserving forest dwelling Woodland Caribou in the boreal forest with the costs estimated in this study.

Since this study was completed, reports from related research have been published which shed more light on the economics of Woodland Caribou protection. Tanguay, Adamowicz, and Boxall (1995) studied the willingness to pay for Woodland Caribou maintenance in Northwestern Saskatchewan. The study employed contingent valuation methods, using both open ended and dichotomous choice approaches. Using a dichotomous choice approach, the results showed Saskatchewan residents had a willingness to pay of \$30.62/person, or \$1.53/person/year over an infinite period at a 5% discount rate. Using the open ended approach, Tanguay *et al.* found a willingness to pay of \$14.66/person, or \$.73/person/year as a 5% annuity over an infinite period.

McKenney (1996) used a stochastic, spatial optimization model to estimate the costs of Woodland Caribou protection in Northwestern Ontario. The study addressed the costs in terms of fibre imputed by restrictions on adjacent harvests under the Woodland Caribou Guidelines, and did not address wildlife or remote recreation. The results were estimated for a single forest rotation. The study found the shadow value of the Woodland Caribou Guidelines to be between \$.74/person/year and \$1.17/person/year as an annuity over an infinite period.

In this study, we estimate the shadow value of the Woodland Caribou Guidelines at \$2.53/person/year. This is substantially larger than that estimated by McKenney. This difference is an indication of the margin of error resulting from our spatial approach, since the remote recreation

and moose values estimated here are small, and discounting removes most of the effects of forest rotations following the initial rotation.

McKenney's results for the cost of Woodland Caribou protection fall within the range of willingness to pay estimated by Tanguay *et al.* The estimated benefits fall well below the costs calculated in this study. Thus, the economic justification for proceeding with the Woodland Caribou Guidelines is dependent on the extent to which the spatial model better represents the Forest management problem.

Limitations

The estimates of the shadow value of caribou should be interpreted with caution. The implementation strategy of the Timber Management Guidelines for Woodland Caribou is still under discussion. More precise articulation of the way that the Caribou Guidelines would be implemented on specific landscapes, interacting with, for example, Aquatic Habitat guidelines, would allow more definitive economic modelling. More accurate information and data on the fibre enterprise in the boreal forest would strengthen the findings of the study. In particular, precise transportation and road building costs in the Northwestern Ontario region would strengthen future studies of this nature. The results of the study show that fibre is the dominant value in the study area¹⁷. Direct estimation of the value of standing timber was not undertaken in this study due to a lack of reliable data. The possibility of increasing returns in harvesting larger cutovers under the Woodland Caribou Guidelines is not investigated because of a lack of accurate data. Similarly, road building and removal costs are

¹⁷ A critical assumption underlying this conclusion is that the differential in fibre values between the Moose and the Woodland Caribou Guidelines applies to the initial harvest as well as to the infinite series of subsequent harvests. Depending on how the Woodland Caribou Guidelines were implemented spatially, this may or may not be an accurate assumption. Additional economic research using spatial mathematical programming techniques is needed to explore this issue.

not dealt with in this study.

The results of this study are constrained by the use of the representative hectare model.¹⁸ A more detailed and accurate analysis could be undertaken with a spatial model and spatially fragmented data. A spatial model would provide the framework required to better incorporate restrictions on adjacent harvests in an economic analysis. Indeed, this study highlights the need for spatial analysis in its finding that constraints on adjacent harvests could account for the majority of the shadow value. This modelling approach is the subject of ongoing research by the authors.

V Recommendations

The shadow value of forest dwelling Woodland Caribou estimated in this study should be interpreted as a preliminary benchmark for public decision makers. It is a measure of the minimum value people must place on Woodland Caribou for the Timber Management Guidelines for Woodland Caribou to be a beneficial policy for the citizens of Ontario if a social welfare or a utilitarian criterion were to be used for policy evaluation. Our results suggest that the major tradeoff in protecting Woodland Caribou in the commercial boreal forest would be in the form of increased fibre transportation costs. The results also suggest that Moose values are likely to decline. The Woodland Caribou Guidelines are expected to enhance wilderness canoeing and camping values, potentially benefitting the remote tourism industry.

The limitations of this study suggest important areas for future research. The results suggest

¹⁸ As indicated in the previous footnote, a spatial mathematical programming model is needed to fully investigate this issue. Nevertheless, a representative hectare model is a readily constructed and useful source of preliminary results that can provide an indication of the magnitude of the effects of a change in policy. The more uniform the landscape over which the model is applied, the more accurate the findings.

that more research is required in the economics of woodlands operations. It is clear from the sensitivity of the results to transportation costs that more research in road building and fibre trucking costs would be beneficial to future studies such as this. This study left open the question of economies of size and harvesting, which could have important implications for the eventual results of the Woodland Caribou Guidelines. Another area for future research is the development of a spatial mathematical programming model capable of representing adjacency constraint on harvesting. The sensitivity of the model in this study to the distance between cutover areas indicates that a more accurate means of handling constraints on adjacent cuts would have been valuable.

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Appendix

Assumptions and Estimation of Forest Growth Functions

The growth functions used in this study were estimated from the growth tables developed by Plonski (1981). Growth functions were estimated for black spruce, jack pine, white birch, and aspen poplar. The growth functions were based on Site Class 2 land. Gross merchantable volume was regressed on stand age. The functions thus give volume in m³/ha as a function of stand age.

Linear, quadratic, and cubic functional forms were tested, with the cubic functional form providing the greater explanatory power. Ordinary least squares was used as the estimation technique. The results for black spruce, jack pine, white birch, and aspen are presented in Tables A-1, A-2, A-3, and A-4, respectively. Table A-1 shows that the relationship estimated for black spruce had a high explanatory power based on its R-squared of .9951. All independent variables are significant at the 95% level.

Table A-2 shows that the estimation of jack pine growth has a high explanatory based on its R-squared value of .999. The linear age coefficient is significant at the 95% level. The other coefficients are significant at the 90% level. Table A-3 gives the regression results for white birch. The square and cubic age terms were significant at the 95% level. The regression gave an R-squared value of .995. The final table gives results for aspen. The linear and the cubic age variable were significant at the 95% level. The regression explained 99.66% of the variability in the data. Adjusted R-squared values were calculated to test whether the R-squared values were influenced by the number of explanatory variables. The adjusted R-squared values were not significantly different from the R-squared values presented in Tables A-1 to A-4.

Table A-1 Regression Results of Volume on Age, Black Spruce

Variable	Coefficient	Standard Error	T-statistic
Constant	69.1576	-	-
Age	-4.9478	.5254	9.417*
(Age) ²	.092	.0068	13.529*
(Age) ³	-.00035	2.65E-05	13.208*

* Significant at 95% confidence level

Sample size	27
R-squared	.9951
Adjusted R-squared	.9945

Table A-2 Regression Results of Volume on Age, Jack Pine

Variable	Coefficient	Standard Error	T-statistic
Constant	-114.594	-	-
Age	6.085	.5166	11.779*
(Age) ²	-.01943	.0093	2.089**
(Age) ³	-9.8727E-05	5.1336E-05	1.923**

* Significant at 95% confidence level

** Significant at 90% confidence level

Sample size	17
R-squared	.999
Adjusted R-squared	.998

Table A-3 Regression Results of Volume on Age, White Birch

Variable	Coefficient	Standard Error	T-statistic
Constant	-49.975	-	-
Age	1.3531	1.1147	1.214
(Age) ²	.0497	.0218	2.280*
(Age) ³	-.00047	.00013	3.638*

* Significant at 95% confidence level

Sample size	15
R-squared	.995
Adjusted R-squared	.9936

Table A-4 Regression Results of Volume on Age, Aspen

Variable	Coefficient	Standard Error	T-statistic
Constant	-178.751	-	-
Age	9.0508	1.6372	5.528*
(Age) ²	-.00626	.0295	.2122
(Age) ³	-.00033	.00016	2.0625**

* Significant at 95% confidence level

** Significant at 90% confidence level

Sample size	17
R-squared	.9966
Adjusted R-squared	.9958

The functions estimated gave negative values for gross merchantable volume through part of their range. This was due to the fact that volume data were only available from age 20 to 150. For white birch, data was only available for age 20 to 90. The growth function was simulated for ages 0 to 200 years. The negative values that were simulated outside of the estimation range were converted to zero for the purposes of this study.

The growth functions were combined to give a single forest growth function for the study region. The growth functions of each species were weighted by their proportion in the Lac Seul Forest. Table A-5 gives the area of each species and its proportion in the Lac Seul Forest. Black spruce accounts for over 50% of the total forest area, while white birch accounts for only 1%. The tree species analyzed here represent about 90% of the area of the Lac Seul Forest.

The composite growth function was solved for the maximum mean annual increment using Equation 11.

$$\underset{[T]}{Max} \frac{V(T)}{T} \quad (11)$$

The maximum mean annual increment occurred at age 93 years, yielding a gross merchantable volume of 147.34 m³/ha.

Table A-5 Forest Area and Proportion by Species, Lac Seul Forest

Species	Area (ha)	Proportion
Black spruce	278,970	.535
Jack pine	153,766	.295
White birch	5640	.0108
Aspen-poplar	30,345	.582
Total productive forest	521,478	-

Source: G. Racey, personal communication