TABLE OF CONTENTS

TABLE OF CONTENTS (contd.)

TABLE OF CONTENTS (contd.)

Volume 4-Chapter 2 TERRESTRIAL ECOSYSTEMS

2.1 INTRODUCTION AND SUMMARY OF FINDINGS

The debate over the advisability of recovering base metals from the earth by mining is not unique to the environmentally aware generations of the 1960s and 1970s. The fundamental questions have been pondered by policy-makers and citizens alike since the beginning of man's use of metals.

> The strongest argument of the detractors is that the fields are devastated by mining operations...the woods and groves are cut down, for there is need of an endless amount of wood for timbers, machines, and the smelting of metals. And when the woods and groves are felled, then are exterminated the beasts and birds, very many of which furnish a pleasant and agreeable food for man. Further, when the ores are washed, the water which has been used poisons the brooks and streams, and either destroys the fish or drives them away...

In response, the supporters of mine developments replied that:

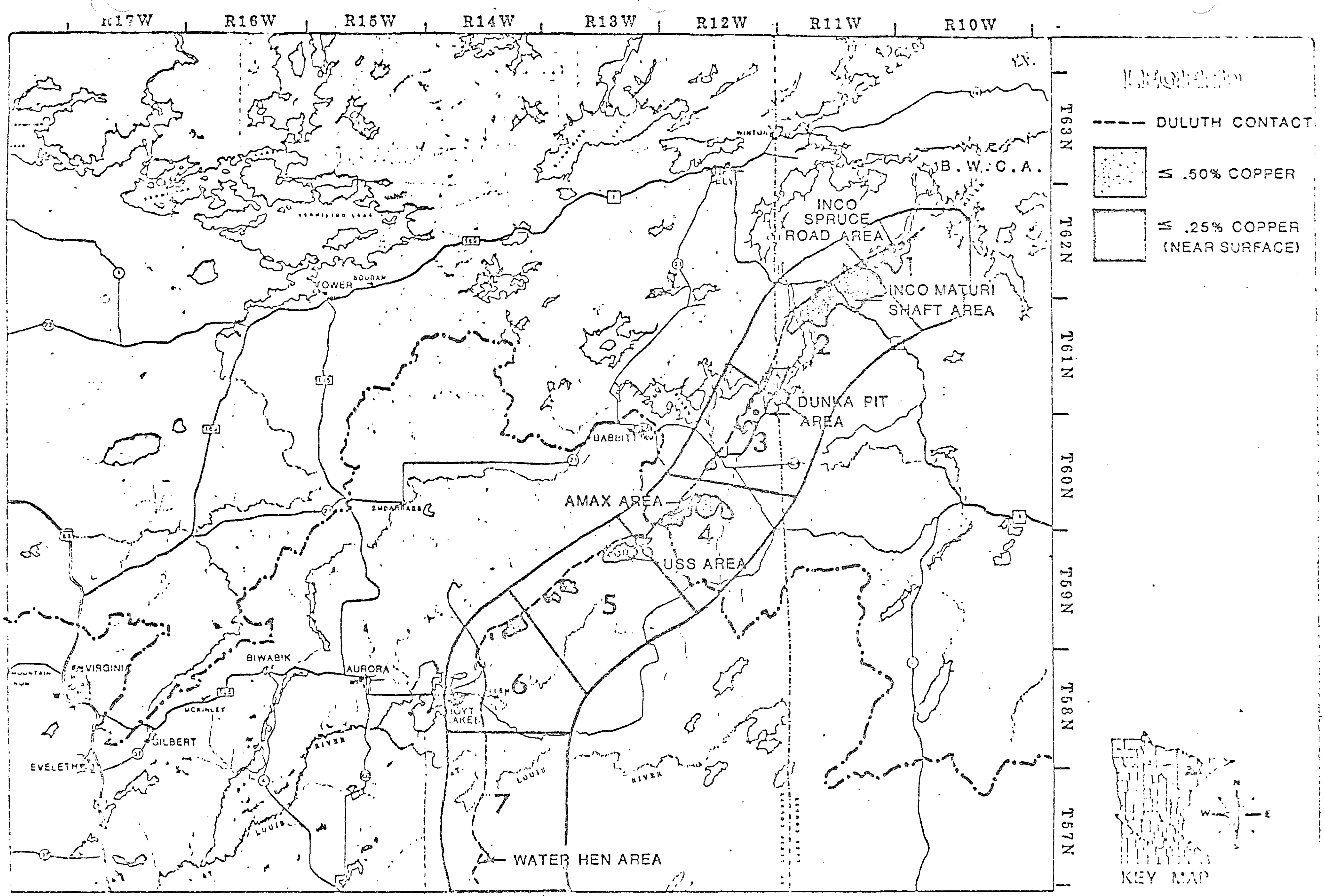
> ...as the miners dig almost exclusively in mountains otherwise unproductive, and in valleys invested in gloom, they do either slight damage to the fields or none at all. Lastly, where woods and glades have been cut down, they may be sown with grain...these new fields soon produce rich crops (Agricola, 1556, De Re Metallica).

Although northeastern Minnesota is not 16th century Germany, the issues raised by Agricola remain alive today. The fields and forests, beasts and birds that were of concern then remain a concern now. The crops, trees, beasts, and birds along with other plants and animals and the inanimate physical environment in which they live, are all parts of the terrestrial ecosystem. Unlike aquatic habitats where the special properties of water are the dominant physical factors, climate and substrate have a greater influence on terrestrial ecosystems.

This report presents a summary of findings from field and literature studies of the terrestrial ecosystems of northeastern Minnesota and the potential impacts of copper-nickel mining on these ecosystems. Copper-nickel mining will be a land-intensive activity which will differentially impact most heavily those lands closest to the resource. The amount of land consumed is directly related to the grade of ore and the total production lifetime of the mines. This production life is in turn related to the available resource. Figure i is a map of the Study Area which illustrates the concentration of the copper-nickel resource in a narrow belt extending roughly from the east side of Birch Lake to Hoyt Lakes. It can be seen from the figure that the major proportion of known resource is concentrated in the zone numbered 2, one of seven zones delineated by known loci of mineralization.

Figure i

Figure ii illustrates the relationship between total production and land consumed by mining. Major impacts on terrestrial ecosystems are expected to vary with the size and type of mining operation. Three hypothetical mine models were developed by the Regional Study: an open pit mine with annual production of 20 X 10^6 metric tons of ore, a combined open pit-underground operation with annual production of 16.68 X 10^6 metric tons, and an underground mine with annual production of 12.35 X 10^6 metric tons (see Volume 2-Chapter 5). In each case, the lifetime of the mine was assumed to be 30 years. As can be seen



MEQB REGIONAL COPPER-NICKEL STUDY

FIGURE i DISTRIBUTION OF MINERAL RESOURCES IN STUDY AREA from Figure ii, total acreage consumed is related to total production over the lifetime of the mine. Total production and land needs of the open pit and processing plant once proposed by INCO are comparable to those of the Study's 12.35 X 10^6 metric ton underground mine model, whereas production of an operation being considered by AMAX exceeds any of the Study's models and would consume over twice the acreage of the Study's 20 X 10^6 metric ton per year open pit mine model. Total acreage takes into account all operational areas including the mines themselves, processing plant sites, storage, tailing basins, wasterock piles, and service areas. Acreage directly consumed will vary with the height and number of piles or size and number of tailings basins.

Figure ii

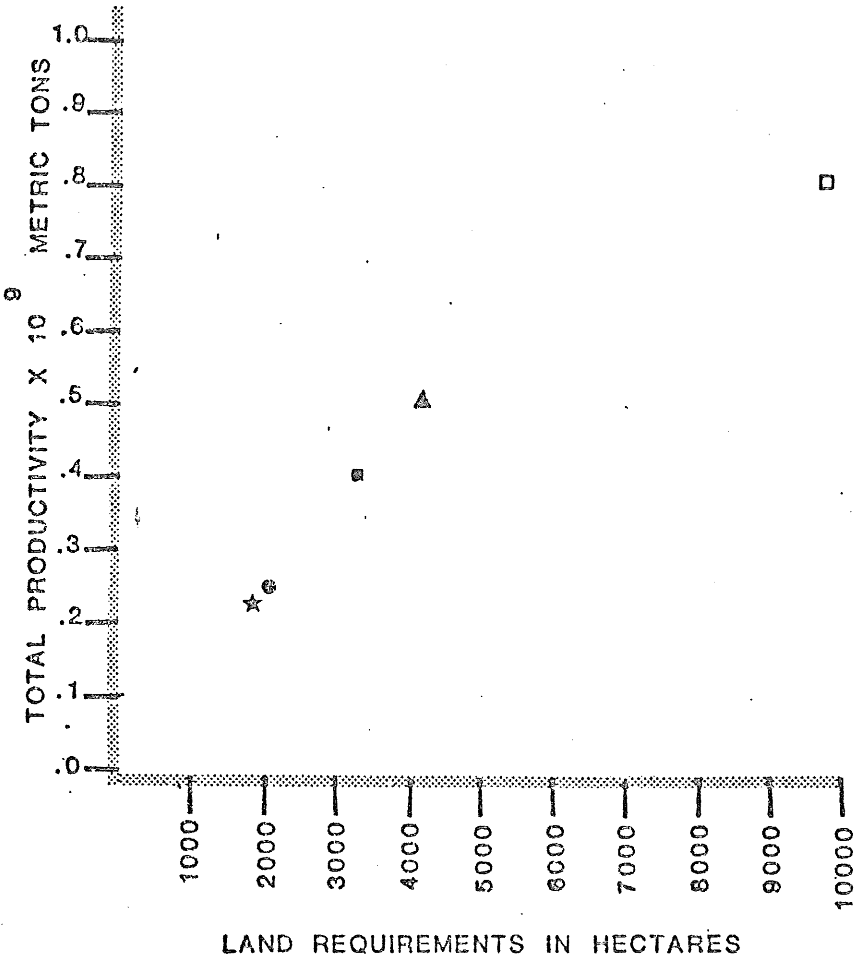
Since the Regional Study is not evaluating the impacts of specific Cu-Ni development proposals, such as the preliminary conceptual layouts of AMAX and INCO, but rather is evaluating the implications of Cu-Ni development anywhere along the Resource Area; the task of assessing impacts becomes significantly complicated.

Although site-specific studies may anticipate particular impacts at given locations, a regional study must rely on some scheme of classification that identifies types of areas that are likely to respond as units to given impacts.

The search for appropriate classification schemes applicable to the Study Area was pursued by utilizing the knowledge that the influences of climate (temperature, moisture, light) and substrate (physiography, soils) are reflected in the dominant plant associations (e.g. pines on thin, dry soils or on southwest facing slopes where higher temperatures cause greater water stress).

FIGURE ii

RELATIONSHIP BETWEEN MINE PRODUCTION AND LAND REQUIREMENTS



REGIONAL STUDY'S MODELS

▲ 20 X 10^6 METRIC TON PER YEAR OPEN PIT MINE

■ 16.68 X 10^6 METRIC TON PER YEAR COMBINED MINE

● 12.35 X 10^6 METRIC TON PER YEAR UNDERGROUND MINE

PROPOSED MINES

□ AMAX OPEN PIT - UNDERGROUND MINE (PRELIMINARY ESTIMATE- BASED ON DIFFERENT OPERATIONAL ASSUMPTIO

★ INCO OPEN PIT MINE

Further, the "beasts and birds" of one plant association are different in kind or number from those of another. Their dependency upon the plant association for food and shelter and their mutual interdependencies among themselves define them as a distinct community.

The Regional study classified terrestrial communities into eleven broad types, each of which is characterized by structurally and floristically distinct vegetation and associated animals. The eleven communities are listed in Table 1. Tables 2 through 4 illustrate the relative importance of associated animal and bird groups in these communities. It can be seen from these tables that more than one habitat is often heavily used by a given large mammal (Table 2), small mammal group (Table 3), or bird association (Table 4). In addition to the eleven mature community types, immature communities are considered in these tables because there are a large number of mammals and birds which prefer immature communities, regardless of their species composition, because of their structural simplicity.

Tables 1,2,3, & 4

Upland deciduous communities are the most widespread in the Study Area. Such communities form a continuum from nearly pure aspen-birch stands to mixed conifer-deciduous stands. Although the total number of songbird species and their species composition change with an increase of coniferous elements, the predominant associations are the same throughout the continuum. The addition of conifers may either create or reflect the moister conditions associated with increased importance of shrews. Upland deciduous communities are the most important forest type for game animals in the Study Area (including deer, moose, and grouse). Consequently, those portions of the Study Area dominated by upland

TABLE 1. Vegetation Communities Recognized by the Regional Copper-Nickel Study.

UPLAND COMMUNITIES	
Deciduous	Aspen-Birch
	Aspen-Birch-Fir
	Mixed Conifer Deciduous
Coniferous	Jack Pine-Spruce
	Jack Pine
	Red Pine
LOWLAND COMMUNITIES	
Deciduous	Ash
	Shrub Carr
Coniferous	Black Spruce
	Tamarack
	Cedar

TABLE 2 HABITAT PREFERENCES OF SELECTED ANIMALS

		LOWLAND					UPLAND							
		BLACK SPRUCE BOG	TAMARACK BOG	CEDAR SWAMP	ASH	SHRUB CARR	BLACK SPRUCE - JACK PINE	JACK PINE	RED PINE	YOUNG CONIFER PLANTATION	ASPEN-BIRCH	ASPEN-BIRCH-FIR	REGENERATING DECIDUOUS	MIXED CONIFEROUS-DECIDOUS
GAME BIRDS AND MAMMALS	WHITE-TAILED DEER	M	S	M	S	M	M	S	S	I	I	I	I	I
	MOOSE	I	M	S	S	I	M	S	S	I	I	I	I	I
	BLACK BEAR	S	S	S	S	S	S	S	S	I	M	M	I	M
	SNOWSHOE HARE	I	M	I	M	I	S	S	S	M	I	I	I	M
	RUFFED GROUSE	S	S	S	S	I	S	S	S	M	I	I	I	M
	SPRUCE GROUSE	I	M	S	S	S	I	M	S	S	S	S	S	M
	WOODCOCK	S	S	S	M	I	S	S	S	I	I	I	M	M
	WATERFOWL 1	M	M	S	M	I	S	S	S	S	S	S	S	S
FUR BEARERS	BEAVER 1	S	S	S	S	M	S	S	S	S	I	I	M	M
	RIVER OTTER 2	M	M	S	M	I	S	S	S	S	S	S	S	S
	FISHER	M	M	M	S	I	M	M	M	S	S	M	S	I
	MINK 2	M	M	S	M	I	S	S	S	S	S	S	S	S
	MUSKRAT 1	M	M	S	M	I	S	S	S	S	S	S	S	S
	RACCOON 2	M	M	S	M	I	S	S	S	S	S	S	S	S
	STRIPED SKUNK 3	S	S	S	S	I	S	S	S	I	S	S	I	S
	BOBCAT	M	M	M	S	S	S	S	S	I	I	M	I	I
	LYNX	I	M	I	S	S	S	S	S	M	I	M	M	I
UNIQUE ANIMALS	BALD EAGLE 2	M	S	S	S	M	M	M	I	S	S	S	S	I
	OSPREY 2	I	M	S	S	S	I	M	M	S	S	S	S	M
	TIMBER WOLF	M	S	M	S	M	M	S	S	I	I	I	M	I
	MARTEN	I	M	I	S	S	I	I	I	S	S	S	S	M
RAPTORS	BROAD-WINGED HAWK	S	S	S	S	M	S	S	S	M	I	I	M	M
	SPARROW HAWK 3	S	S	S	S	I	S	S	S	I	M	M	I	S
	RED-TAILED HAWK	S	S	S	S	M	S	S	S	M	I	I	M	I
	GOSHAWK	S	S	S	S	S	M	M	M	S	I	I	S	I
	COOPER'S HAWK	S	S	S	S	S	S	I	I	S	M	M	S	I
	SHARP-SHINNED HAWK	I	S	S	S	S	I	I	I	S	M	M	S	I
	MARSH HAWK 2	S	M	S	S	I	S	S	S	M	S	S	S	S
	GREAT HORNED OWL	M	S	M	S	S	M	I	I	S	I	I	S	I
	BARRED OWL	S	S	M	M	S	S	I	I	S	M	M	S	S
	LONG-EARED OWL	I	S	S	M	S	I	I	I	S	S	S	S	M
	SHORT-EARED OWL 3	S	S	S	S	I	S	S	S	I	S	S	I	S
	SAW-WHET OWL	I	S	S	I	S	I	I	I	S	M	M	S	M
OTHERS	PORCUPINE	S	M	S	S	S	S	M	I	S	S	S	S	I
	RED SQUIRREL	I	M	I	S	S	I	M	M	S	S	S	S	M

INTENSIVELY USED

MODERATELY USED

SELDOM USED

1 PRIMARILY AQUATIC SPECIES

2 RIVERINE AND MARSH SPECIES

3 SPECIES PREFERRING OPEN HABITATS

TABLE 3 COMPARISON OF SMALL MAMMAL GROUPS BY HABITATS

UNIMPORTANT
SOMEWHAT IMPORTANT
IMPORTANT
NOT SAMPLED ND

	DECIDUOUS WETLANDS			CONIFER WETLANDS			CONIFER UPLANDS			DECIDUOUS UPLANDS			IMMATURE COMMUNITIES	
	SHRUB CARR	ASH (DRAW)	ASH (FLOODPLAIN)	CEDAR BOG	TAMARACK BOG	SPRUCE BOG	BLACK SPRUCE JACK PINE	JACK PINE	RED PINE	ASPEN-BIRCH	ASPEN-BIRCH FIR	MIXED CONIFER -DECIDUOUS	PINE CLEAR-CUTS AND PLANTATIONS	ASPEN BIRCH REGENERATION
SHREW GROUP		ND	ND				ND							
MICE-VOLE GROUP		ND	ND				ND							
CHIPMUNK GROUP		ND	ND				ND							

TABLE 4 COMPARISON OF SONGBIRD ASSEMBLAGES BY HABITATS

- UNIMPORTANT (blank)
- SOMEWHAT IMPORTANT (dense shading)
- IMPORTANT (light shading)
- NOT SAMPLED: ND

	DECIDUOUS WETLANDS			CONIFER WETLANDS			CONIFER UPLANDS			DECIDUOUS UPLANDS			IMMATURE COMMUNITIES	
	SHRUB CARR	ASH (DRAW)	ASH (FLOODPLAIN)	CEDAR BOG	TAMARACK BOG	SPRUCE BOG	BLACK SPRUCE JACK PINE	JACK PINE	RED PINE	ASPEN-BIRCH	ASPEN-BIRCH FIR	MIXED CONIFER -DECIDUOUS	PINE CLEAR-CUTS AND PLANTATIONS	ASPEN BIRCH REGENERATION
CHICKADEE-GOLDEN CROWNED KINGLET		ND	ND				ND							
SPARROW HAWK-BROWN THRASHER		ND	ND				ND							
EASTERN WOOD PEWEE-SCARLET TANAGER		ND	ND				ND							
CATBIRD-SONG SPARROW		ND	ND				ND							
HERMIT THRUSH-BLACKBURNIAN WARBLER		ND	ND				ND							
YELLOW BELLIED FLYCATCHER CONNECTICUT WARBLER		ND	ND				ND							
COMMON FLICKER-BROWN HEADED COWBIRD		ND	ND				ND							
MOURNING WARBLER CHESTNUT SIDED WARBLER		ND	ND				ND							
RED EYED VIREO OVENBIRD		ND	ND				ND							

deciduous stands, such as the Toimi Drumlin Field, are most important for these animals. Despite their relative importance, upland deciduous forests in the Study Area produce generally lower populations of game species than similar forests elsewhere in the state. Perhaps more important than their browse value is their proximity to the center of the state's wolf population (in the northeastern section of the Study Area). Wolves in the mixed forest and conifer-dominated sections of the Study Area have seriously depleted their principal prey, the deer. Better browse in parts of the area dominated by aspen-birch may support better deer populations and encourage wolf populations.

Conifer uplands in the Study Area include both spruce and pines and consist of both natural communities and plantations. Jack pine and red pine communities recognized by the Regional Study are concentrated in the northern and eastern parts of the Study Area. In general, these communities support fewer game species, but more species of particular interest. Together with mature conifer wetlands, conifer uplands are distinguished by the importance of the Blackburnian warbler-hermit thrush songbird association. The distinguishing large mammals occur in small numbers and include several uncommon species or species near their range limits, including fisher, marten, lynx, eagles, ospreys, and timber wolves. Within the Study Area, the best geographic area for most of these species lies east of Ely where mixed black spruce-jack pine stands are most common and the largest proportion of mature pine forests persists. Timber management in the last two decades has tended toward conversion of mixed stands to conifers and re-establishment of harvested conifers. These management practices are reflected in the large number of jack and red pine plantations in the northeastern part of the area. With respect to bird and small mammal associations, the overriding structural attributes of young stands result in a greater similarity of young plantations to young deciduous stands than to mature conifer stands.

Few virgin lands exist in the Study Area. Those that do are mainly conifer wetlands or "unproductive" wetlands dominated by low shrubs. From the standpoint of rare or unique biological features, wetlands are the most important community. Cedar stands are unusual and contain a large number of rare or uncommon ferns, fern allies, mosses, and lichens. Uncommon and rare species in the Study Area are generally either members of protected groups (such as the orchid family) or are species that are more common northward or southward but are at their range limits in northeastern Minnesota. Such species are important reservoirs of genetic variability. The value of cedar bogs as natural preserves for rare species is somewhat limited by their small size and extent of previous disturbance. Unlike cedar bogs elsewhere in the upper midwest, they do not appear to provide wintering grounds for deer.

The continuum of black spruce to tamarack bogs is varied both floristically and structurally, with the smallest bogs the most floristically diverse. Small mammal populations of these communities were dominated by moisture-loving shrews. The more uncommon southern bog lemming was present in only one wetland, where it was found both years of this study. Wetlands provided a haven for the most unique avian assemblage, comprised of birds that nest on the ground but glean in the canopy. Species unique to conifer wetlands were the ruby crowned kinglet, Tennessee warbler, Cape May warbler, gray jay, and Swainson's thrush. In addition to providing a haven for this unique bird fauna, conifer wetlands provide favorable habitat for boreal plants and for members of the orchid family. As is the case with most rare and unique forms of life, the more extensive the contiguous habitat (in this case bog), the more available are the special resources needed by the rarer species and the less competition they experience from species that can thrive over a wide range of habitats.

One part of the Study Area, the Sand Lake Wetland, has been nominated for the state's Scientific and Natural Areas program but was not sampled as part of this Study. This wetland is characterized by the presence of patterned bog visible on aerial photographs. Serial examination of aerial photographs taken at 10-year intervals since 1937 suggests that portions of the bog have never been cut. The large size of this wetland, its possible virgin character, the presence of a completely surrounded bog lake, and the fact that its flora is unknown contribute to the need for its further investigation.

Deciduous wetlands are less common in the Study Area than elsewhere in the state. The extremely uncommon floodplain ash community is best developed along the St. Louis River in the southwestern part of the Study Area. Vegetation of this community was sampled near Birch Lake. The black ash community is important only because of its proximity to its range limits in the Quetico. Alder carrs in the Toimi Drumlin Field may represent an early stage in wetland succession, because they appear to post-date the Palo-Markham Aurora fire. Like the ash community, they are better developed elsewhere in the state. Their major importance within the Study Area rests in their juxtaposition with aspen uplands which provides the best available habitat for woodcock and grouse. As is the case with upland habitat for game animals, they would not be considered outstanding on a statewide basis.

As can be seen from the previous discussion several of the natural features of the Study Area are important from a local perspective, but not regionally, statewide, or nationally. Other features, such as rare species, that may be valuable on a national scale are common and less valued locally. In order to assess possible impacts, it is necessary to provide a ranking of habitats on the basis of natural characteristics. This ranking must take into account the scale at which each attribute is considered valuable.

Three major criteria can be used to rank the habitats: how uncommon is it locally, on a statewide basis, or nationally; how widespread is it; and how likely is it to differ genetically or functionally from other members of its group. Table 4a provides a general view of the relative importance of the eleven habitat types on a nationwide, statewide, and local scale based on their unique attributes, how widespread they are in the Study Area, and how common they are on a local or statewide scale.

Table 4a

Uncommon on a local scale are good hunting areas, on a statewide basis certain plants and animals of boreal distribution, and on a national scale wolves, eagles, and ospreys. The aspen-birch community is important locally, whereas mature conifer uplands and wetlands are more important on a statewide and national scale. Because of the dependency of wolves on deer, aspen-birch communities that are sufficiently isolated from human activity take on a greater national significance than they would otherwise have. From the perspective of developments in the near future, the areas of actual wolf concentrations may be more important than their potential habitat. These areas lie mainly in the northeastern part of the Study Area dominated mainly by conifers and mixed stands.

Four major classes of environmental impacts from copper-nickel mining are expected in terrestrial ecosystems: direct land loss, air pollution damage,

TABLE 4A IMPORTANCE OF COMMUNITIES AT NATIONAL STATEWIDE, AND LOCAL LEVELS

	LOWLAND					UPLAND					
	BLACK SPRUCE BOG	TAMARACK BOG	CEDAR SWAMP	ASH	SHRUB CARR	BLACK SPRUCE-JACKPINE	JACK PINE	RED PINE	ASPEN-BIRCH	ASPEN-BIRCH-FIR	MIXED CONIFER DECIDUOUS
NATIONALLY IMPORTANT											
RARE SPECIES						IMPORTANT	IMPORTANT	IMPORTANT			IMPORTANT
RARE COMMUNITY											
IMPORTANT IN STATE											
RARE SPECIES			IMPORTANT								
RARE COMMUNITY						LESS IMPORTANT					
SPECIES AT RANGE LIMITS	IMPORTANT	LESS IMPORTANT	IMPORTANT	IMPORTANT							
COMMUNITY AT RANGE LIMITS				IMPORTANT							
LOCALLY IMPORTANT											
COMMUNITY RARE IN STUDY AREA			IMPORTANT	LESS IMPORTANT							
WILDLIFE HABITAT									IMPORTANT	IMPORTANT	LESS IMPORTANT
DOMINANT COMMUNITY									IMPORTANT	IMPORTANT	IMPORTANT

IMPORTANT LESS IMPORTANT UNIMPORTANT

seepage of waters from mine wastes, and increased noise levels.

Direct land loss is generally regarded as a short-term impact. Lands may be classed as permanently lost, reclaimable, or restorable. Permanent loss from further non-mine uses is anticipated only for the area actually occupied by the pit in any open pit mining operation. The Regional Study's 20 X 10^6 mtpy open pit model suggests an open pit of 228 ha, whereas permanent loss according to the 16.68 mtpy combined model would include only a 175 ha pit.

Reclaimable lands are those that can be returned to alternative post-operational uses, for example; industrial, residential, or natural. Modern technology allows for the reclamation of most minelands with the aid of such soil amelioration practices as topsoiling, liming, and fertilization. Soil amelioration is a prerequisite for revegetation of inhospitable areas such as tailing basins and waste rock piles. Reclaimed lands may support productive forests even though these forests do not compare floristically or functionally with previous forests of the area.

Restoration implies the restitution of a community similar to that previously in the area with comparable floristic composition, soil and hydrologic properties and ecosystem functioning. Restoration of mature communities requires a time period long enough for successional processes to take place. Within the Study Area, restoration is a feasible goal for mature communities dominated by pioneer species (e.g. aspen-birch) on thick soils which can be stockpiled and reapplied to the area to be reclaimed. Even in areas dominated by such vegetation and soils, restoration is unfeasible in minelands such as wasterock piles, which have been topographically altered beyond the natural range of variability. Because restoration implies return to comparable ecosystem function as well as species composition, replanting of formerly dominant species does not in itself constitute restoration. For example, mining companies customarily favor lowland which can contain significant areas of wetlands for tailing disposal because of the savings on dike construction. Replanting of bog species in a completed tailing basin would not restore the original community because soil properties of ameliorated tailing material would be sufficiently different from those of natural organic soils that ecosystem functioning of the new community would not be comparable with that of the old. Community restoration in the Study Area is most feasible in the extreme south and least feasible in the northeast, where the likelihood of impacts is greatest.

Impacts on terrestrial ecosystems of air pollution resulting from copper-nickel mining and smelting (under normal operating conditions) are expected to be limited. Projected levels of SO_2 are well below those known to cause visible damage to forest ecosystems. Classes of damage that cannot be directly observed are known to occur in industrial areas, but the levels that cause damage and etiology of damage are not well documented. Reduced growth is the most widely suspected result of low-level pollution. Levels at which growth reduction has been documented are orders of magnitude greater than those expected in the Study Area. Within 8-10 km of a smelter, visible damage may occur as a result of short-term fumigations during infrequent breakdowns of smelter air pollution control systems. Such incidents are expected to occur infrequently with peak 3-hour fumigations no greater than a few thousand ug/m^3, 2-8 km from the source, assuming that emissions occur through the stack. Damage is expected to be greatest during the summer months when the vegetation is most susceptible to impacts. Regional changes in air quality from all sources with or without copper-nickel smelting are likely to result in increased acidification of rainfall over the entire Study Area (see Volume 3-Chapter 4), causing slowed recycling of nutrients which may result in reduced forest growth.

If mine wastes are not located such that leachates can be captured, toxic seepage from stockpiles and waste rock piles may enter wetland systems. Resultant damage to the vegetation will depend on the amount of organic soil available to take up heavy metal ions, the depth to which throughflow waters penetrate, the tolerance of particular plant species, and the particular ions involved. Studies of a cedar bog receiving drainage from a Duluth Gabbro stockpile exhibit a gradient in the concentration of heavy metals decreasing with distance from the source. Although it appears that organic soils are taking up metals within the area affected by surface flow, the more labile elements, such as nickel, are being taken up by the plants. Elevated levels of nickel in the foliage of several species are accompanied by symptoms resembling iron-deficiency chlorosis. The dynamics of such vegetation damage from leachate are not well understood at this time, and it is not possible to estimate the area that might be effected.

Although noises associated with mining are expected to travel long distances, it is likely that only noises of a discontinous, interruptive nature (such as blasting) will have observable affects on animal populations. Blasting near the nests of birds of prey may reduce their nesting success. Large mammals are expected to avoid noisy areas if the noise reaches stressful levels.

In general, it appears the northeastern portion of the Study Area is most susceptible to all four classes of impacts. This area is characterized by mature coniferous forest communities and is inhabited by animals of statewide and national interest. The proximity to the BWCA and presence of eagle and osprey nests increases the susceptibility of the Kawishiwi-Birch Lake area to impacts of seepage and noise, respectively. The thin, coarse soils are both more erodable and less easily reclaimed than soils elsewhere in the Study Area.

In general, it appears that the northeastern portion of the Study Area is most susceptible to all four classes of impacts, both because of attributes of the ecosystem and because of constraints on siting of direct mining developments. The Kawishiwi-Birch Lake portion of the area is characterized by mature conifer forests and inhabited by several species of national and statewide interest including wolves, marten, eagles, and ospreys.

The relative importance of coniferous communities in the Study Area as compared with the state as a whole can be seen from Table 4b. The combination of past logging practices, forest management, and natural distribution of species has resulted in a concentration of mature pineries in the BWCA, the eastern Superior National Forest, and the Chippewa National Forest. Although 2.6 percent of forests in the state are pinelands, 8.7 percent of the Study Area's forested lands are in pine. The spruce-fir forest type, which is composed of several upland and wetland communities, is even more differentially concentrated within the Study Area. Although 6.6 percent of forests in Minnesota are classified by MLMIS as spruce-fir, 23.5 percent of lands in the Study Area fall into this group. Of the communities comprising the spruce-fir type, the mixed upland black spruce-jack pine community is restricted to northeastern Minnesota and is therefore one of the most important in the Study Area, with respect to direct land loss.

Table 4b

Table 4b. Proportion of communities in Study Area and state.

FOREST TYPE	HA. IN STUDY AREA	% OF STUDY AREA	HA. IN STATE	% OF STATE	% OF STATEWIDE TOTAL IN STUDY AREA
White, Red, Jack Pine	47.927	8.7	560,153	2.6	8.6
Spruce-Fir	129,712	23.5	1,428,342	6.6	9.1
Oak	0	0	558,927	2.6	0
Elm-Ash-Cottonwood	777	1.0	534,746	2.5	0.1
Maple-Birch-Basswood	113	0.0	422,974	1.9	0.0
Unproductive	25,758	4.7	434,395	2.0	5.9
Unforested	59,416	20.0	13,571,724	62.3	.4
Aspen-Birch	288,434	52.2	4,283,342	19.7	6.7

Although there is a great over-representation of aspen-birch forests in the Study Area in comparison with the state as a whole (52.2% vs. 19.7%), the actual percent of the statewide total located in the Study Area is less for aspen-birch than for pines and spruce-fir. Direct land loss of the entire Study Area would result in loss of roughly 9 percent of state pine and spruce-fir lands, but 7 percent of aspen-birch. The rapid natural regeneration of aspen-birch throughout the northern third of the state suggests that direct land loss from this community would have a less significant statewide impact than loss of pine-lands, which only regenerate by seeding and planting. Because of the geographic distribution of aspen-birch in the Study Area, it appears that direct land loss in the southern portion of the area would therefore have a less significant impact than in the north.

Indirect impacts on forest communities will depend on the sensitivity of the community and proximity to a smelter. Within the constraints of available transportation and economic considerations, siting of a smelter is flexible. Coniferous species are generally most sensitive to levels of pollution that may arise from a smelter under breakdown conditions. Areas dominated by conifers can be expected to be most susceptible to SO_2 damage if a smelter is located nearby. Although aspen is nearly as sensitive to SO_2 fumigation as conifers, aspen forests can be expected to regenerate unless exposed to repeated pollution incidents.

Forest species that dominate in other areas of Minnesota (basswood, maple, and oak) are less sensitive to pollution injury than those of northeastern Minnesota (see Table 24). In addition to the predominance of sensitive species in the Arrowhead Region, soils in northeastern Minnesota are less calcareous than elsewhere in the state, resulting in reduced ability to bind heavy metals and reduced capacity to buffer acid rainfall. The combination of these factors makes forested areas of the Arrowhead Region generally more susceptible to pollution than areas elsewhere in the state. Agricultural lands in the southwestern portion of the Study Area are devoted mainly to pastures and haylands. Legumes such as alfalfa are reported to be highly sensitive to SO_2 damage (Krupa et al. 1977). Crops such as corn and potatoes, grown in the western and southern portions of the state, are reported to be less sensitive. Together, these trends suggest that northeastern Minnesota is the most sensitive part of the state in which to site a smelter.

2.2 PHILOSOPHY AND METHOD OF APPROACH TO REGIONAL CHARACTERIZATION

The study of terrestrial ecosystems requires an understanding of the interactions and interdependencies of the organisms. Generally, studies of this type consider individual habitat types because the reliance of organisms on a particular habitat involves a large number of relationships, some simple and some quite complex. Preferred habitats optimize a variety of factors for animals, including food, water, cover, escape routes and good den sites for bedding or nesting. For example, the songbird association of conifer wetlands is a unique bird community with many members that are restricted to conifer wetlands. Examination of the functional attributes of this avian community reveals that over three-fourths of the individuals are ground nesters that rely on the low shrub cover and abundant sphagnum mosses for nest sites. Yet appropriate nesting sites alone do not account for the preference of these bird species for bogs. Equally important is the coniferous tree layer, because it harbors the insects that provide food for these bird species. Thus, two separate attributes of the vegetation are important in determining which birds live in the community. But one of these attributes is important not in and of itself but because it supports another population (insects) on which the birds in turn depend.

Some dependencies on habitat are more restricted. Ruffed grouse, for example, use alder carrs only when the broods are very young. The dense cover of these brushy wetlands hides the chicks from avian predators while they dine on insects hidden in the ferns (their sole diet during their early weeks). Without the presence of this sheltering habitat during a brief period of their lives, the birds would be subject to greater chick mortality.

Behavioral adaptations of animals also play a large part in determining which plant communities provide habitat where they will be most successful. For example, both deer and moose use small recent clearcuts for browse. But clear-cuts larger than 50 hectares (ha=2.47 acres) are used exclusively by moose. Within the Study Area healthy moose have no natural enemies, so they can afford to stand exposed in large open areas. Deer, on the other hand, must remain wary of wolves, and avoid large open areas in which they would be more vulnerable. Yet even if the deer were less wary, it would not be to the advantage of the wolves to deplete their population. In areas of the BWCA where wolves have decimated the deer population, the pups are now dying of malnutrition.

Animals are not alone in their adaptation to their environment. The tolerance of needle-leaved plants for drier conditions is a result of the fact that less leaf area is exposed for evaporation. Many plant species have such individual adaptations which allow them to survive otherwise severe conditions. In another example, "carnivorous" plants such as the pitcher plant and sundew are restricted to particular bogs because they have the ability to break down and absorb nitrogen from animal (insect) protein and thereby outcompete "normal" plants that are nitrogen limited. Within most habitats nitrogen is available in sufficient amounts to negate such an unusual strategy. Other habitats may be dominated by species such as alder, capable of fixing atmospheric nitrogen by the action of special bacteria located in nodules on the roots. Some wetlands receive most of their nitrogen in the form of organic matter washed in from neighboring communities. In the case of the sundew and pitcher plant, the bogs in which they live receive their nutrients mainly from rainfall. Little nitrogenous matter enters the system from runoff. So the carnivorous plants "short-circuit" the system by capturing nitrogen from insects that may have originated in more nitrogen-rich communities. In addition to this unique adaptation by forest floor plants, bluegreen algae in lichens on black spruce fix N and contribute significantly to black spruce nutrition.

Within each of the communities, or habitat types, in the Study Area, this report will present some of the structural attributes of the ecosystem such as numbers and distribution of individuals. The subtle interactions that link components of the community are not always as easy to see as a hawk killing a snowshoe hare. Nonetheless, they are there. If each community is examined in detail, great numbers of trophic and behavioral relationships become evident and the relationships between components of a community appear more like a network and less like a chain. Each individual organism is vitally linked into the network. The greater the preference of an animal for a particular community, the more closely it is linked into the network of that community. Hence, the more likely it is that anything which destroys even a few of the attributes of that community will affect the success of the plant or animal in question.

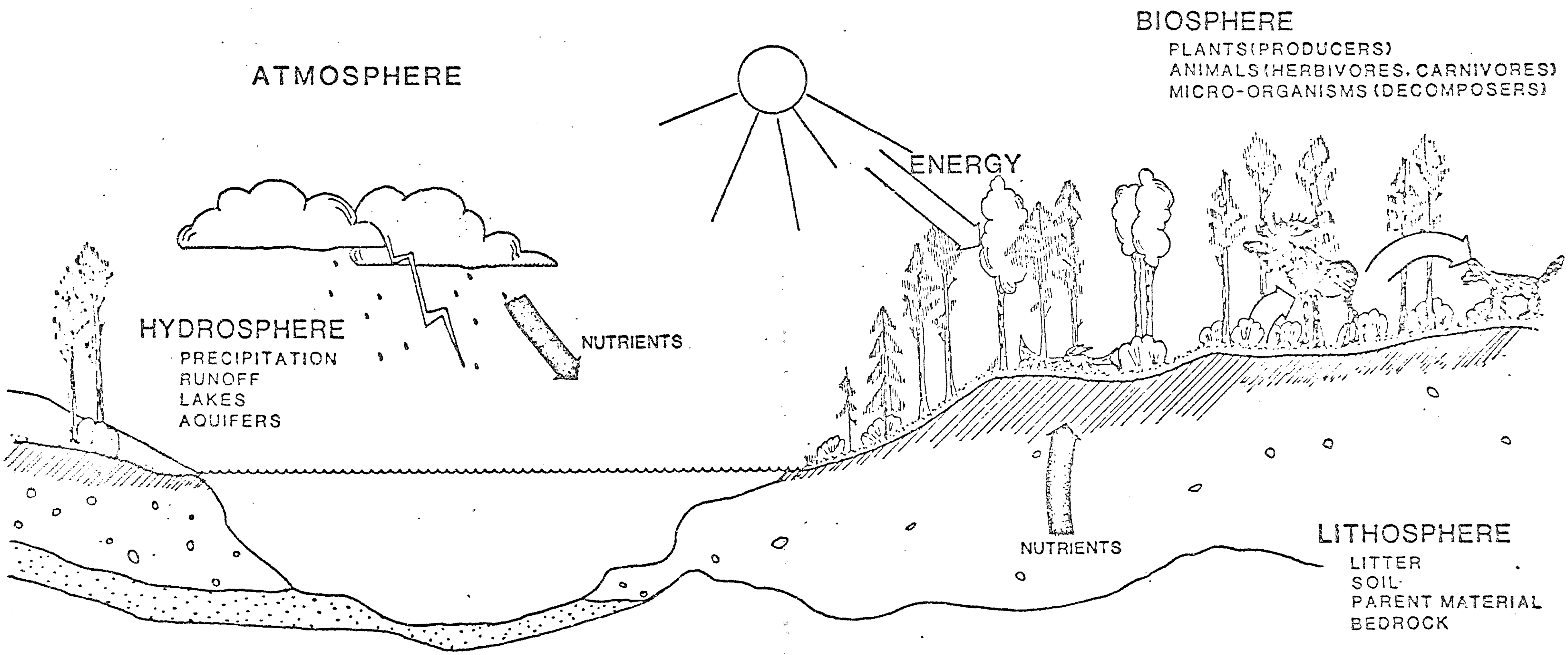
For the purposes of this study, terrestrial ecosystems were taken as forest communities. Both upland and lowland communities are considered to be terrestrial ecosystems. Although the distinction between aquatic and terrestrial ecosystems is somewhat difficult in areas where sedges dominate the vegetation and water levels are frequently high, such habitats were not sampled as part of the Terrestrial Biology program. The Regional Study focused its sampling efforts on forested communities because they lie within and adjacent to the mineral resource zone and are most likely to be directly affected by mining. Within the Study Area, agricultural lands generally lie west of the mineral resource zone.

Terrestrial ecosystems are comprised of living and nonliving components--attributes that all or most ecosystems have in common (Figure 1). Components chosen for study included soils, vegetation, small mammals, songbirds, game birds, raptors, and large mammals. The Regional Study was directed toward characterizing each of these components in as much detail as possible during the time alloted for sampling. In addition to characterizing components, an effort was made to determine potential stresses related to copper-nickel mining that might affect individual components. Because all components could not be subjected to all possible stresses, stress response studies frequently had to be based upon reviews of literature that describe how components are affected by development in areas where mining and smelting of ores are currently practiced. Subsequent impact analyses incorporate information gained from characterization and stress response studies in an effort to determine how the unique communities of northeastern Minnesota will respond to mining activities that might occur in the future.

Figure 1

Fundamental to the analysis of mining impacts on terrestrial ecosystems is an understanding of the ecosystem concept. This idea, first proposed by A. G. Tansley in 1935, views all components of ecosystems as being interrelated and interdependent. A forest ecosystem, for example, can then be viewed as receiving a finite amount of energy from external sources (e.g. the sun) over a discrete period of time. Energy is then partitioned and transferred among the various ecosystem components through their trophic (feeding) relationships. For example, plants are producers, insects that feed on them are primary consumers (herbivores), and birds that glean the insects are secondary consumers (carnivores). At each trophic level some energy is spent in metabolism so that not all the original energy captured by photosynthesis or obtained by feeding is

FIGURE 1 COMPONENTS OF THE TERRESTRIAL ECOSYSTEM



available to the next trophic level. As organisms die, their remains are utilized by decomposer organisms (e.g. fungi and bacteria) that release both energy and organically bound nutrients. Energy drives ecosystem processes and is utilized to develop and maintain the structural integrity of the system.

An understanding of ecosystem relationships is important to assessing mining impacts because impacts frequently are expressed with respect to individual components or processes. The ecosystem concept suggests that if a specific process, such as photosynthesis or decomposition, is altered by a pollutant, many other components and processes will be affected in a secondary manner. Furthermore, responses of some components may not be directly harmful to that component, yet be very harmful to a component that is dependent upon the first. As an example, individual plants may contain non-toxic levels of heavy metals, but animals feeding on many such plants may accumulate the metal until it reaches levels that cause physiological abnormalities, such as altered orienteering behavior in bees gathering pollen in polluted areas.

In addition to studying intra-system characteristics of ecosystems, it is often necessary to examine interactions between individual communities. Ecosystem analysis is, in fact, most useful when examining systems on an input-output basis. This is especially true for pollution assessment work where potentially toxic materials are added to a system. Communities, as with individual organisms, vary in their ability to absorb pollutants without suffering adverse effects, and ecosystem analysis allows the researcher not only to quantify gains and losses, but also to follow the progress of added materials through ecosystems.

The definition of community boundaries within a region is somewhat arbitrary. Boundaries may often be adjusted depending upon the reasons for studying an area. Classification of major ecosystem components (e.g. vegetation or soils) is often used to define limits because all communities within an area can rarely be studied and it is often valid to assume that communities with like characteristics will react in a similar and unique manner to an individual stress. Within the Study Area as a whole, the boundaries of terrestrial ecosystems as opposed to aquatic ecosystems, were drawn where wetland communities (including Shrub Carrs) met open water. Several factors were used to define individual communities. Dominant plant species were the most important factors considered. Generalized inventories of the vegetation of the region existed in advance of the Study and were used initially to separate major vegetation types. An inventory of soil types also existed and was used to differentiate occurrences of given vegetation types (e.g. jack pine or aspen-birch) on more than one soil type. Plant species distributions often depend upon somewhat narrowly defined moisture and nutrient requirements, and quantitative sampling of vegetation types was stratified so that sites were on soils that were typical of those on which the vegetation type normally occurred (e.g. jack pine on coarse-textured soils, black spruce on organic soils).

The boundaries between communities vary not only spatially but over time. The natural temporal variability within a community is known as succession and is based on the observation that a dominant species often influences its environment in ways that are detrimental to its perpetuation. Species that are favored by the altered conditions will in time replace the original species "successively" until a hypothetical situation is reached in which the dominant species can persist in the environment which they generate. An example of the successional process in the Study Area is the progression of forests on one site from "sunloving" aspen forests to forests dominated by more shade tolerant species, such as balsam fir. The "climax theory" of Clements (1916) proposed that single forest types would dominate entire climatic regions if natural processes were left undisturbed. Within the Study Area, debate has centered around whether the climax would be dominated by long-lived species such as pine (Stallard 1929; Waring 1959) or shade-tolerant species such as spruce, fir, and cedar (Cooper 1913; Kittredge 1934; Grant 1934; Grigal and Ohmann 1975). In practice, differences in soil types and recurring disturbances such as fires and wind storms throughout history (Heinselman 1973) have retained the area as a mosaic of communities.

The concept of succession is important to the impact analysis, for it indicates that communities of the Study Area will change in the future, with or without the inclusion of copper-nickel mining and possible associated stresses. One of the most difficult aspects of impact analysis is that of discriminating between natural successional changes (including forest management) and changes that occur as a direct result of development stress. Often synergistic effects may occur. For example, forest management practices may cause extensive areas to be occupied by stands dominated by a single tree species. If that species is one that is susceptible to damage by air pollutants, increasing levels of a toxicant could cause more widespread ecosystem destruction than if mixed stands had been maintained.

2.3 REGIONAL OVERVIEW

2.3.1 Physiography

Nine broad physiographic regions (Figure 2) can be distinguished within the Regional Copper-Nickel Study Area (Study Area)(see Volume 3-Chapter 1). Of these only one, the Embarrass Mountains Taconite Mining Province (A)(Olcott and Siegal 1978) is a bedrock feature. This province includes the Giants Range, which extends from Grand Rapids to Babbitt and the associated Biwabik Iron Formation.

Figure 2

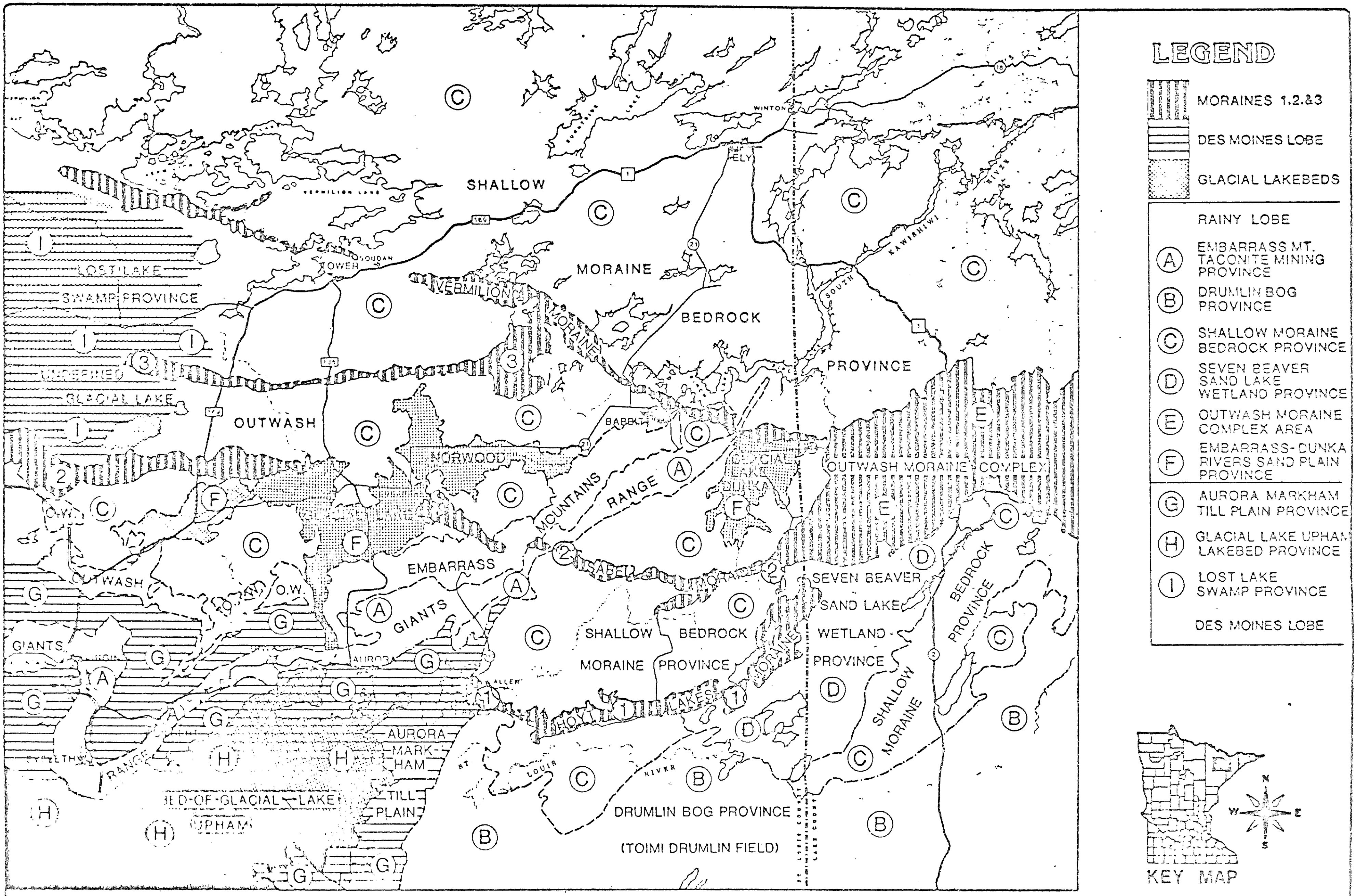
The remaining eight provinces are dominated by geomorphic features of glacial origin. The entire area was glaciated by the Rainy Lobe of the Laurentian ice sheet. The contemporaneous glaciation of the Superior Lowlands by the Superior Lobe affected the Study Area indirectly by impounding the St. Louis River to create Glacial Lake Upham in the broad plain south of Hibbing and Virginia. North of the Giants Range glacial deposits are generally thinner and bedrock is more exposed than south of the range.

Physiographic provinces in the area include:

A) Embarrass Mountains, Taconite Mining Province.

B) The Drumlin Bog Province, composed of the Toimi Drumlin Field and intervening wetlands.

C) Shallow Moraine Bedrock Province, encompassing over half the area, especially in the north. The province includes three parallel sets of end moraines and intervening areas of ground moraine.



MEQB REGIONAL COPPER-NICKEL STUDY

FIGURE 2 PHYSIOGRAPHIC PROVINCES & GLACIAL FEATURES

SOURCES: Olcott and Siegal 1978 and Winter, Cottam and Young 1973

D) Associated historically with the Outwash Moraine Complex Province is the Seven Beaver-Sand Lake Wetland Province, an extensive peatland overlying undescribed glacial material associated with the still stand of the Rainy Lobe in the Outwash Moraine Complex Province. The underlain mineral materials may be either outwash or lacustrine sediments.

E) The Outwash Moraine Complex Province, which lies at the east end of the Vermilion Moraine complex. The landscape is pockmarked by small ice-block lakes centered around Slate Lake.

F) The Embarrass-Dunka Rivers Sand Plain Province, formed by the impoundment of northward flowing streams by the Rainy Lobe. The province is comprised of two glacial lake beds, Glacial Lake Norwood in the valleys of the Pike and Embarrass rivers, and Glacial Lake Dunka in the Dunka River valley.

G) The Aurora-Markham Till Plain Province, which is one of two provinces associated with activities of the St. Louis Sublobe of the Des Moines Lobe. This lobe originated in the Red River Valley Lowland, and the St. Louis Sublobe extended eastward as far as the Study Area overriding lake sediments in the bed of Glacial Lake Upham, which had receded after the retreat of the Rainy and Superior lobes.

H) The bed of Glacial Lake Upham, which forms a separate province south of Virginia and Hibbing. The bed was twice occupied by glacial lakes resulting from the blockage of the St. Louis River, first by Superior Lobe ice and later by St. Louis Sublobe ice.

I) The province southwest of Vermillion Lake is the bed of an undefined glacial lake whose history has not been investigated.

The Laurentian Divide passes through the Study Area separating north-flowing waters of the Hudson's Bay drainage from south-flowing waters of the Lake Superior drainage. The Kawishiwi River and its tributaries--the Dunka, Stony, and Isabella rivers--drain northward through the BWCA. Farther west the Pike River and upper reaches of the Little Fork River also drain northward. The St. Louis River and its tributaries--the North, Partridge, Embarrass, and Whiteface rivers--drain southward into Lake Superior. The Laurentian Divide does not follow the ridge of the Giants Range, but rather the height of land between the Embarrass and Pike rivers with southward drainage passing through the Embarrass channel. To the east it passes through the Seven Beaver-Sand Lake wetland separating the drainage of the North and Stony rivers.

2.3.2 Soils

Soils of the Study Area are the result of weathering of parent material (either glacial deposits or bedrock) and decomposition of organic matter over a long period of time. The texture (particle size) of the soil is dependent on the nature of the parent material and is an important influence on the type of vegetation that develops. Thin soils and coarse-textured soils tend to support xeric species (tolerant of dry conditions) such as jack pine, whereas finer-textured soils which hold more water, allow more mesic species such as aspen, maple, and white pine to thrive. Organic or peat soils, resulting from incomplete decomposition of organic matter in waterlogged situations, support those species that can withstand poor drainage, such as tamarack and black spruce.

An example of thin soils in the Study Area is the Mesaba-Barto Association located mainly in the northeastern part of the area (Figure 3). The Cloquet-

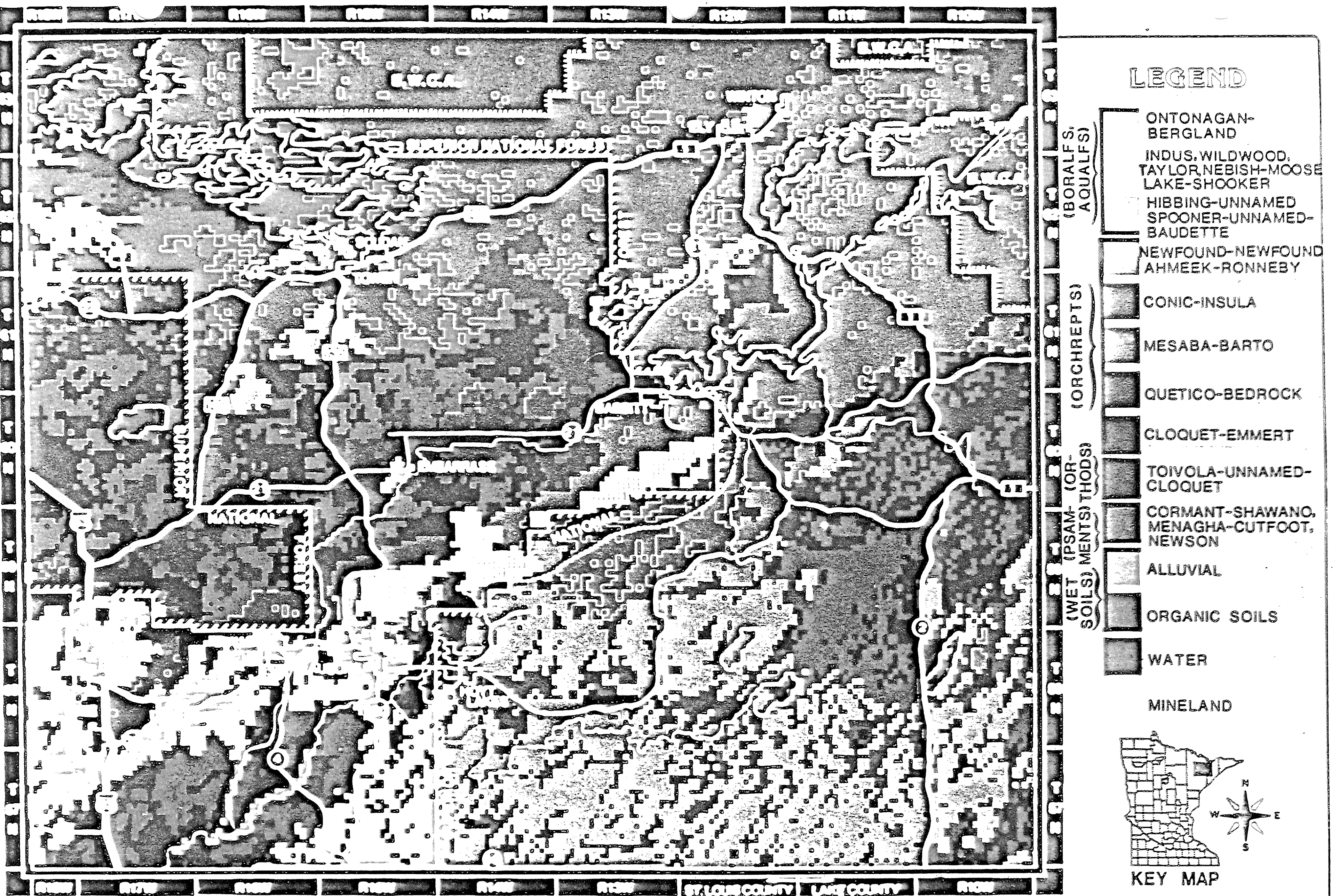
Unnamed-Toivola soils that are common on uplands in the central portion of the Study Area are deeper than the Mesaba-Barto soils, but often support xeric forest communities because these loamy soils overly sands and gravels that cause excessive drainage. On the other hand, the thick Newfound soils that are more common in the Toimi Drumlin Field are less well-drained and more likely to support aspen-birch communities. Poorly-drained organic soils such as the Mooselake and Greenwood series are widespread throughout the area and overlie several types of parent materials including bedrock in the north, lake clays in the southwest and northwest, and outwash in the southeast parts of the Study Area. Once organic soils begin to build, they perpetuate poor drainage conditions because of the high water retention capacity of Sphagnum, which develops on them. On mineral (non-organic) soils in the Study Area, litter decomposition appears to be most rapid on soils of the Newfound association (see Volume 3-Chapter 1).

Figure 3

Characteristics of soil associations found in the Area are presented in more detail in Volume 3-Chapter 1 of this report and in the first level reports on soils of the Study Area and soil decomposition.

2.3.3 Major Plant Communities

The vegetation of northeastern Minnesota has long been recognized as a mosaic of forest communities. Marshner's (1930) map of the state's presettlement vegetation (based on records of the General Land Survey Office) illustrates this mosaic very well. The section of this map showing the vegetation of the Study Area (Figure 4) is based on land surveys done in the 1880s. On a gross scale



MEQB REGIONAL COPPER-NICKEL STUDY

FIGURE 4

SOIL ASSOCIATIONS

the vegetation appears to correspond well with physiographic units, with aspen-birch communities most extensive in the Toimi Drumlin Field, jack pine in the Shallow Moraine Bedrock Province, white and red pine in extensive areas of ground moraine, wetlands in glacial lake plains, and hardwoods mixed with pines along the Giants Range. On a finer scale, the influence of topography can be seen in the inclusion of wetlands within areas of other extensive vegetation types. Common canopy species of northeastern Minnesota have centers of origin lying either within the Lake States or farther to the east and south (sugar maple, basswood, northern red oak, white pine, red pine) or in Canada (spruce, fir, aspen, paper birch). In general, the vegetation of the area has been recognized as having affinities with the forests of the Lake States (Sargent 1884; Weaver and Clements 1929; Nichols 1935; Braun 1950; Bakuzis and Hansen 1959; Rowe 1954). Modern distribution of the vegetation (Figures 5 and 6) is similar to the original vegetation on a gross scale, but varies on a fine scale depending on the history of land use in the intervening period.

<u>Figures 4,5, & 6</u>

2.3.3.1 <u>Succession</u>--A computer model developed by the Regional Study (Sloss 1977) was used to predict future community distribution in the Study Area. The model uses a set of linear equations to account simultaneously for the influences of natural succession, natural biotic and abiotic disturbances, and management. Trends in natural succession were derived from the literature and from comments by ecologists familiar with the Study Area. Epidemics of spruce budworm and white pine blister rust were considered as the major forms of disturbance affecting the area. Current management guidelines for the Superior National Forest were used to determine management vectors. The area was assumed

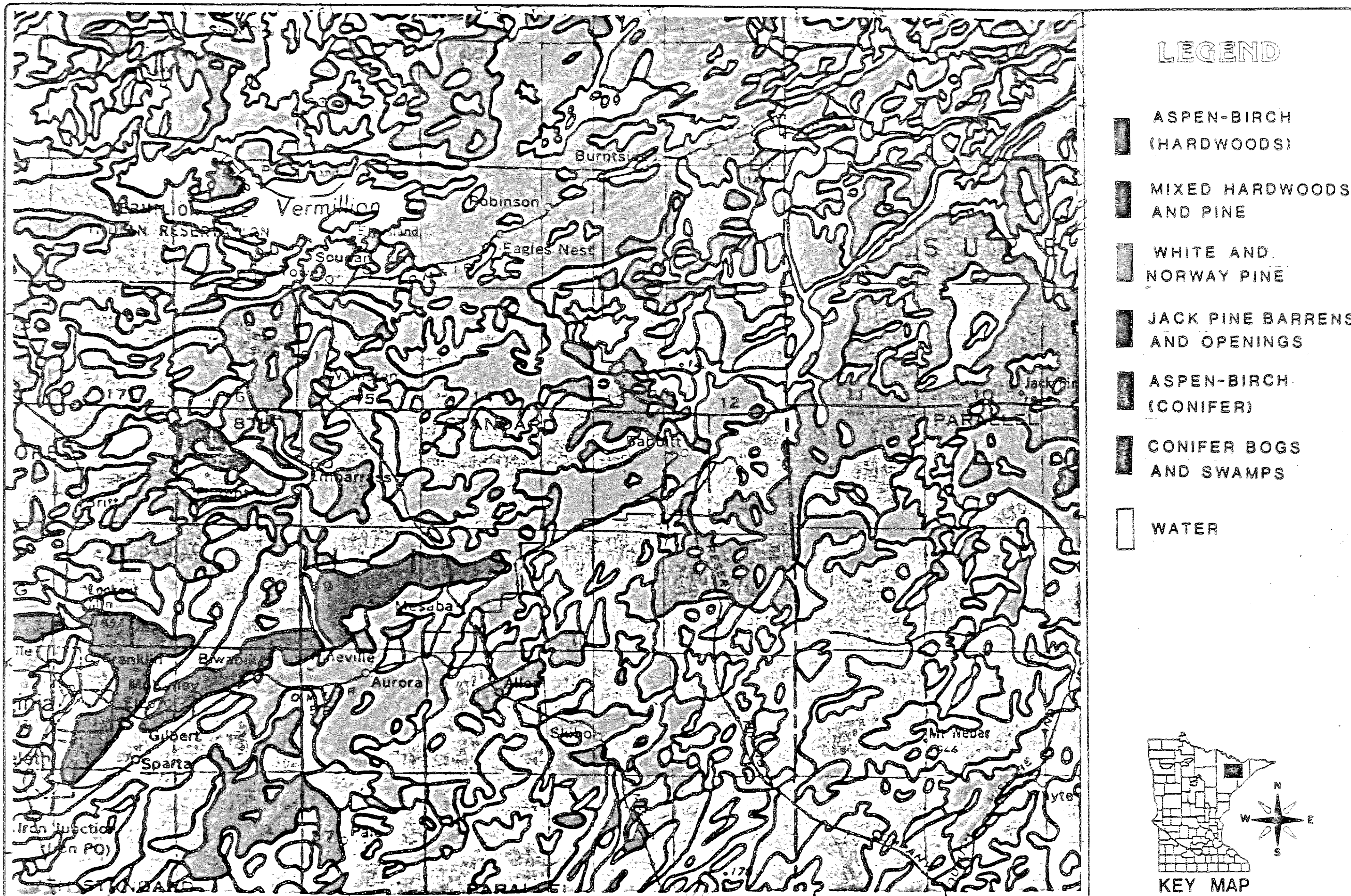
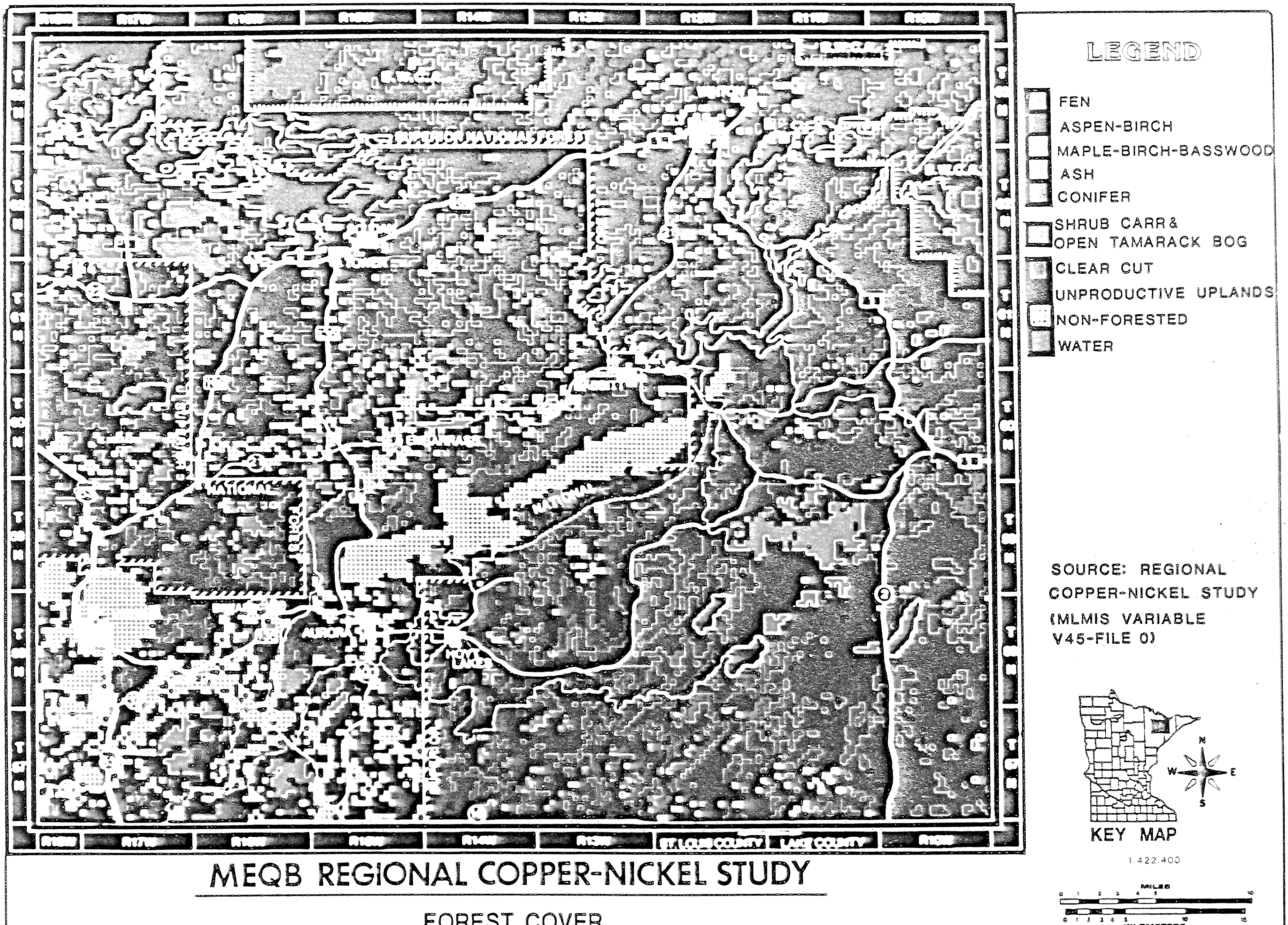


FIGURE 4

MEQB REGIONAL COPPER-NICKEL STUDY

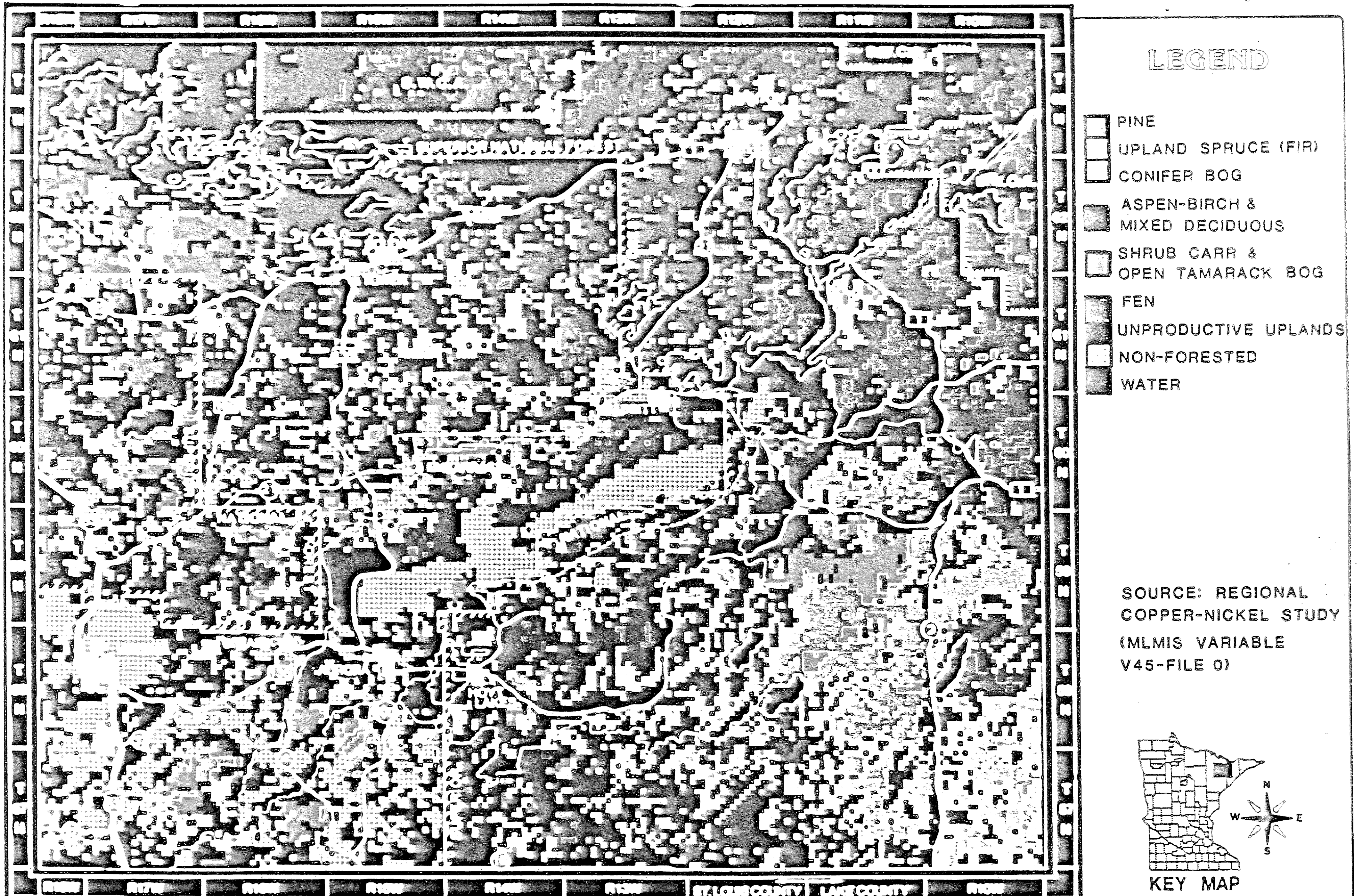
ORIGINAL VEGETATION OF THE STUDY AREA
ACCORDING TO MARSHNER (1930)



MEQB REGIONAL COPPER-NICKEL STUDY

FOREST COVER

DETAILED DECIDUOUS



MEQB REGIONAL COPPER-NICKEL STUDY

FOREST COVER

DETAILED CONIFEROUS

to be comprised of discrete forest cover types (those used by the Forest Service), which were assumed to change from one type to another by discrete increments. Three sorts of information were needed to construct the data matrices: the age at which the first species is succeeded by a second, the probability of succession by a given succeeding species, and the age of the succeeding species at the time it gains canopy dominance.

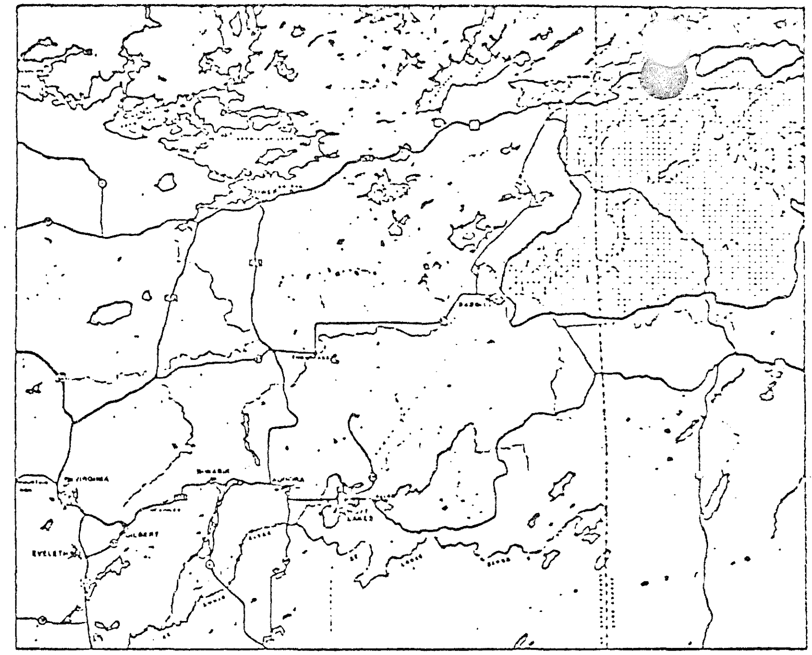
Figure 7a-c summarizes the results of the model for changes within the northeastern sixth of the Study Area over the next 100 years. The fir-spruce-deciduous community was assumed to be the climax community for the area. As can be seen, the model predicts decreases in pioneer species and increases in shade-tolerant species over time. Predicted increases in red pine and white spruce over the next 100 years reflect forest management for these types. The slow trend toward increasing lowland black spruce reflects succession from tamarack and sedge communities to this type. Although "mixed bog" is believed by many ecologists to be the lowland climax, its failure to increase during the next 100 years reflects the model's assumption that lowland succession is an extremely slow process. Further discussion of the model and its results is presented in the first level report "Predicting Forest Cover Type Changes for a Region of Northeastern Minnesota" (Sloss 1977).

Figure 7a-c

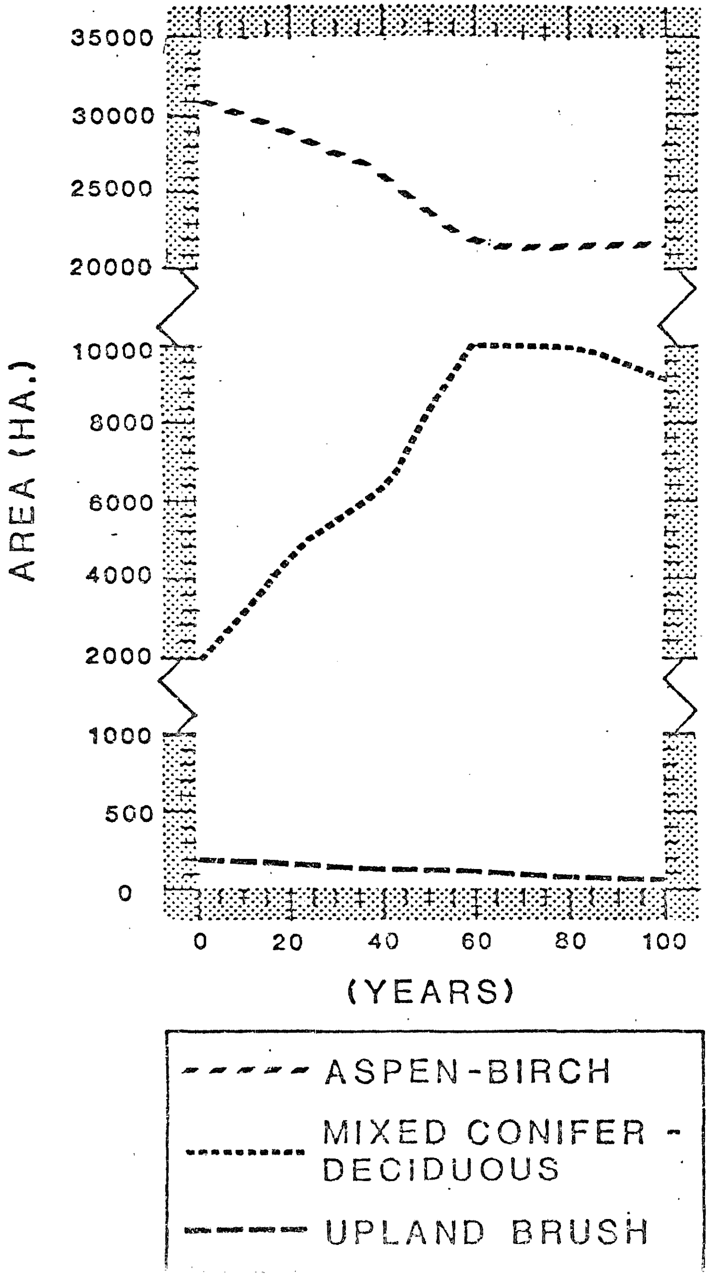
2.3.4 Seasonal Patterns

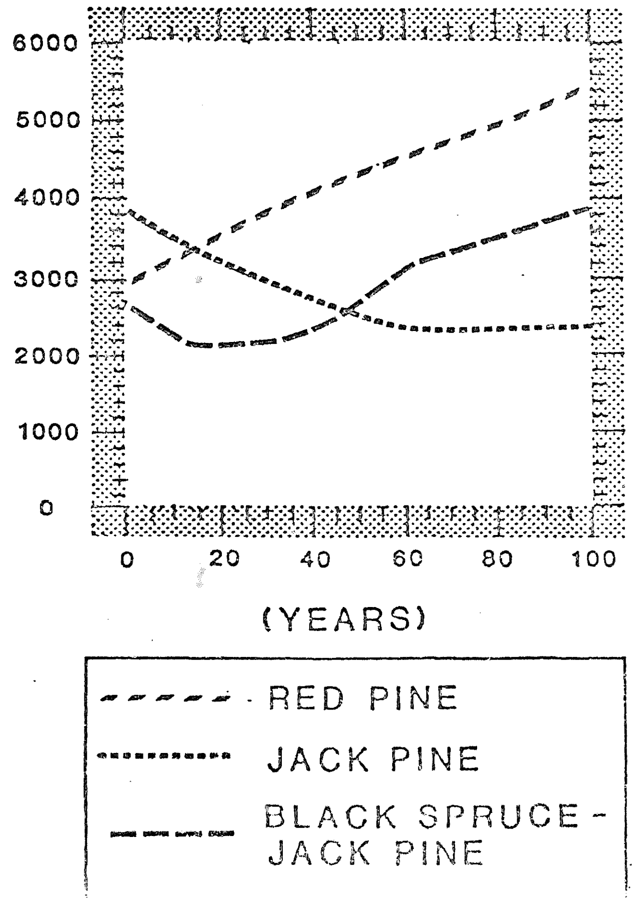
2.3.4.1 Plants--Observable patterns of leaf out, color change, and leaf-fall in plants are related to physiological changes within the plants. Certain elements are distributed to the leaves when the sap rises but are translocated back into

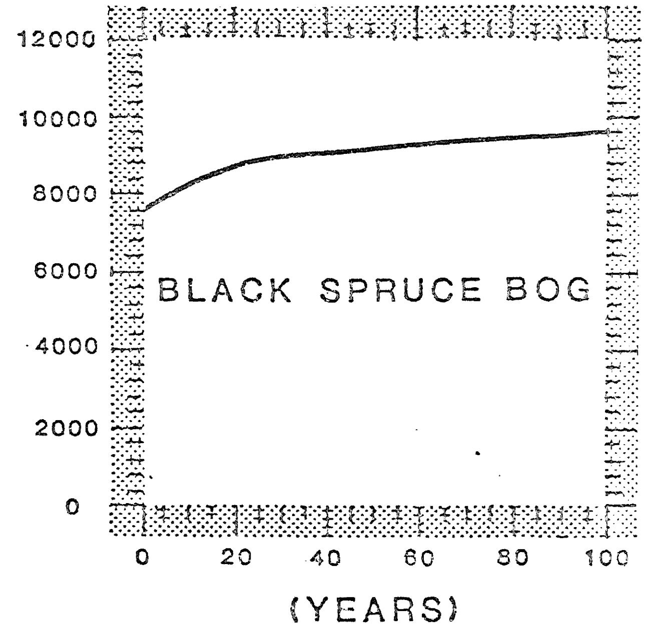
FIGURE 7A PROJECTED SUCCESSIONAL TRENDS



SUCCESSION MODEL STUDY REGION







SOURCE: Sloss 1978

the bole and roots at the end of the season. Others are lost as the leaves fall. The metabolism of rapidly growing leaves and of actively photosynthesizing leaves differs from that of senescent leaves. Thus, the value of plants to animals varies seasonally, not only in the amount of leaf area present, but in nutrient value.

Phenological studies are an important contribution to the understanding of potential impacts because they establish an understanding of the timing of seasonal changes. Unless normal dates of phenological changes are known for an area, chlorosis caused by air pollution could be mistaken for normal color change. Premature leaf senescence and abcission have been reported in deciduous species near a nickel smelter in Thompson, Manitoba (Blauel and Hocking 1974). More important than the possibiity that symptoms of injury may be confused with normal changes are differences in susceptibiity to pollution at different phenological stages. Contrary to early reports (Zimmerman and Crocker 1934), newly emerged leaves of deciduous species are apparently more resistant to SO_2 fumigations than fully developed leaves (Tamm and Aronsson 1972). In addition to differing susceptibilities at different stages of leaf development, studies have shown that the stage of development of staminate and pistillate flowers of aspen affects the influence of pollutants on reproduction.

During the two field seasons phenological observations were made at twenty sites along a north-south transect through the Study Area. Eleven deciduous woody species were observed from mid April (1977) or mid May (1976) through the end of May and from mid August through October. Percentage data were recorded for leaf-out, flowering, color change, and leaf-fall for each tree at each site.

Dates of initial leaf-out varied from late April for tamarack to late May for black ash. The small size of the sample for most species and the within-site variability make it difficult to document the obvious time lag of several days between the southern and northern parts of the Study Area.

No evergreen species were observed as part of this study, but Ahlgren (1957) found that evergreens leaf-out in late May and June and that most flower slightly before leaf-out. Five of seven evergreen species observed by Ahlgren responded to temperature cues, such as maximum and minimum temperatures, to initiate activity. Only four of twelve deciduous species responded to such cues.

The relationship of flowering to vegetative bud swell followed consistent patterns over the five years of Ahlgren's study. Four patterns of response are reported in his work: flowering preceding vegetative bud swell, flowering following bud swell but preceding leaf-out, flowering following initial leafing, and simultaneous bud swell and flowering. The Regional Study's 1977 observations were consistent with Ahlgren's findings for species observed in both studies. Flowering of black ash preceded leafing by 2 to 3 weeks whereas that of tamarack followed leaf-out.

During the 1976 season leaf color change in the Study Area began about two weeks earlier than in 1977, but leaves of several species persisted longer in 1976 than 1977. This anomalous pattern is mainly explained by the fact that in 1976 many leaves wilted and turned brown (in response to severe drought) before forming abcission layers. These leaves were retained until late fall.

Leaf-fall for evergreens is documented by Sargent (1933). White pine retains its needles for 2 years, jack pine 2-3 years, red pine 4-5 years, both spruce species 7-10 years, and fir 8-10 years. Evergreenness is an adaptation that enables the plant to photosynthesize early in the season before energy is allocated for the formation of new needles in areas where the growing season is short. There is some evidence (C.C. Gordon, University of Montana, personal communication 1978) that air pollution reduces the retention time of evergreen needles, diminishing the photosynthetic efficiency of the plant.

2.3.4.2 Small Mammals--The only species of small mammals collected in the Study Area that hibernate during the winter are the chipmunks (*Eutamias minimus* and *Tamias striatus*) and jumping mice (*Zapus hudsonicus* and *Napaeozapus insignis*). All others are active under the snow. The majority are small seed-eaters that must rely on scavenging during the winter. Winter food resources for shrews are not well understood but immature stages of insects may constitute a large part of their diet. Red squirrels (*Tamiasciurus hudsonicus*) cache pine seeds for winter food.

Reproduction in all small mammals in the Study Area is limited to the summer period. No more than two litters are produced in a summer.

2.3.4.3 Large Mammals--Among the large mammals of the Study Area, only three--the black bear (*Ursus americanus*), raccoon (*Procyon lotor*), and striped skunk (*Mephitis mephitis*)-- are winter dormant. All emerge in March or April. Porcupines (*Erithizon dorsatum*), muskrats (*Ondatra zibethicus*), and beaver (*Castor canadensis*) establish winter dens or houses but remain active using either nearby food or caches. The herbivores--moose (*Alces alces*), deer (*Odocoileus virginianus*), and snowshoe hare (*Lepus americanus*)--use different food and cover in the winter than in the summer. Both moose and hare concentrate in black spruce lowlands during the winter. In the Agassiz lowland of northwestern Minnesota moose have been reported to move as far as 20 miles to favored winter habitat (Phillips, Berg, and Siniff 1973). Deer may migrate similar distances and tend to concentrate in traditional wintering areas even after food supplies have been depleted. Winter-use areas in a belt from Burntside Lake to Garden Lake are generally associated with buffer zones between wolf packs (Hoskinson and Mech 1976; Mech and Karns 1977). Winter-use areas in the Study Area exhibit lower densities than winter deer yards along the North Shore.

Predators such as wolves (Canis lupus lycaeon), fisher (Martes pennanti), marten (Martes americana), otter (Lontra canadensis), mink (Mustela vison), and weasel (Mustela spp.) remain active and in the same territories throughout the year. Those that rely on prey that change habitats during the winter tend to redefine their use areas to follow those of their prey.

Reproductive activities of large mammals vary with the duration of gestation. Regardless of gestation period, breeding activity occurs at a time of year that results in parturition during the spring. Bears are among the earliest large mammals to give birth because the young are born in the den during dormancy, usually around February. Young of most other species are generally born no earlier than March and no later than May or early June. Only two species--the snowshoe hare and muskrat--have more than one litter at Minnesota's latitude. In both cases the average number of litters is slightly over two.

2.3.4.4 Raptors and Game Birds--Among the game birds, both ruffed grouse (Bonasa umbellus) and spruce grouse (Canachites canadensis) are year-round residents, whereas the woodcock (Philohela minor) is migratory. Display periods for all three species extend from March through May.

Resident raptors include the goshawk (Accipiter gentilis), great horned owl (Bubo virginianus), barred owl (Strix varia), and saw-whet owl (Aegolius acadicus). All other hawks and owls, bald eagles (Heliaeetus leucocephalus), and ospreys (Pandion heliaetus) are migratory. Owls breed in March, all other raptors in May or June. The path of southward migration is concentrated in the area of Duluth by the combined effect of the lake, the presence of thermals, and the southeastward extension of coniferous forests. The Hawk Ridge Reserve, four miles east of downtown Duluth, has the highest numbers of migratory raptors in the state, with peak levels in September. Seventy percent of birds passing this point are broad-winged hawks (Buteo platypterus), but the list of species includes all migratory raptors present in the Study Area as well as several with declining populations and the endangered Peregrine falcon (Falco peregrinus).

2.3.4.5 Songbirds--Four general categories of songbirds are present in the Study Area: migratory summer residents, permanent residents, winter visitants, and migrants. Over 95 percent of summer observations were of migratory summer residents, whereas approximately 60 percent of winter observations were of permanent residents.

Migration begins in late March with migratory finches and thrushes passing northward into breeding areas in Canada. Summer residents generally arrive in late April and early May. As Erskine (1977) points out, strictly insectivorous birds such as swallows, warblers, flycatchers, and vireos cannot afford to arrive until about mid May and must leave by September. The resident season for seed-eaters is extended somewhat in the autumn because their resources remain available longer. Insectivores are resident for about 3 months, seed-eaters for 4-5 months.

For almost all species except resident fruit-eaters the breeding season extends from the last week of May through the second week of July. Fruit-eaters (mainly waxwings) breed later when their food source is more available. Between the breeding season and migration the birds become inconspicuous to avoid predation while they are in molt.

Year-round residents draw on all possible food sources including seeds, insect larvae, fruits, prey, and carrion. A remarkable feature of winter bird populations is the 1 or 2 year oscillation in populations of seed-eaters that varies with heavy seed crops of the boreal conifers. The Study's winter-bird data reflect this pattern because the 1976-1977 season was one of low finch populations throughout the state.

2.3.5 Rare Species

Rare species are those whose ability to perpetuate themselves is jeopardized either because of small population size, human exploitation, limited habitat, habitat destruction, or other reasons. Many species actually in danger of extinction are classified as "endangered" or "threatened" [Smithsonian Institution 1975 (plants), U.S. Fish and Wildlife Service (animals)]. A species may be considered rare for a geographic location despite the fact that it is abundant elsewhere. Isolated or outlying populations are likely to differ genetically from large continuous populations in the center of distribution. Loss of such isolated or outlying populations means a loss in the genetic variability of the species as a whole. The preservation of genetic variability is probably the biggest single reason for interest in species that are rare within one geographic area but widespread elsewhere.

Protective legislation generally regulates the killing or sale of members of an endangered or threatened species. An example is Minnesota Statute 17.23, which prohibits the sale of native orchids. Not all species that are protected are actually rare. Plants that are curiosities, subject to exploitation, or that look like rare plants are often protected. Truly rare species are often rare because their habitats are restricted. No measures for protection of individual species can be successful unless the places where they live are also protected.

No exhaustive field inventory of rare species was conducted by the Copper-Nickel Study. During the course of normal data collection, however, records of rare species were made along with those of more common species.

2.3.5.1 Plants--Locations of rare and protected plants were extracted from species lists for 277 Braun-Blanquet releve (vegetation survey) sites. Twenty-two species of rare or protected higher plants were recorded in a total of seventy-four occurrences. None of the five northeastern Minnesota species recommended by the Report on Endangered and Threatened Plant Species of the United States (Smithsonian Institution 1975) was recorded within the Study Area. Two species listed by Morley (1972) as "rare in Minnesota" were located during the course of the study. Both of these species, northern comandra (*Geocaulon lividum*) and large leaved sandwort (*Arenaria macrophylla*), are boreal plants near their southern range limits. Twenty species of plants protected by Minnesota Statute 17.23 were located within the Study Area. A list of rare species and their number of records is presented in Table 5.

Table 5

Field data for rare plants were augmented by a review of all previous locations recorded at the University of Minnesota Herbarium. This review covered all spe-

Table 5. Rare species reported within the Study Area as part of the Regional Copper-Nickel Study.

SPECIES	NUMBER OF OBSERVATIONS STATIONS
Higher plants recorded in the Braun-Blanquet releves	
Rare in Minnesota	
northern comandra (Geocaulon lividum)	1
large-leaved sandwort (Arenaria macrophylla)	1
Protected by Minnesota Statute 17.23	
swamp pink (Arethusa bulbosa)	1
spotted coral-root (Corallorhiza maculata)	14
striped coral-root (Corallorhiza striata)	3
early coral-root (Corallorhiza trifida)	2
moccasin flower (Cypripedium acaule)	9
trailing arbutus (Epigaea repens)	1
redstem gentian (Gentiana rubricaulis)	2
creeping lattice-leaf (Goodyera repens)	12
greater lattice-leaf (Goodyera tesselata)	3
white bog orchid (Habenaria dilatata)	1
northern rein orchid (Habenaria hyperborea)	5
small rein orchid (Habenaria obtusata)	1
round-leaved rein orchid (Habenaria orbiculata)	1
fringed pink orchid (Habenaria psychodes)	1
heart-leaved twayblade (Listera cordata)	1
green malaxis (Malaxis unifolia)	1
rose pogonia (Pogonia ophioglossoides)	1
slender ladies-tresses (Spiranthes lacera)	1
northern ladies-tresses (Spiranthes romanzoffiana)	1
nodding trillium (Trillium cernuum)	7
Songbirds observed during the breeding bird census	
Rare in the Superior National Forest	
goshawk	1
*sharp-shinned hawk (Accipiter striatus)	1
sparrow hawk (Falco sparverius)	
spruce grouse (Canachites canadensis)	2
sora (Porzana carolina)	2
killdeer (Charadrius vociferus)	3
common snipe (Capella gallinago)	7
solitary sandpiper (Tringa solitaria)	1
barred owl (Strix varia)	1
saw-whet owl (Aegolius acadicus)	1
pileated woodpecker (Dryocopus pileatus)	12
black-backed 3-toed woodpecker (Picoides arcticus)	1
eastern phoebe (Sayornis phoebe)	1
boreal chickadee (Parus hudsonicus)	7

Table 5 continued.

SPECIES	NUMBER OF OBSERVATIONS STATIONS
white-breasted nuthatch (*Sitta carolinensis*)	2
brown creeper (*Certhia familiaris*)	24
house wren (*Troglodytes aedon*)	2
short-billed marsh wren (*Cistothorus platensis*)	4
catbird (*Dumatella carolinensis*)	18
Philadelphia vireo (*Vireo philadelphicus*)	8
yellow warbler (*Dendroica petechia*)	7
Connecticut warbler (*Oporornis agilis*)	74
Baltimore oriole (*Icterus galbula*)	2
Brewer's blackbird (*Euphagus cyanocephalus*)	43
indigo bunting (*Passerina cyanea*)	1
Lincoln's sparrow (*Melospiza lincolnii*)	35
Very rare in the Superior National Forest	
whip-poor-will (*Caprimulgus vociferus*)	1
great crested flycatcher (*Myiarchus crinitus*)	1
brown thrasher (*Toxostoma rufum*)	32
clay-colored sparrow (*Spizella pallida*)	6
New in the Superior National Forest (circumstantial evidence)	
golden-winged warbler (*Vermivora chrysoptera*)	61
Additional Blue List species	
*sparrow hawk (*Falco sparverius*)	30
*common nighthawk (*Chordeiles minor*)	9
Raptors	
Endangered (random observations)	
bald eagle (*Heliaetus leucocephalus*)	7
*osprey (*Pandion heliaetus*)	
Other Blue List species (random observations)	
marsh hawk (*Circus cyaneus*)	2
sparrow hawk (*Falco sparverius*)	53
Small Mammals (number of sites from which the species was collected)	
Franklin's ground squirrel (*Spermophilus franklinii*)	2
southern bog lemming (*Synaptomys cooperi*)	1
Large Mammals (random observations)	
eastern timber wolf (*Canis lupus lycaon*)	7
eastern cougar (*Felis concolor schorgeri*)	4

* Denotes Blue List species

cies in Lake and St. Louis counties that were recommended by the Smithsonian Institution for national listing as threatened or endangered species, recognized as rare in Minnesota (Morley 1972), or protected by Minnesota Statute 17.23. A series of maps and lists of previously recorded stations prepared from this review is presented in the first level report "Rare Plants in the Study Area and the Arrowhead Region" (Sather 1977).

Seventy-four lichens were collected for the Copper-Nickel Study at only one or two out of 64 collection sites. Two of these species (Parmelia revoluta and Lobaria quercizans) were new records for the state. The previously recorded range of Parmelia revoluta is several hundred miles farther south.

Of 107 mosses collected at 22 sites, 60 were present in only 1 or 2 plots. Six rare species were collected: Trematodon ambiguus (first record for the state), Grimmia hermanni (first record for the state), Calliergon richardsonii, Mnium drummondii, Tomenthypnum nitens v. falcifolium, and Meersia triquetra.

2.3.5.2 Songbirds--Thirty of the 104 species of birds recorded in the Copper-Nickel Study breeding bird survey are recognized as rare or very rare in the Superior National Forest (Green 1971). These species are listed in the first level report "Songbirds of the Study Area" (Pfannmuller 1977). Three of the 104 species are on the National Audubon Society Blue List--a listing of species undergoing widespread or local population declines. Not all these species are rare in the Superior National Forest. All Blue List species are noted with an asterisk in Table 5. Although no nest was located, repeated observations suggest that the Yellow Warbler (Vermivora chrysoptera) was nesting in the Study Area. This species has not been previously reported as a nester in the Superior National Forest. Two other warblers observed during the breeding bird survey have been recognized by the State of Minnesota (MDNR 1975) as "meriting special concern." These species are the Tennessee warbler (Vermivora peregrina) and the Cape May warbler (Dendroica tigrina).

2.3.5.3 Raptors--The peregrine falcon (Falco peregrinus) is the only raptor classified under federal regulations as an endangered species. It was not observed in the Study Area. Minnesota law protects three additional raptor species--the bald eagle (Heliaeetus leucocephalus), marsh hawk (Circus cyaneus), and Cooper's hawk (Accipiter cooperi). The first two species were recorded as chance observations but were not encountered during the breeding bird survey. The secretive habits of the Cooper's hawk may account for the lack of any observations during the two year study period. The osprey (Pandion heliaetus), a species of uncertain status (MDNR 1975), was recorded both as a chance observation and during the breeding bird survey.

2.3.5.4 Small Mammals--The only small mammal listed by the MDNR (1975) as an animal "in need of special consideration" is the rock vole (Microtus chrotorrhinus). Although the rock vole was not observed as a part of this study, it has been reported within the Study Area near Burntside Lake (Swanson 1945; Handley 1954). Other species of interest are the heather vole (Phenacomys intermedius), not observed during this study; the Franklin's ground squirrel (Spermophilus franklinii), collected at two sites; and the southern bog lemming (Synaptomys cooperi), collected at one site.

2.3.5.5 Large Mammals--The eastern timber wolf (Canis lupus lycaon) is the only large mammal in the Study Area that has been accorded national recognition. The Study Area lies within the prime habitat for wolves within the contiguous United States. Recorded population densities of one wolf per 10-13 square miles are as high as anywhere in the United States and densities are highest along the north shore of Lake Superior (Van Ballenbergue 1972). A second species of interest is the eastern cougar (Felis concolor schorgeri), listed with "species that are extirpated or rare in Minnesota and have little future" (MDNR 1975). Four sightings of the eastern cougar have been made between 1974 and 1977 in the Study Area.

2.3.6 Existing Human Disturbances

Table 6 summarizes land-use and the distribution of forest communities in the Study Area. Activities associated with human development affect only about 12 percent of the area, but nearly all of the land has been altered since European man settled northeastern Minnesota 100 years ago. The most dramatic impacts are those associated with the construction of townsites and industrial development, especially iron ore and taconite mining. Natural ecosystems in these areas have essentially been destroyed or at least altered to such an extent that they are no longer recognizable. The magnitude of alteration increases in the order agriculture less than urban/residential less than mining, although many areas associated with mining (e.g. plant sites, tailings ponds, waste rock piles) can potentially be reclaimed to some of their pre-operational ecosystem functions. Agriculture in the region is concentrated on the harvesting of hay and forage. Farms are generally small (40-80 acres or less) and are interspersed among forested areas. As a result, they frequently complement adjacent natural ecosystems, at least with respect to wildlife habitat. Forested areas have also been significantly impacted by other human activities, although changes are subtle and often reversible.

Table 6

Table 6. Distribution of forest communities.

LAND USE (MLMIS)	% OF STUDY AREA	MLMIS COMMUNITY TYPE	% OF COMMERCIAL FOREST IN ARROWHEAD REGION	% OF STUDY AREA	% OF MINESITE AREA		% OF COMMERCIAL FOREST IN ARROWHEAD REGION	STUDY AREA COMMUNITY TYPE	SAF COMMUNITY TYPE
Upland Forest	64	White, Red, and Jack Pine	10.0	8.7	4.2	3.3	6.0	Jack Pine	Jack Pine
						.9	3.1	Red Pine	Red Pine
		Aspen-Birch	50.6	52.2	43.8	2.9		Mixed Conifer-Deciduous	Black Spruce-Aspen Jack Pine-Aspen Jack Pine-Paper Birch
						40.9	50.6	Aspen-Birch-Fir	White Spruce-Balsam Fir-Aspen
								Aspen-Birch	Aspen Aspen-Paper Birch Paper Birch
		Maple Basswood	4.4	.02	0.0	0.0	4.4		Sugar Maple-Basswood
Lowland Forest	16	Spruce-Fir	17.6	23.5	18.4	8.1	1.2		White Spruce
							1.6	Black Spruce-Jack Pine	Jack Pine-Black Spruce
						1.1	2.6	Cedar Swamp	Northern White Cedar
						9.1	10.5	Black Spruce	Black Spruce
						.1	1.7	Tamarack	Black Spruce-Tamarack Tamarack
		Unproductive	1.2	4.7	4.6	4.6	1.2	Shrub Carr	Unproductive Swamp
		Elm-Ash Cottonwood	3.0	1	3.9	3.9	3.0	Ash	Black Ash-American Elm-Red Maple
Non-forested	20	Mining		3		2.9		Nonforested	Nonforested
		Urban Residential		1.5					
		Open-Vacant		.5		1.0			
		Agriculture		2					
		Water		8		4.2			
SOURCE: MLMIS			SOURCE: USFS	SOURCE: MLMIS		SOURCE: MINESITE	SOURCE: USFS	SOURCE: Sather 1979c	SOURCE: SAF 1954

Table 6 continued.

Table 6 permits comparison of several schemes of land use and community classification that have been used in inventories of foreted lands in northeastern Minnesota. The communities fit into a hierarchy of classifications that are not always equivalent. From the most general to the most specific land uses and communities are distinguished by the following systems of classification:

1) MLMIS land use types are inventories for the area on the basis of 40-acre cells. Land uses are distinguishable on aerial photos at a scale of 1:80,000 and forest land uses can be further subdivided into MLMIS community types as shown in the table.

2) MLMIS community types are inventoried for the area on the basis of 40-acre cells, distinguishable on aerial photos at a scale of 1:80,000. These subdivisions of MLMIS forest land use types include the Regional Study's more detailed community types as shown in the table. Note that MLMIS spruce-fir forests include both upland and lowland types as defined by the Regional Study's classification.

3) The Regional Study's community types are based on numerical classification of 277 field sites and can be distinguished on aerial photos at a scale of 1:15,840. Except for upland spruce-fir communities, these types correspond well with the MDNR's Minesite classification for which areal coverage data are available on the basis of hectare cells in the eastern portion of the Study Area. Comparison of the proportions of Minesite and MLMIS communities in the Minesite area and the Arrowhead Region provide the only indication of the actual proportion of the Regional Study's community types throughout the Study Area because vegetation mapping was not included as a part of the Regional Study.

4) Society of American Foresters' cover types are used by the Forest Service in its compartment inventories and can be distinguished on aerial photos at a scale of 1:15,840. These more detailed types are included within the Regional Study's broader types as shown. SAF types are included in the table because they are the management types within the Superior National Forest and the terminology likely to be found in Forest Service Publications.

Recent studies (most notably that of Heinselman 1973) show that the forests of northern Minnesota burned extensively before the arrival of European man and that the virgin stands of pine that occupied the area were in fact dependent upon recurrent fire for their perpetuation. Between 1880 and 1920 most of these pine stands were harvested and the incidence of fire greatly increased as large quantities of slash provided fuel for fires. Fires were so extensive that they made habitation of the region dangerous, and extensive fire suppression efforts were instituted in the early 20th Century. Once logging activities diminished fire suppression efforts became increasingly successful and the incidence of fire in recent years has been greatly reduced. Thus, post-logging vegetation has developed under conditions quite different from those that existed prior to about 1880.

In the absence of fire, timber cutting and other forest management activities have increasingly affected the terrestrial ecosystems of the Study Area. A large proportion of the Study Area lies within the boundaries of the Superior National Forest (SNF) and timber production is a major use for these lands. Activities such as timber cutting, mechanical site preparation, prescribed burning, tree planting, and herbicide spraying strongly influence the character of vegetation in the SNF. Although management is not so extensive, timber harvesting on state, county, and private lands outside the national forest is growing in importance as regional and national demands for building materials, paper, and other forest products increase.

The uses of forests for other amenities (e.g. recreation, water, and wildlife) are also important but generally have more localized impacts than timber cutting. Mining development directly or indirectly affects most of these amenities. Because individual operations affect small areas compared to the region as a whole, impacts are likely to be greatest on forest amenities other than timber production. As demand increases for all these amenities, conflicts with mining will inevitably increase.

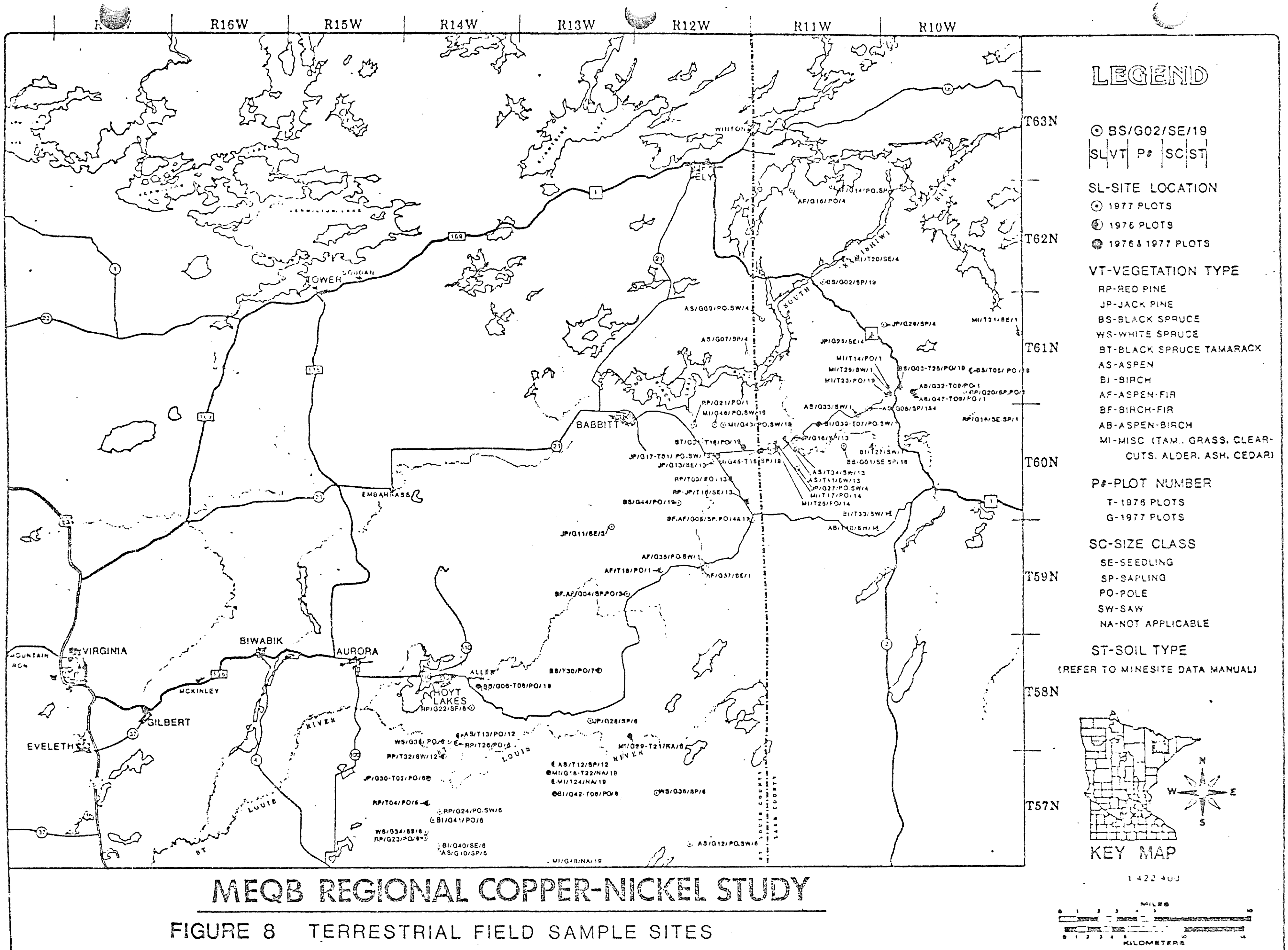
2.3.7 Habitat Types

Findings summarized in the following community descriptions are drawn from both primary and secondary data sources.

A set of 277 semi-quantitative field surveys (Braun-Blanquet releves) provides the basis for classification of the vegetation into community types. Quantitative data are available for 62 of the 277 stands. Figure 8 shows the locations of the 62 sites used in quantitative sampling. Summaries dealing with the floristic composition of vegetation types are based on the releve' data, whereas estimates of plant species density, coverage, and basal area are based on the quantitative data set. Plant communities were identified by a computerized method of cluster analysis that joins together stands with similar floristic composition, while taking into account the relative coverages of the respective species (Orloci 1967).

Figure 8

Discussions of small mammals within each habitat type are based on data from removal censuses (trapping) conducted in both 1976 and 1977. A total of 86 grids were trapped at 61 sites in all habitat types except ash stands and mixed black spruce-jack pine stands. Characteristic species were identified by summarizing relative densities and frequencies for each small mammal species within each habitat type and comparing these values between habitat types. Only those mammals capable of being caught in a "Museum Special" (rat-sized) trap were



MEQB REGIONAL COPPER-NICKEL STUDY

FIGURE 8 TERRESTRIAL FIELD SAMPLE SITES

included in the census. Examples of such mammals are mice, shrews, and small members of the squirrel family.

Habitat preferences for larger mammals (e.g. weasel, porcupine, deer, bear) were ascertained from an extensive literature review. This review was supplemented, where possible, by examination of Minnesota Department of Natural Resources (MDNR) records. Such records are useful in identifying the portions of the Study Area being used most intensively by particular species. Deer-hunter surveys and aerial censuses for deer and moose provided additional information. The literature review pertaining to game-birds and waterfowl was supplemented by a spring singing-ground census for woodcock and a spring drumming census for ruffed grouse. These techniques underestimate game-bird populations because they only account for resident displaying male birds. They do, however, provide an index by which to compare use in different habitats. An aerial census of migratory waterfowl was conducted during the migration season, when numbers of birds are highest, in order to compare use of different watersheds. The migratory waterfowl census does not reflect resident breeding duck and geese populations.

The songbird census, on the other hand, was directed at the breeding population. Censuses were conducted in 45 stands of 9 habitat types during the 1977 breeding season (late May through mid July). Each stand was visited 4 to 6 times and locations of singing birds were mapped. Data from these observations were subjected to cluster analysis based on bird species composition. Stable clusters of stands were identified as bird communities that were then related to the major vegetation types. Winter bird censuses were also conducted in the major habitat types.

2.4 FORM OF THE ANALYTICAL RESULTS

Independent analyses of vegetation, small mammal, and bird data produced independent classifications of species assemblages for the three groups. Species assemblages recognized among the small mammals and birds do not always correspond directly with communities recognized from the vegetation data.

2.4.1 Plant Communities

Nine major forest groups were identified from the releve data by cluster analysis based on canopy species composition. These groups fall into the following broad framework and represent eleven plant communities:

Wetlands

Group 1. Shrub carr, dominated by speckled alder or heath bog (*Alnus rugosa*)

Group 2. Wetland conifers

- A. Spruce bog, dominated by black spruce (*Picea mariana*)
- B. Tamarack bog, dominated by tamarack (*Larix laricina*)
- C. Cedar bog, dominated by northern white cedar (*Thuja occidentalis*)

Group 3. Ash wetlands, dominated by black ash (*Fraxinus nigra*)

Uplands

Group 4. Mixed black spruce-jack pine dominated by black spruce and jack pine (*Pinus banksiana*)

Group 5. Jack pine, dominated by jack pine

Group 6. Red pine, dominated by red pine (*Pinus resinosa*)

Group 7. Aspen-birch, dominated by trembling aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*)

A. Nearly pure aspen-birch

B. Aspen-birch with fir (Abies balsamea)

Group 8. Mixed coniferous-deciduous, dominated by combinations of aspen, birch, black spruce, fir, and jack pine

Group 9. White spruce plantations dominated by white spruce (Picea glauca) (not one of the eleven major plant communities)

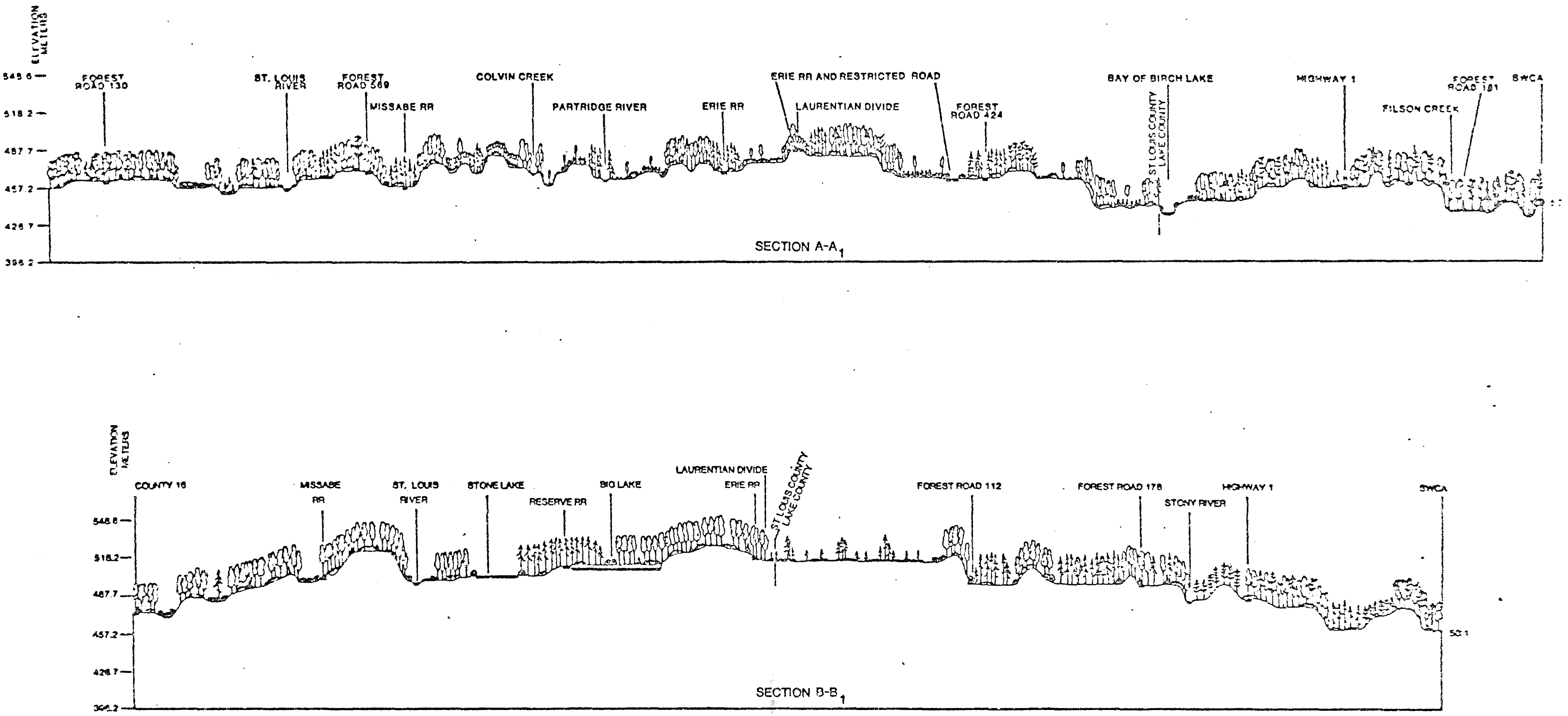
Comparison of these community types with those defined by the Minesite and MLMIS inventory programs (computer based inventories of the MDNR and State Planning Agency) indicates a high correspondence. Tabulations from these inventory systems can therefore be used to estimate the proportion of the Study Area in a given vegetation type.

These community types differ from those that were present in the area before logging. Marshner's (1930) reconstruction of the original vegetation of Minnesota from the General Land Office Survey notes shows that communities present in the 1880s generally correspond with physiographic provinces (Figure 2). The portion of Marshner's map that covers the Study Area is shown in Figure 4. The relationship of present vegetation to physiography can be seen by consulting Figures 9a-e, a series of cross-sections through the Study Area.

Figures 9a-e

The eleven plant community types defined for the Study Area are differentiated on the basis of both structural (Table 7) and floristic (Table 8) properties. Structural characteristics and species composition vary along a continuum in undisturbed stands. This continuum is reflected in Table 8 by the attrition of wetland species and increasing dominance of upland species along a gradient from

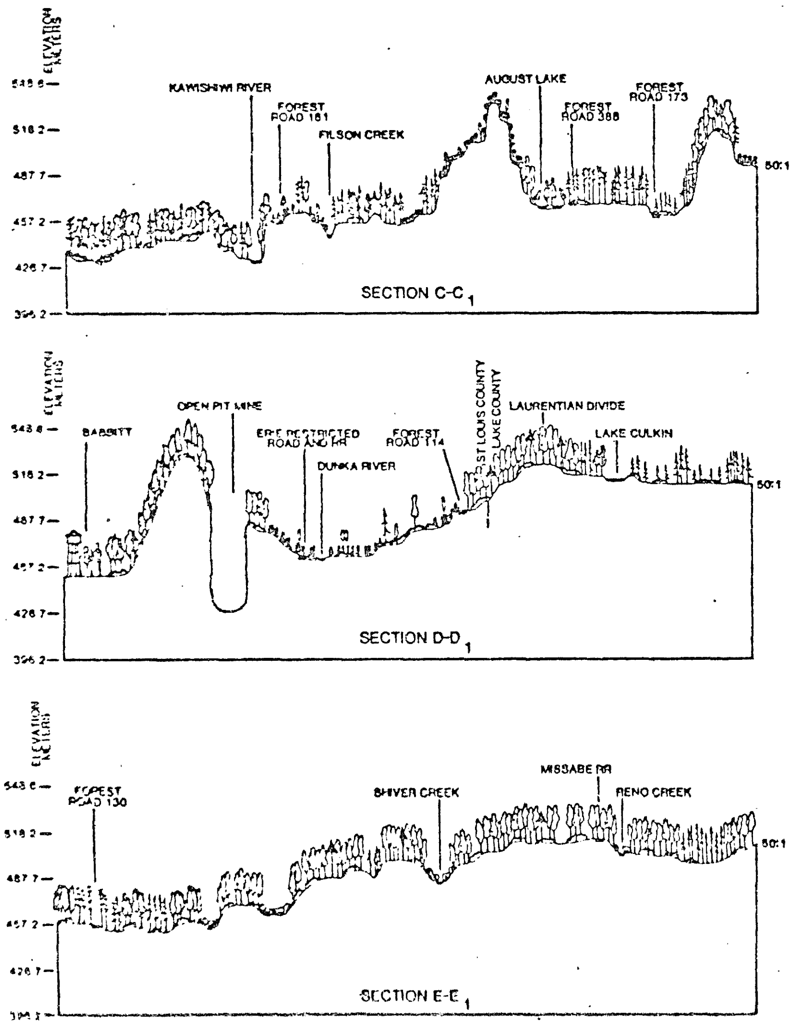
FIGURE 9A-E RELATIONSHIP OF PLANT COMMUNITIES AND PHYSIOGRAPHIC FEATURES

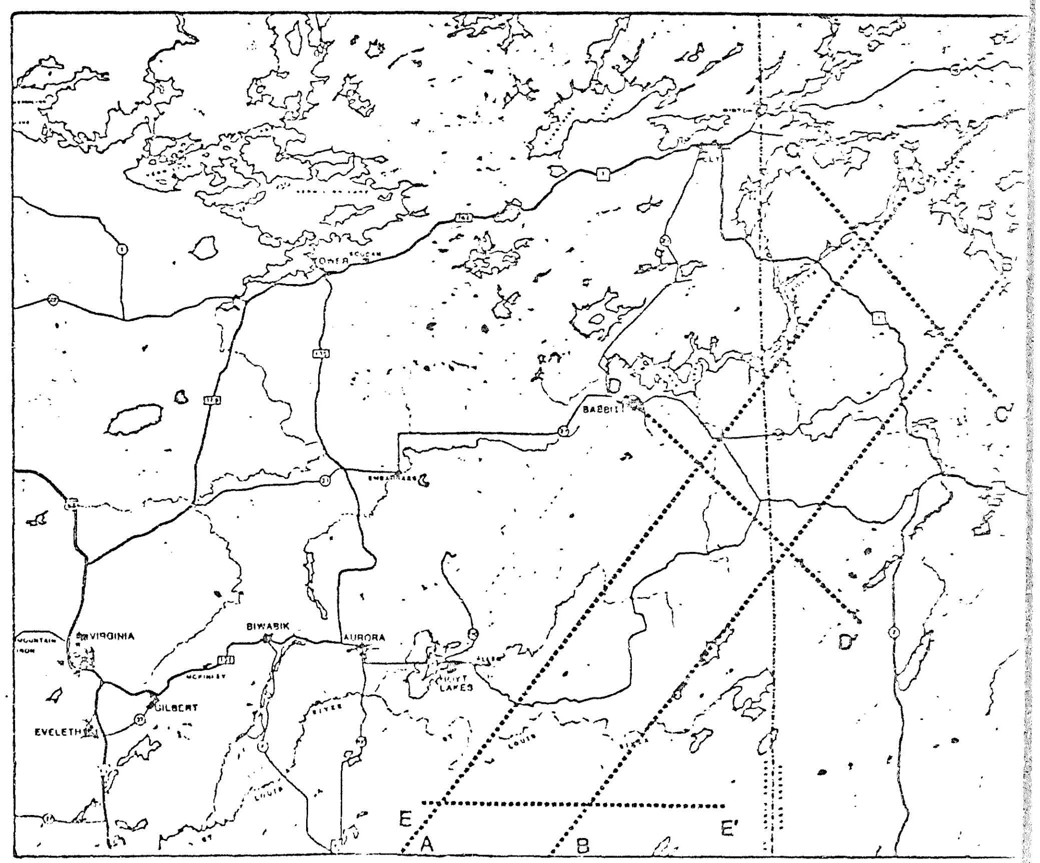


1cm = 7km

0 7 14 21

FIGURE 9A-E CONT.





LOCATIONS OF CROSS-SECTIONS IN STUDY AREA

Ash to Conifer-Deciduous communities. Where disturbance such as logging has occurred, the structural attributes of the community are simplified, regardless of its floristic composition (Table 7). Elements of the ecosystem, such as small mammals, which respond more to structural than floristic properties, therefore, exhibit habitat preferences that relate more to successional stage than to community type.

Tables 7 & 8

2.4.2 Small Mammals

Cluster analysis of stands based on relative densities of small mammal species did not prove useful. Three groups were recognized, a group dominated by shrews (*Sorex cinereus*), one dominated by the red-back voles (*Clethrionomys gapperi*), and one dominated by woodland deer mice (*Peromyscus maniculatus*). Although the shrew group was significantly correlated with high moisture values derived from synecological coordinates (Bakuzis and Hansen 1959), the other groups did not exhibit similar correlations. The functional approach proved more useful for relating small mammals to habitat types. Of the three functional groups that were recognized, granivores (chipmunks, *Eutamias*; woodland mice, *Peromyscus*; and jumping mice, *Zapus* and *Napaeozapus*) were most abundant in open habitats such as young successional stages and grassland. Grazers (voles, *Microtus*; and southern bog lemming, *Synaptomys*) were more abundant in closed upland forests where grasses and sedges are less likely to bear seed. In wetlands, where the forest floor is often dominated by mosses, carnivores (shrews, *Sorex* and *Microsorex*) were most abundant.

2.4.3 Songbirds

ABLE 7

:OMPARISON OF COVER BY STRUCTURAL LAYERS, MATURE COMMUNITIES

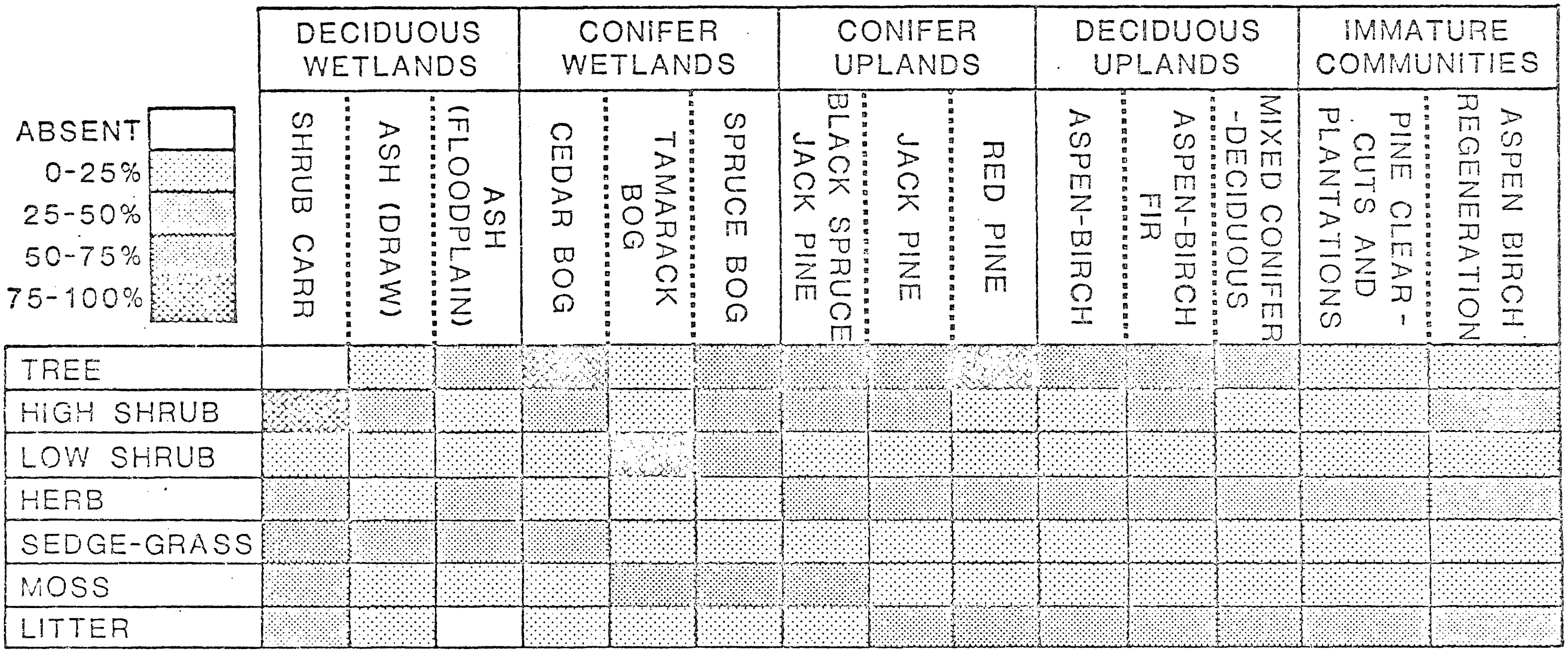


TABLE 8 PERCENT PRESENCE OF SELECTED PLANTS IN FOREST COMMUNITIES

Number of Plots in Sample	11	13	3	9	54	20	29	22	29	22	55	
Common Name / Habitat	Ash	Carr	Cedar	Tamarack	Black Spruce	Spruce-Pine	Jack Pine	Red Pine	Aspen-Birch	Aspen-Birch-Fir	Conifer-Deciduous	Scientific Name
Balsam fir	ooo		▒		ooo	▒	ooo	▒	ooo	▒	▒	*Abies balsamea*
Mountain ash	:::		▒		:::	▒	ooo	:::	:::	▒	▒	*Sorbus americana*
Bluebead lily	:::		▒	:::	ooo	▒	▒	ooo	▒	▒	▒	*Clintonia borealis*
Twinflower			▒		ooo	▒	▒	▒	:::	ooo	▒	*Linnaea borealis*
Mountain rice	:::					▒	▒	▒	ooo	ooo	ooo	*Oryzopsis* spp.
Jack pine				:::	:::	▒	▒	ooo	:::	:::	▒	*Pinus banksiana*
Early sweet blueberry	:::	:::	▒	:::	ooo	▒	▒	▒	ooo	ooo	ooo	*Vaccinium angustifolium*
Bunchberry	:::	:::	▒	ooo	ooo	▒	▒	▒	▒	▒	▒	*Cornus canadensis*
Dewberry	▒	:::	▒	:::	:::	ooo	▒	▒	▒	▒	ooo	*Rubus pubescens*
Wild rose	ooo		▒	:::	:::	▒	▒	▒	▒	▒	▒	*Rosa acicularis*
Strawberry	:::		▒	:::	:::	▒	▒	▒	▒	▒	▒	*Fragaria* spp.
Bebb's willow	:::	:::	▒		:::	ooo	▒	ooo	:::	ooo	ooo	*Salix bebbiana*
Velvet-leaved blueberry			▒		ooo	ooo	▒	▒	▒	ooo	▒	*Vaccinium myrtilloides*
Downy arrow-head			▒	:::	:::	ooo	▒	▒	ooo	ooo	ooo	*Viburnum rafinesquianum*
Violet	ooo	ooo	▒	:::	:::	:::	ooo	▒	ooo	ooo	ooo	*Viola* spp.
Starflower	:::	:::	▒	:::	ooo	ooo	ooo	▒	▒	▒	▒	*Trientalis borealis*
Wood fern	:::	ooo	▒		:::	ooo	ooo	ooo	ooo	ooo	:::	*Dryopteris spinulosa*
Ground pine		:::	ooo		:::	ooo	ooo	▒	ooo	▒	▒	*Lycopodium obscurum*
Sweet fern						ooo	ooo	ooo			ooo	*Comptonia peregrina*
Dogbane					:::	:::	▒	ooo	▒	ooo	ooo	*Apocynum androsaemifolium*
Red pine						:::	ooo	▒		:::	:::	*Pinus resinosa*
Cow wheat					:::	:::	ooo	ooo	:::	:::	:::	*Melampyrum lineare*
White spruce					:::		ooo	:::	:::	:::	:::	*Picea glauca*
Round leaved dogwood	:::	:::	▒	:::	:::	:::	:::	ooo	ooo	ooo	:::	*Cornus rugosa*
Fly honeysuckle			▒	:::	:::	ooo	ooo	ooo	ooo	▒	ooo	*Lonicera canadensis*
Sweet bedstraw	ooo	:::		:::	:::	:::	ooo	ooo	▒	▒	ooo	*Galium triflorum*
Mountain maple	:::		▒	ooo	:::	:::	:::	ooo	ooo		ooo	*Acer spicatum*
Coltsfoot			ooo		:::	:::	:::	:::	:::	ooo	:::	*Petasites palmatus*
False lily of the valley	ooo	:::		:::	ooo	▒	▒	▒	▒	▒	▒	*Smilacina trifolia*

TABLE 8 CONTINUED

Number of Plots in Sample	11	13	3	54	9	20	29	22	29	22	55	
Habitat	Ash	Carr	Cedar	Tamarack	Black Spruce	Spruce-Pine	Jack Pine	Red Pine	Aspen-Birch	Aspen-Birch-Fir	Conifer-Deciduous	
Soft maple	○											*Acer saccharinum*
Sweet mint	∷	∷										*Mentha arvensis*
Jewelweed	∷	○	○						○	○		*Impatiens capensis*
Ash	▒	∷	▒			∷			∷	∷	∷	*Fraxinus nigra*
White cedar	○	∷	▒	∷								*Thuja occidentalis*
Cattail	∷	∷	∷	∷	∷							*Typha* spp.
Swamp blue aster	▒	○	○	∷	∷		∷					*Aster puniceus*
Marsh marigold	○	∷	∷	∷	∷		∷					*Caltha palustris*
Iris	∷	○	○	∷	∷							*Iris versicolor*
Water horehound	▒	▒	∷		∷	∷				∷		*Lycopus uniflorus*
Black alder		○	○	∷	∷		∷	∷				*Ilex verticillata*
Sedges	▒	▒	▒	▒	▒	∷	○	∷	○	○	∷	*Carex* spp.
Speckled alder	▒	○	▒	○	○	∷	∷	∷	∷	○	∷	*Alnus rugosa*
Red osier dogwood	∷	○	∷	∷	∷	∷	∷	∷	∷	∷	∷	*Cornus stolonifera*
False Solomon's seal	○	∷	▒	▒	▒	∷	∷	∷			∷	*Smilacina trifolia*
Leatherleaf	∷	○		▒	▒		∷					*Chamaedaphne calyculata*
Spaghnum moss	∷	∷	▒	▒	○		∷	∷				*Sphagnum* spp.
Tamarack			○	▒	○	∷	∷			∷	∷	*Larix laricina*
Bog cranberry			▒	▒	○	∷	∷			∷	∷	*Vaccinium oxycoccos*
Labrador tea	∷	∷	▒	▒	▒	▒	○	∷	∷	∷	○	*Ledum groenlandicum*
Bog birch			○	▒	∷	∷	∷					*Betula pumila*
Creeping snowberry			▒	○	▒	∷	∷	∷	∷	∷	∷	*Gaultheria hispidula*
Bog laurel			○	▒	○		∷					*Kalmia polifolia*
Sundew			○	∷	∷							*Drosera rotundifolia*
Bog rosemary				▒	∷		∷					*Andromeda glaucophylla*
Pitcher plant				▒	∷							*Sarracenia purpurea*
Arctic raspberry				∷								*Rubus acaulis*
Black spruce	∷	∷	▒	▒	▒	▒	▒	○	○	○	▒	*Picea mariana*

TABLE 8 CONTINUED

Number of Plots in Sample	11	13	3	9	54	20	29	22	29	22	55	
Habitat	Ash	Carr	Cedar	Tamarack	Black Spruce	Spruce-Pine	Jack Pine	Red Pine	Aspen-Birch	Aspen-Birch-Fir	Conifer-Deciduous	
Paper birch	1-25%	1-25%	51-75%	1-25%	26-50%	51-75%	51-75%	51-75%	76-100%	76-100%	26-50%	*Betula papyrifera*
Large-leaved aster			26-50%		1-25%	76-100%	76-100%	76-100%	76-100%	76-100%	76-100%	*Aster macrophyllus*
Wild sarsaparilla					1-25%	76-100%	76-100%	76-100%	76-100%	76-100%	76-100%	*Aralia nudicaulis*
Raspberry	51-75%	26-50%	51-75%		1-25%	76-100%	76-100%	76-100%	76-100%	26-50%	51-75%	*Rubus idaeus*
Wood anemone			51-75%		1-25%	1-25%	26-50%	26-50%	26-50%	26-50%	26-50%	*Anemone quinquefolia*
Bush honeysuckle			26-50%		1-25%	51-75%	51-75%	76-100%	51-75%	51-75%	51-75%	*Diervilla lonicera*
Lady fern	1-25%		26-50%		1-25%		26-50%	1-25%	1-25%	26-50%	1-25%	*Athyrium filix-femina*
Red maple	1-25%		1-25%		1-25%	1-25%	26-50%	26-50%	26-50%	26-50%	26-50%	*Acer rubrum*
Twisted stalk	1-25%			1-25%	1-25%	1-25%	26-50%	26-50%	51-75%	76-100%	26-50%	*Streptopus roseus*
Hazel					1-25%	51-75%	76-100%	76-100%	76-100%	76-100%	51-75%	*Corylus cornuta*
Bracken fern					1-25%	26-50%	51-75%	51-75%	51-75%	51-75%	26-50%	*Pteridium aquilinum*
Trembling aspen	1-25%				1-25%	26-50%	51-75%	51-75%	76-100%	76-100%	76-100%	*Populus tremuloides*
Pearly everlasting					1-25%	1-25%	26-50%	26-50%	1-25%	1-25%	1-25%	*Anaphalis margaritacea*
White pine					1-25%	1-25%	1-25%	1-25%		1-25%	26-50%	*Pinus strobus*
Fireweed					1-25%		26-50%	26-50%	26-50%	1-25%	1-25%	*Epilobium angustifolium*
Juneberry					1-25%	1-25%	1-25%	26-50%	26-50%	1-25%	1-25%	*Amelanchier* spp.
American vetch							26-50%	26-50%	26-50%	26-50%	1-25%	*Vicia americana*
Wild sweet pea					1-25%	1-25%	1-25%	26-50%	26-50%	26-50%	26-50%	*Lathyrus venosus*
Spring beauty									1-25%			*Claytonia caroliniana*
Hepatica									1-25%	1-25%		*Hepatica americana*
Wild ginger									1-25%			*Asarum canadense*
Trillium	1-25%						1-25%		1-25%	1-25%	1-25%	*Trillium cernuum*
Ladyslipper			26-50%			26-50%	1-25%	1-25%	1-25%		1-25%	*Cypripedium acaule*
Coral root						1-25%	1-25%	1-25%	1-25%	1-25%	1-25%	*Corallorhiza maculata*
Rattlesnake plantain				51-75%		51-75%	51-75%		1-25%	1-25%		*Goodyera repens*

Absent from plots in this habitat

Present in 1-25% of plots in this habitat

Present in 26-50% of plots in this habitat

Present in 51-75% of plots in this habitat

Present in 76-100% of plots in this habitat

Cluster analysis based on bird species composition recognizes nine distinct bird communities that are mainly associated with structural attributes of habitats (Figure 10 and Table 7). In order of increasing structural complexity these communities are:

I. Grassland, characterized by the mourning warbler/chestnut-sided warbler and brown thrasher/sparrow hawk species associations

II. Recent clearcut, characterized by the mourning warbler/chestnut-sided warbler and brown thrasher/sparrow hawk species associations

III. Young plantation, characterized by the mourning warbler/chestnut-sided warbler and common flicker/brown-headed cowbird species associations

IV. Aspen regeneration, characterized by the red-eyed vireo/ovenbird, mourning warbler/chestnut-sided warbler and common flicker/brown-headed cowbird associations

V. Alder carr, characterized by the gray catbird/swamp sparrow species association

VI. Disturbed shrub, characterized by the red-eyed vireo/ovenbird and mourning warbler/chestnut-sided warbler species associations

VII. Conifer bog, characterized by the yellow-bellied flycatcher/Connecticut warbler species association

VIII. Mature coniferous upland, characterized by the hermit thrush/Blackburnian warbler species association

IX. Mature deciduous upland, characterized by the red-eyed vireo/ ovenbird species association

Within these songbird communities, groups of species make use of similar resources and can be divided into functional guilds, as shown in Figure 16. Such guilds are generally related to the structural attributes of the community. For example, comparison of Table 7 with Figure 16 reveals that in recent clearcuts where the canopy layer is unimportant, timber-feeders are less important than in other communities.

Figure 16

The above groupings are summarized in Table 7b. The community characterizations that follow are based on the organizational fra-mework provided by the classification of plant communities. Discussions of distinct small mammal and bird communities are presented where appropriate.

Figure 10, Table 7b

FIGURE 16
FORAGING GUILD COMPOSITION OF SONGBIRD ASSOCIATIONS IN MAJOR COMMUNITIES AT VARIOUS SUCCESSIONAL STAGES

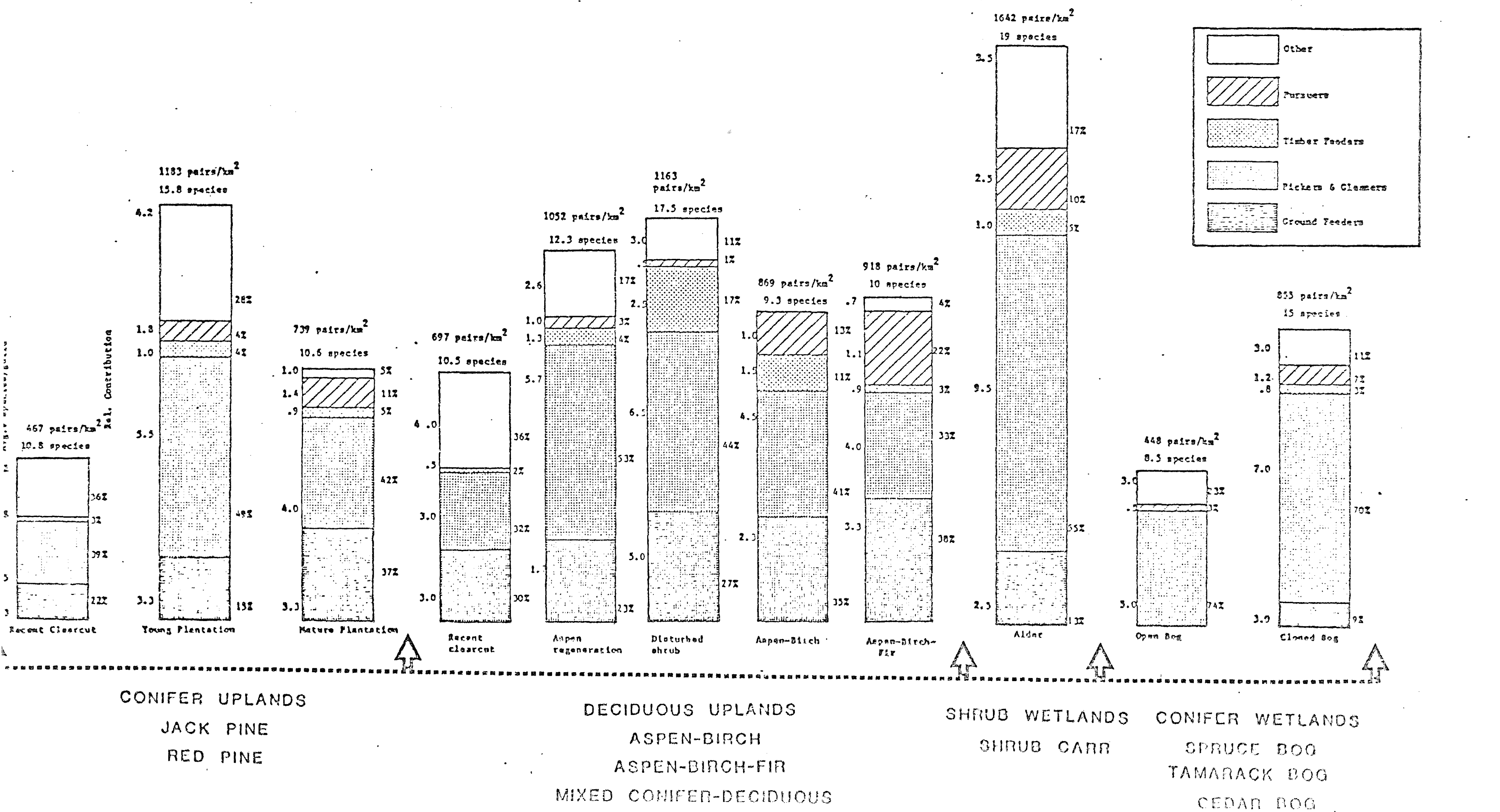


FIGURE 10

STRUCTURAL CHARACTERISTICS OF THE HABITAT

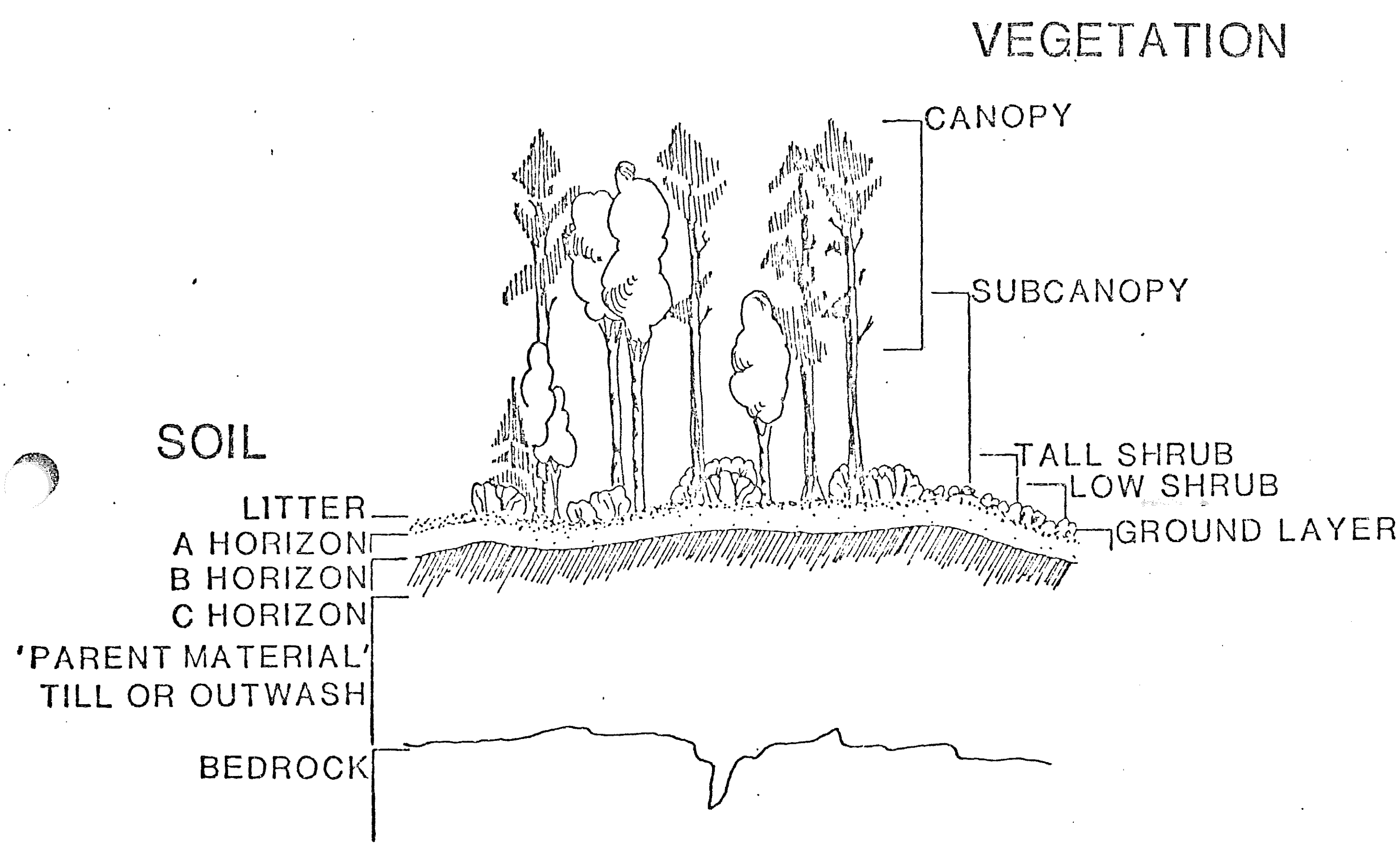


TABLE 7B INTERRELATIONSHIPS OF TERRESTRIAL CLASSIFICATIONS

<table>
<tr><th>PLANT COMMUNITIES</th><th colspan="2">SONGBIRD ASSOCIATIONS</th><th>SMALL MAMMAL GUILDS</th></tr>
<tr><td>1 SHRUB CARR</td><td colspan="2">GRAY CATBIRD-
SWAMP SPARROW</td><td rowspan="4">CARNIVORE
(INSECTIVORE)</td></tr>
<tr><td>2 SPRUCE BOG</td><td colspan="2" rowspan="3">YELLOW BELLIED
FLYCATCHER-
CONNECTICUT WARBLER</td></tr>
<tr><td>3 TAMARACK BOG</td></tr>
<tr><td>4 CEDAR SWAMP</td></tr>
<tr><td>5 ASH WETLANDS</td><td colspan="2" rowspan="2">NOT SAMPLED</td><td rowspan="2">NOT SAMPLED</td></tr>
<tr><td>6 BLACK SPRUCE-
JACK PINE</td></tr>
<tr><td>JACK PINE</td><td colspan="2" rowspan="2">HERMIT THRUSH-
BLACKBURNIAN WARBLER</td><td rowspan="4">GRAZER</td></tr>
<tr><td>8 RED PINE</td></tr>
<tr><td>9 ASPEN-BIRCH</td><td colspan="2" rowspan="2">RED EYED VIREO-
OVENBIRD</td></tr>
<tr><td>10 ASPEN-BIRCH-FIR</td></tr>
<tr><td>11 MIXED CONIFER-
DECIDUOUS</td><td rowspan="2"></td><td rowspan="6">MOURNING
WARBLER-
CHESTNUT
SIDED
WARBLER</td><td rowspan="6">GRANIVORE</td></tr>
<tr><td>(DISTURBED SHRUB)</td></tr>
<tr><td>(ASPEN REGENERATION)</td><td rowspan="2">COMMON
FLICKER-
BROWN
HEADED
CATBIRD</td></tr>
<tr><td>(YOUNG PLANTATION)</td></tr>
<tr><td>(RECENT CLEARCUT)</td><td rowspan="2">BROWN
THRASHER-
SPARROW
HAWK</td></tr>
<tr><td>(GRASSLAND)</td></tr>
</table>

2.5 REGIONAL CHARACTERIZATION

2.5.1 Wetlands

Wetlands vary from treeless sedge mats to forested bogs usually dominated by conifers, and from cattail marshes to alder carrs and ash stands (Figure 11). Wetland communities intergrade with uplands wherever and whenever conditions are suitable for the species of one community to invade the other. In dry years upland species such as birch may invade wetlands, and in wet years or in areas where beavers (Castor canadensis) are active wetland species may become established on upland sites.

Figure 11

The releve sample included treeless wetlands which were either classified according to the few scattered trees present or were excluded from the analysis because the cluster analysis that was used to classify these communities was based on prevalent canopy species only. No treeless wetlands were sampled as part of the quantitative studies.

2.5.1.1 Shrub Carr--Treeless wetlands vary from fen (open grass and sedge meadows usually adjoining lakes and streams) through heath bogs, dominated by low shrubs, to carrs dominated by tall shrubs. All of these types were sampled in the releve sample set, but only alder carrs were sampled quantitatively for vegetation, small mammals, and songbirds.

Heath bogs occur throughout the Study Area in association with open spruce and tamarack bogs. In the northern part of the Study Area they are best developed in draws between rocky ridges and at the margins of lakes. The type is most

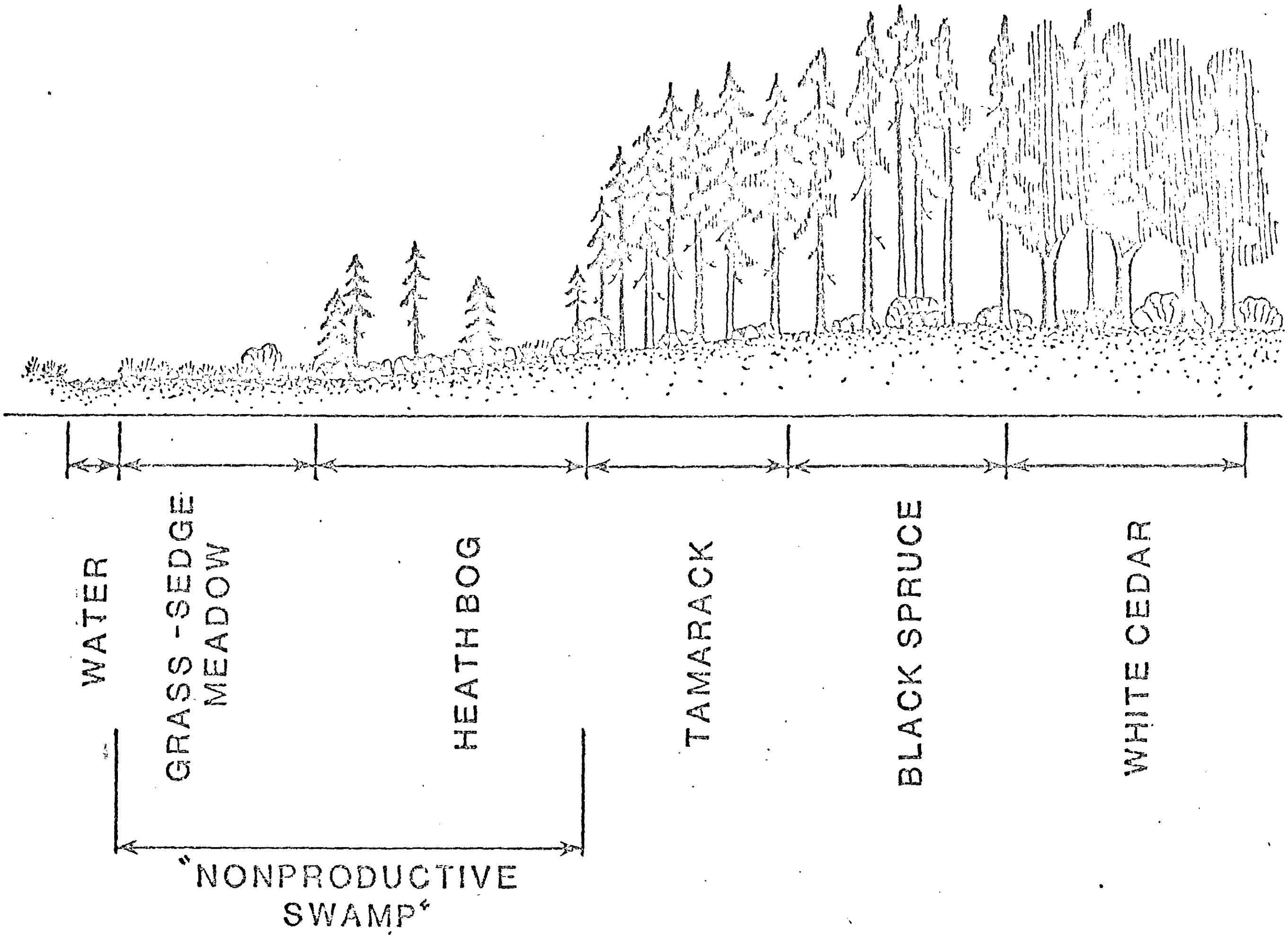


FIGURE 11 RELATIONSHIPS BETWEEN DIFFERENT TYPES OF WETLANDS

extensively developed in the watershed of the North River on bog soils overlying glacial outwash. Heath bogs are uncommon in the St. Louis River watershed. Because they generally have poorly developed tree and high shrub layers, these bogs are usually classified by foresters as "nonproductive swamp." The continuous low shrub layer is dominated by members of the heath family (Ericaceae) such as leatherleaf (Chamaedaphne calyculata), bog laurel (Kalmia polifolia), and bog rosemary (Andromeda glaucophylla)(Table 8). The herb layer is generally sparse and of low species diversity, dominated by sedges (Cyperaceae) and bog cranberries (Vaccinium oxycoccos). Carnivorous plants such as pitcher plants (Sarracenia purpurea) and sundew (Drosera rotundifolia) develop their best populations here, relying on insects as a source of nitrogen. The habitat is preferred by several orchid species, including Arethusa (Arethusa bulbosa), rose pogonia (Pogonia ophioglossoides), grass pink (Calopogon pulchellus), and Lister's twayblade (Listera cordata). Sphagnum mosses form a continuous groundcover.

Heath bogs are high in both moisture and sunlight. Because their nutrient supply is derived more from rainfall than runoff from neighboring uplands, they are acidic and poor in nutrients. Accumulation of undecomposed organic matter, especially Sphagnum mosses and sedges (Carex spp.), in water-logged, acidic conditions results in the development of deep peat soils. Where such wetlands are extensively developed they exhibit patterns in the vegetation that reflect the flow of nutrients in watercourses and the nuances of underlying topography. An example is the patterning, associated with the underlying Laurentian Divide, in the Sand Lake wetland lying in T.59N., R.10W.

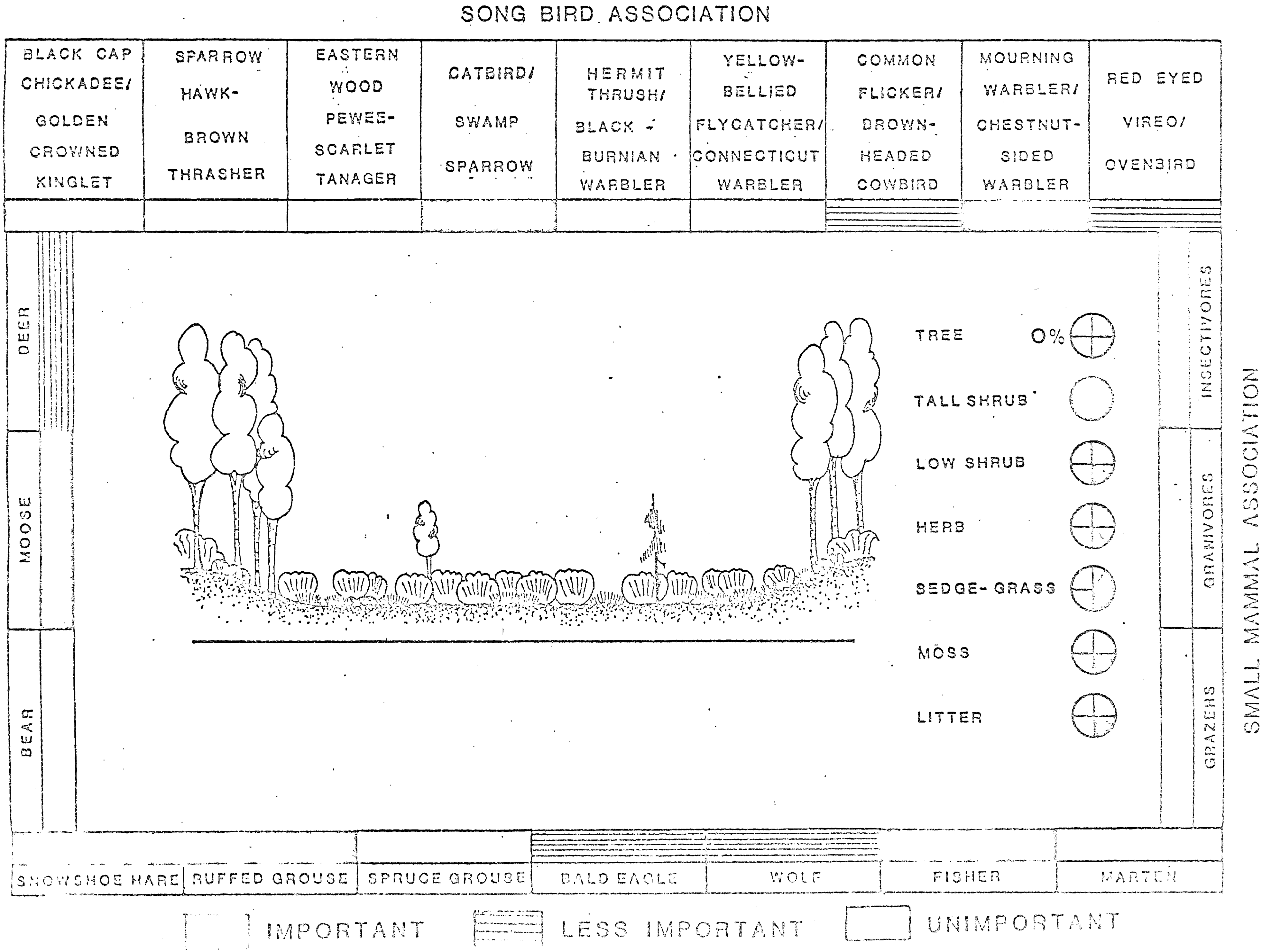
Where heath bogs grade into open sedge meadows (fens) near water, they become important for waterfowl, which rely on the sedges for food. The fens in the watersheds of the North and St. Louis rivers may partially account for the spring concentration of migrating waterfowl in these areas. Use of heath bogs by large mammals, especially moose (Alces alces), appears to be occasional as they pass through on their way to water or food. Winter use is limited by deep accumulations of snow. Although the habitat per se was not sampled for small mammals, there is a drop in the number of characteristic species between closed and open tamarack bogs, suggesting that only those mammal species characteristic of open bogs (e.g. the arctic shrew [Sorex arcticus] and masked shrew [Sorex cinereus]) would persist in heath bogs.

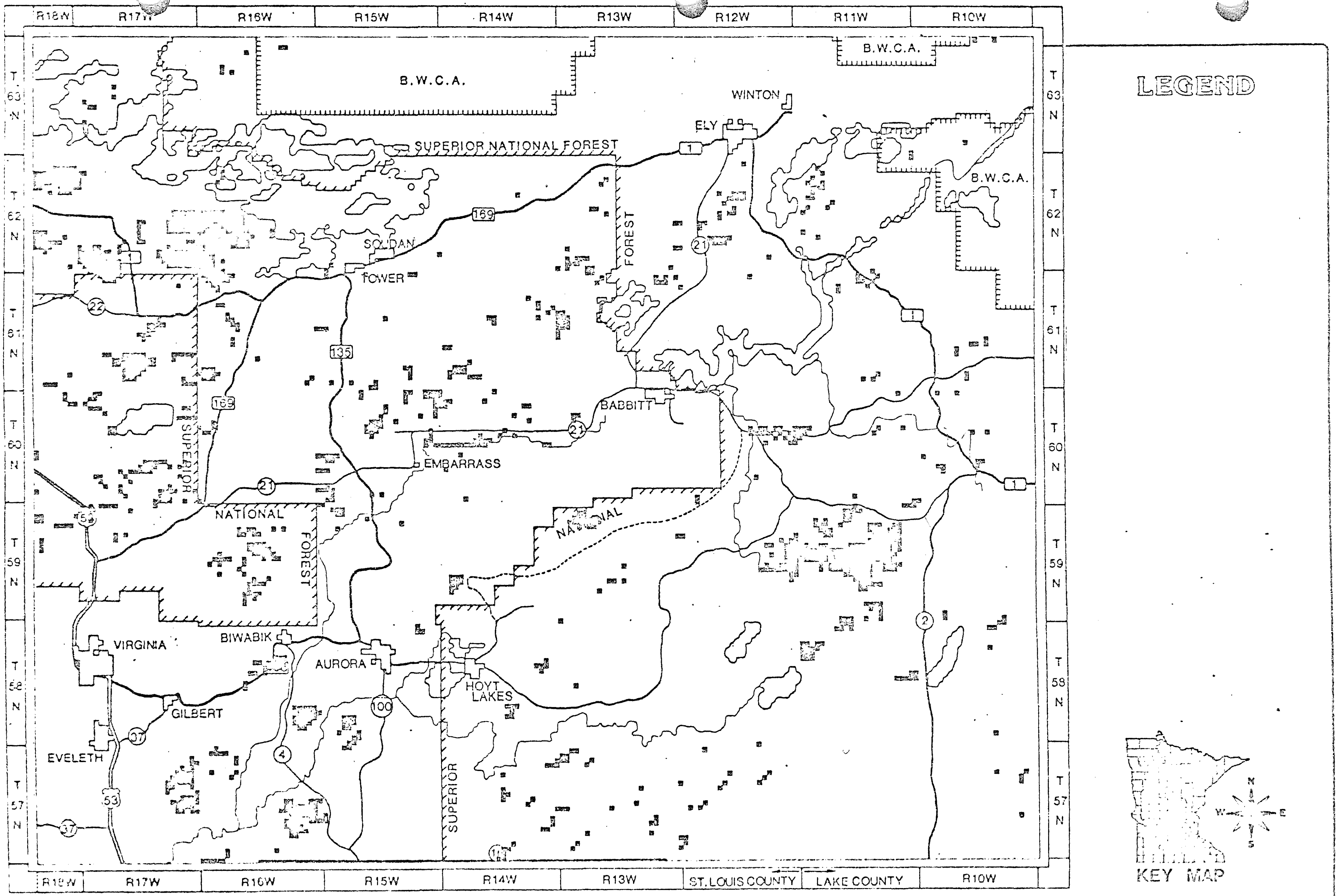
Alder carrs differ from heath bogs in both their structure and species composition (Figure 12). Trees and low shrubs are generally infrequent, whereas shrubs between one and three meters in height achieve their highest basal area in this habitat. Within the Study Area carrs are best represented by alder carrs in the Toimi Drumlin Field on bog soils between the drumlins (Figure 13). In contrast with ericaceous bogs, which are better developed on outwash soils or between thin-soiled ridges of the Kawishiwi and Isabella watersheds, alder carrs are well supplied with nutrients from runoff from the deep-soiled, loamy drumlins. The good supply of minerals is enhanced by the nitrogen-fixing abilities of the alder. Cluster analysis of wetlands based on synecological coordinates suggests that within the Study Area alder carrs are most similar to cedar bogs in their physical attributes.

Figures 12 and 13

Speckled alder (Alnus rugosa) is the dominant shrub species, but willows (Salix spp.), red osier dogwood (Cornus stolinifera), and "green alder" (Ilex verticellata) are frequent (Table 8). Leading families in the herb layer are

FIGUR 12 SHRUB CARR





MEQB REGIONAL COPPER-NICKEL STUDY

FIGURE 13

FEN AND SHRUB CARR

SOURCE: MLMIS 1978

the daisy family (Compositae), buckwheat family (Polygonaceae), and madder family (Rubiaceae). The ground layer is patchy with exposed mud and water interspersed with sedges, forbs such as violets (Viola spp.), and water horehound (Lycopus uniflorus). Plant species diversity is high, but rare plants are infrequent.

Characteristic small mammals of alder carrs are shrews (Sorex arcticus and Sorex cinereus), which prefer moist habitats. Large mammal use is generally restricted to moose, which use the willow and red osier dogwood for food and the habitat for spring and fall cover. Some of the highest densities of moose in the Study Area are located in the watersheds of the St. Louis and Whiteface rivers where alder carrs, recent cutovers, mature deciduous stands, and slow-flowing streams abounding in aquatic macrophytes combine to fill all the moose's seasonal needs.

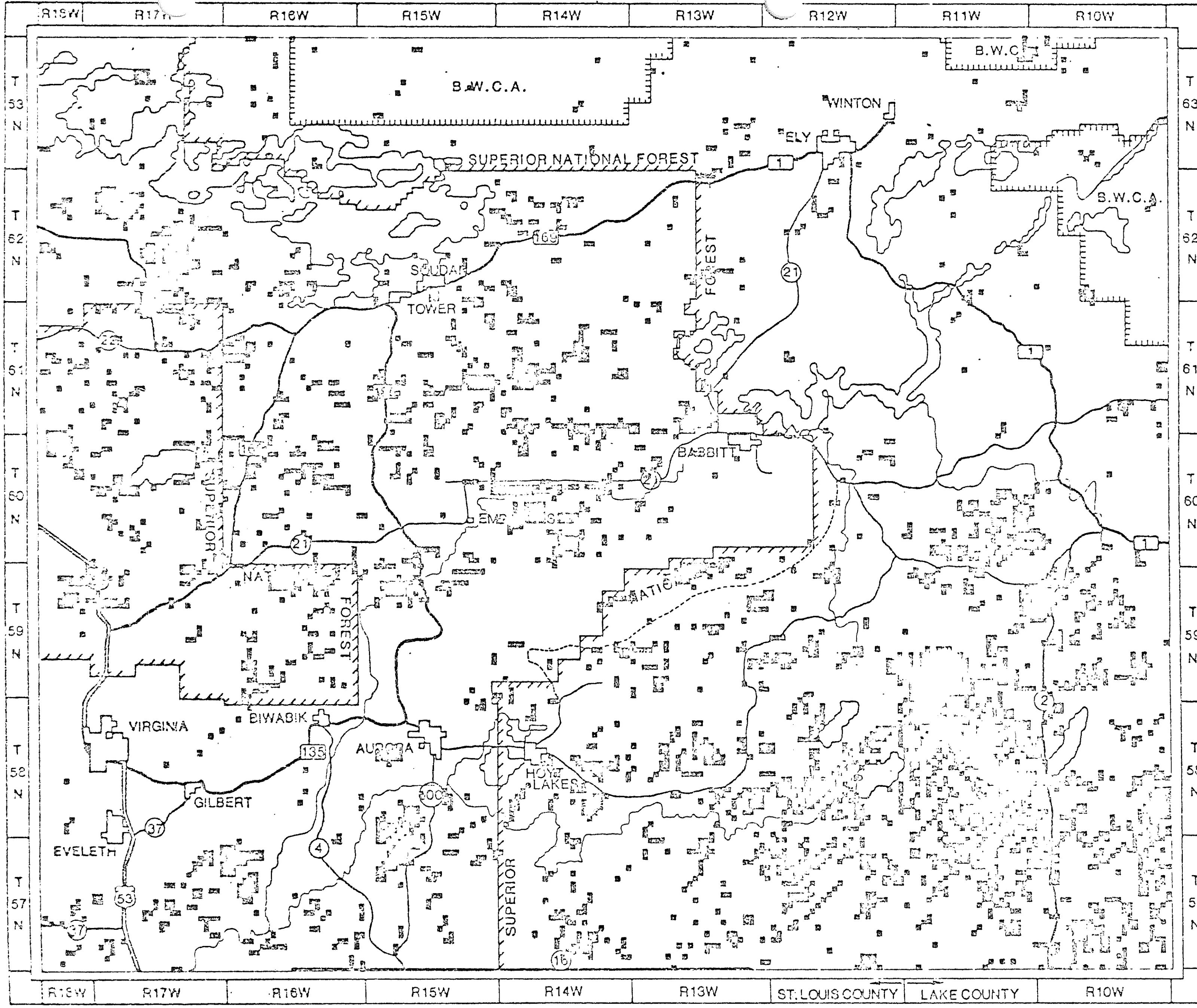
Alder carrs are prime habitat for woodcock (Philohela minor) throughout their period of summer residence. This habitat is used for cover, food, display grounds, nesting, and staging areas for fall migration. The importance of alder carrs for woodcock suggests the Toimi Drumlin Field as a target area for future management of this relatively unexploited game species. Alder carr also provides summer cover for hens and broods of ruffed grouse (Bonasa umbellus). In addition to protection from avian predators, the habitat offers an ample supply of the chick's sole diet for their first three weeks--insects harbored among the ferns.

Songbird communities of alder carrs are faunistically distinct from those of other habitats. Characteristic species include the alder flycatcher (Empidonax trailii), catbird (Dumatella carolinensis), veery (Hylocichla fuscescens), golden-winged warbler (Vermivora chrysoptera), common yellowthroat (Geothlypis trichas) and swamp sparrow (Melospiza georgiana). The two alder plots sampled in the breeding bird census differed from each other markedly in both the number of species and density of birds. The highest density of birds (2400 pairs per km^2) and the largest number of species (26) in the entire survey were found in the more structurally diverse of these two plots.

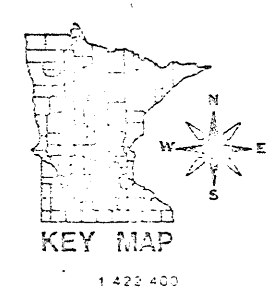
2.5.1.2 Black Spruce Bogs--Black spruce bogs are well developed throughout the Study area except in the Toimi Drumlin Field where they are replaced by alder carrs (Figure 14). North and east of the Giants Range they occupy narrow draws between the uplands, and they encircle small lakes. Portions of the extensive Seven Beaver-Sand Lake wetland have developed spruce of merchantable size. Spruce bogs are also an important element in the bed of Glacial Lake Dunka, southeast of Babbitt. In the east-central portion of the Study Area, spruce bogs are well developed along the major streams, especially between the upper forks of the Dunka River. The more extensive nature of these bogs compared to those in the Kawishiwi watershed has resulted in their commercial use. Customary practice usually involves logging in strips, rather than clearcutting. Regeneration is usually good. Logged spruce bogs along Twenty-Proof Creek are less dense than their unlogged counterparts of the same age, but the trees left after thinning are of greater diameter. Where spruce bogs grade into heath bogs and nutrient supplies are poor, trees are widely spaced and dwarfed. Such open-grown forms are commercially valuable only as Christmas trees.

Figure 14

The wetland black spruce community is usually characterized by open or closed spruce canopies (Figure 15), often festooned with the lichen "Old Man's Beard"



LEGEND



MEQB REGIONAL COPPER-NICKEL STUDY

FIGURE 14 BLACK SPRUCE BOG SOURCE: MLMIS 1978

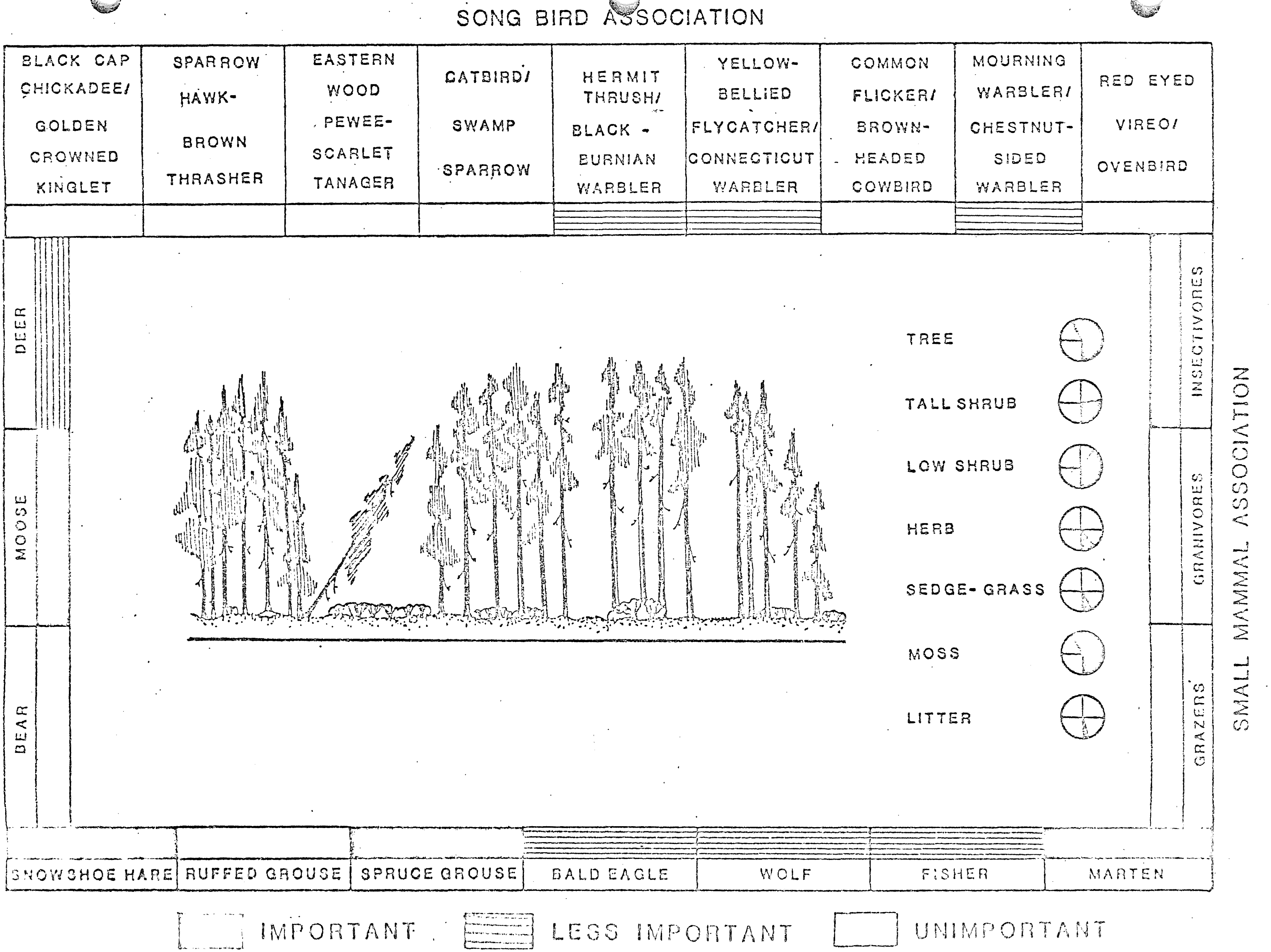
(Usnea spp.), which is used by the white-tailed deer (Odocoileus virginianus) as winter food. Generally there are few high shrubs and a variable low shrub layer dominated by Labrador tea (Ledum groenlandicum), leatherleaf, and dwarf birch (Betula pumila). Herbaceous layers vary according to the available nutrient supply, moisture, and light. Acid, wet situations favor the development of Sphagnum, sedges, false Solomon's seal (Smilacina trifolia), and bog cranberry (Table 8). Where the bog inter-grades with the transitional black spruce-jack pine community, feather mosses, creeping snowberry (Gaultheria hispidula), bunchberry (Cornus canadensis), blueberry (Vaccinium angustifolium and Vaccinium myrtilloides), and bluebead lily (Clintonia borealis) are more frequent. Of habitats investigated in this study, spruce bogs exhibited the highest fidelity of subcanopy structural layers (herbs and shrubs) to canopy type. That is to say, species of herbs and shrubs were more frequently found together in consistent assemblages in this community than in any other.

Figure 15

Considering the large number of spruce bogs sampled, the proportion of rare plants in this community is lower than in other wetland coniferous communities. Most rare species found in spruce bogs are members of the orchid family (Orchidaceae). The northern comandra (Geocaulon lividum), a boreal member of the sandalwood family (Santalaceae), is at its southern range limits in the Study Area and was found in one spruce bog (plot T05) where it had been previously collected by Lakela (Lakela 1965).

Spruce bogs are not the single most important habitat for any of the small mammal species. The arctic shrew attains high frequencies in all conifer bogs, where its relative density is positively correlated with the number of low shrub

FIGURE 15 BLACK SPRUCE BOG



stems. This preference suggests that it should be more common in more open spruce bogs with ericaceous understories than in the closed mature bogs with well developed moss layers and poor development of high shrubs, low shrubs, and herbs. The abundance of both the masked shrew and pigmy shrew (Microsorex hoyi) is positively correlated with higher cover of mosses, suggesting that these species should be more important in more mature, shaded spruce bogs with open shrub layers. Three additional small mammal species that are characteristic of black spruce bogs are the short-tailed shrew (Blarina brevicauda), red-backed vole, and meadow vole (Microtus pennsylvanicus).

Black spruce bogs provide winter cover for deer, moose, and snowshoe hare (Lepus americanus)(Table 2). Both fisher (Martes pennati) and marten (Martes americana) prefer mature coniferous habitats, although in regions where bogs are present martens dominate pure conifer stands and fishers use mixed stands.

Mature spruce bogs provide nesting sites for ospreys (Pandion heliaetus), and, to a smaller extent, bald eagles (Heliaeetus leucocephalus), especially when these bogs are near water. Both species rely on fish as their major food source. The single most important game bird using spruce bogs is the spruce grouse (Canachites canadensis), which uses the habitat year round for food (spruce needles), cover, display grounds, and brood cover.

Results of the breeding bird census showed that conifer wetlands as a group are characterized by a distinctive avian fauna, but that the cover types of wetlands could not be distinguished on the basis of bird species composition. Perhaps the most distinguishing feature of the unique bird community associated with wetland conifers is that nearly three-quarters of the individuals present are groundnesters, dependent on the Sphagnum ground layer and ericaceous low-shrub layer for nesting material and cover. At the same time these birds are pickers and gleaners, dependent for their food supply on the insects harbored in the evergreen canopy. The percentage of ground-nesters is higher than in any other community type.

Ground-nesters characteristic of conifer lowlands include the Nashville warbler (Vermivora ruficapilla), Connecticut warbler (Oporornis agilis), Lincoln's sparrow (Melospiza lincolnii), yellow-bellied flycatcher (Empidonax flaviventris), winter wren (Troglodytes troglodytes), Tennessee warbler (Vermivora peregrina), and dark-eyed junco (Junco hyemalis). The Tennessee warbler has been recognized by the state of Minnesota (MDNR 1975) as a species "meriting special concern." All but one of these ground-nesters, the Nashville warbler, have been recognized as a potentially critical, unique, or indigenous species dependent on habitats found in northeastern Minnesota (Niemi 1977, Lake Superior Basin Study, Duluth, unpublished data).

Winter observations showed very low numbers of birds in all habitats. Conifer wetlands with closed canopies averaged twice as many observations per five-hour observation period as those with open canopies, probably because closed stands provide more surface area for foraging and protect the birds more from exposure to winds that cause loss of body heat. Characteristic winter birds of the conifer lowlands included the gray jay (Perisoreus canadensis), northern three-toed woodpecker (Picoides tridactylus), and boreal chickadee (Parus hudsonicus). Of these, the boreal chickadee is the only species unique to conifer lowlands.

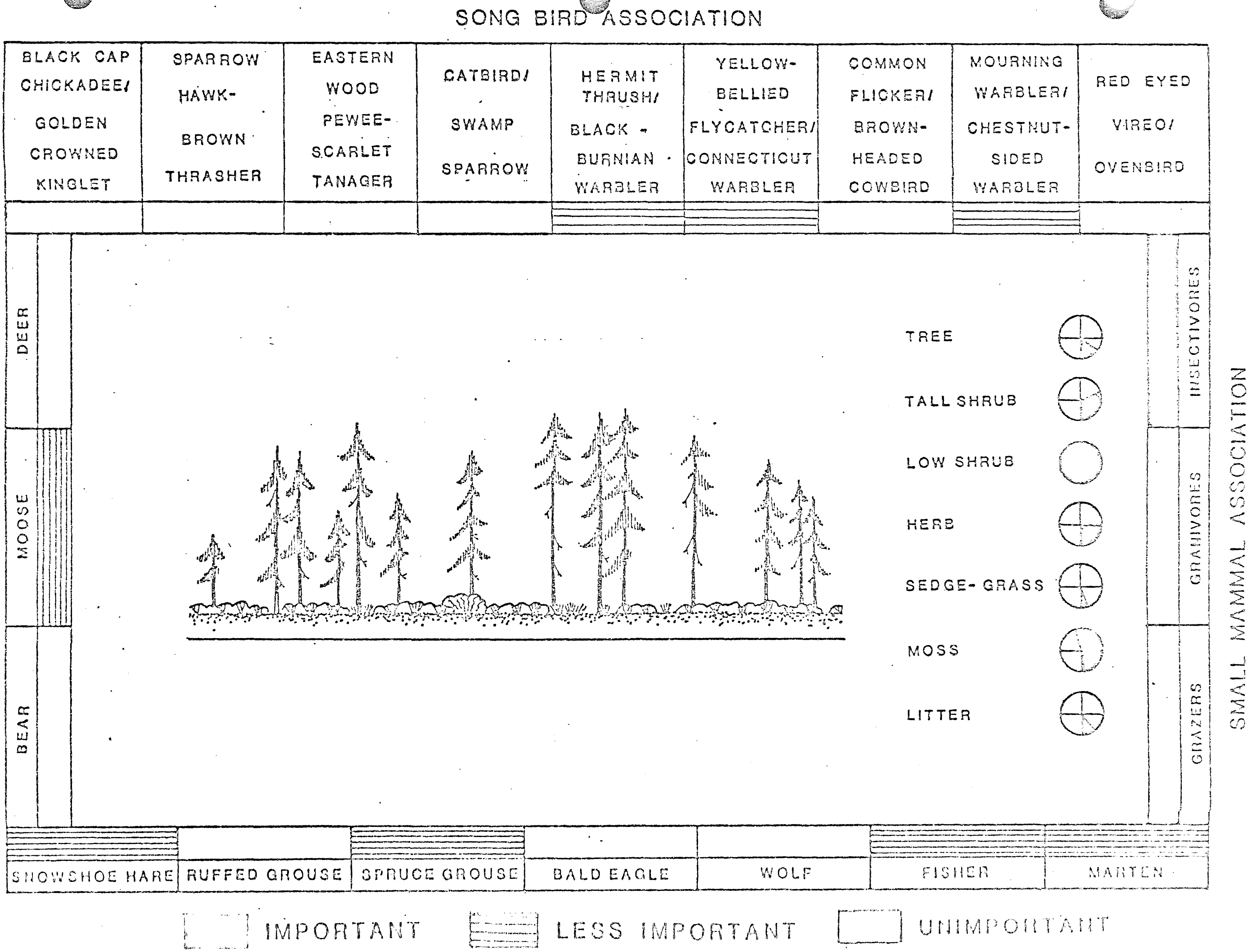
2.5.1.3 Tamarack Bogs--Conifer wetlands form a series from the nutrient-poor, well-lighted tamarack bogs to the nutrient-rich, shady cedar bogs. Tamarack bogs are generally less influenced by surrounding uplands than either black spruce or cedar bogs.

Within the eastern portion of the Study Area, the distribution of tamarack bogs is similar to that of ericaceous and black spruce bogs with which they intergrade. Such bogs are best developed on peat soils in draws between ridges in the Kawishiwi watershed, around lakes, or overlying outwash plains in the central and southeastern portions of the area.

In general, the canopy of tamarack bogs is more open than spruce canopies and is not as tall (Figure 17). High shrubs are virtually absent. Low shrubs are generally sun-loving members of the heath family such as leatherleaf and Labrador tea. In pure tamarack stands the herbaceous flora is limited in species and charac-terized by bog cranberries, false Solomon's seal, sedges, and carnivorous plants such as the pitcher plant (Table 8). Sphagnum mosses often form a continuous ground cover. Considering the low overall species diversity of pure tamarack bogs (83 species), the number of rare species is quite high (5 species). Rare species are generally members of the orchid family such as rose pogonia, grass pink, Arethusa, and Lister's twayblade. The largest continuous tamarack bog sampled as part of the Regional Copper-Nickel Study (plot G45) contained a population of blooming arctic raspberry (Rubus acaulis). This plant is not considered rare for the state, but is on the edge of its range. Although tamarack bogs are often viewed as a successional stage between ericaceous wetlands and spruce bogs, their slow growth rate and susceptibility to flooding, insect damage, and windthrow often inhibit succession to the point where they appear to be stable communities.

Figure 17

FIGURE 17 TAMARACK BOG



Only three small mammals are characteristic of open tamarack bogs: the arctic shrew, masked shrew, and meadow vole. The meadow vole, generally a denizen of grasslands, achieves densities of 10-11 per hectare in open tamarack stands, three times higher than in all other habitats except grassland and cedar. In the absence of large tracts of agricultural land, the voles apparently turn for food to wetlands with abundant sedges. Small mammal populations of closed tamarack bogs resemble those of spruce bogs with five characteristic species: masked shrew, short-tailed shrew, pigmy shrew, red-backed vole, and meadow vole.

Although their open structure and deciduous canopy make tamarack bogs unsuitable cover for large mammals, summer browsing by snowshoe hare may cause heavy loss of tamarack seedlings.

The songbird community of tamarack bogs is that characteristic of coniferous wetlands in general. As has already been discussed, this community is distinctive because of the high proportion of unique species, especially ground-nesters that are dependent on the canopy for their food source.

2.5.1.4 Cedar Bogs--White cedar stands (Figure 18) within the eastern portion of the Study Area appear to be restricted to isolated wetlands that are well supplied with nutrient runoff from surrounding uplands. Such stands are present in both the northern and southern parts of the area. Cedar bogs may well be the most unique vegetation type in the area, both because of their limited areal extent and because of their floristic composition. Although the shade tolerance of cedar would suggest that it might be the final stage of wetland succession, this status is seldom attained, because most wetlands in the Study Area lack the internal water flow and nutrient supply that cedar need. Wetland cedar stands develop better on shallow sedge or wood peat than on deep sphagnum peat. Cedar bogs in the Study Area are of more diverse species composition, wetter, and more open than those in the north-central part of the state. Stands included in this study were all near or in areas influenced by roads or logging. Their open canopies and high species diversity may be largely accounted for by the non-homogeneous and disturbed nature of the stands.

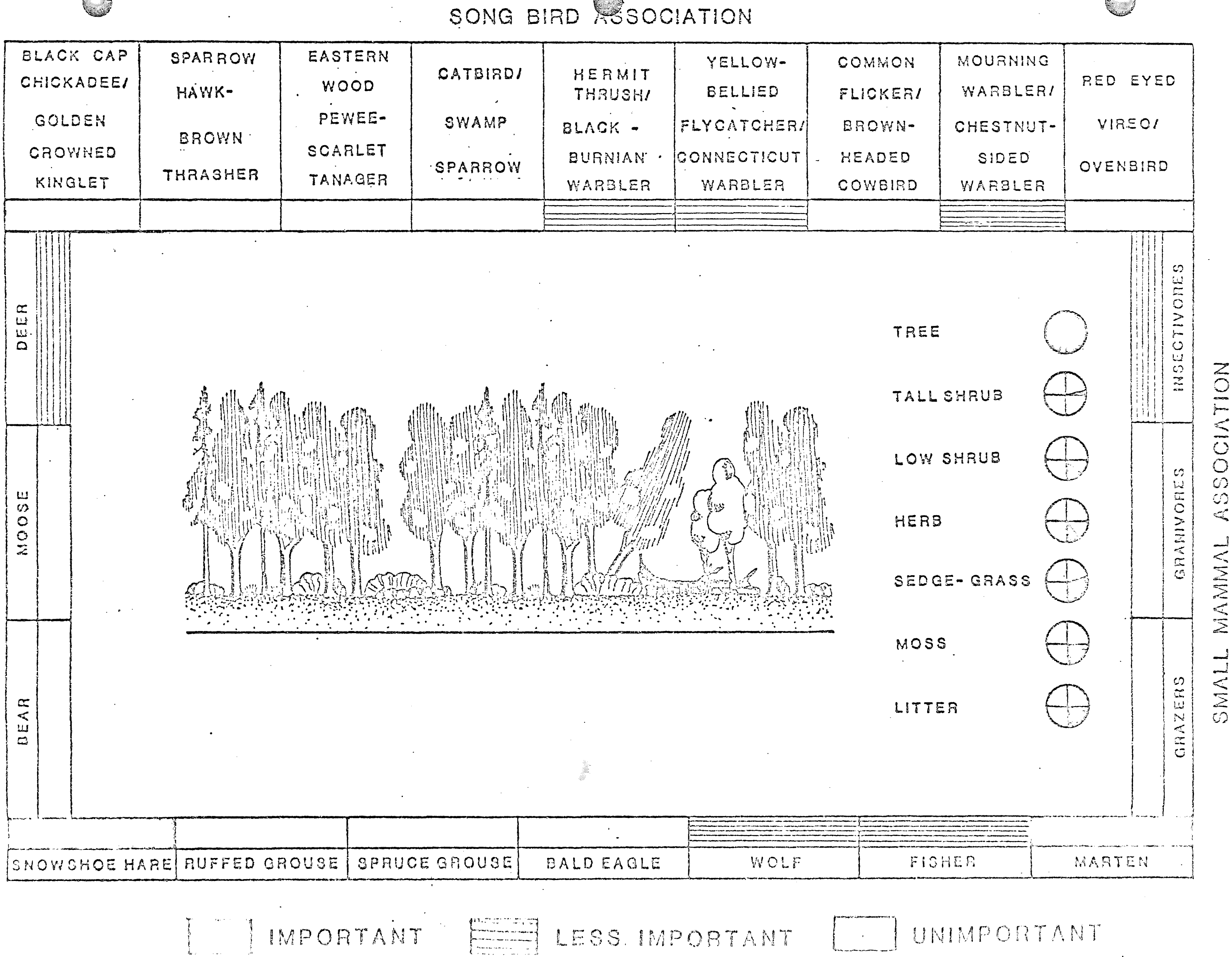
Figure 18

Floristically, cedar bogs have affinities with both spruce bogs and alder carrs (Table 8). Although feather mosses (e.g. Pleurozium schreberi, Ptilium crista-castrensis, Hylocomnium splendens) and damp forest floor species such as bluebead lily and creeping snowberry are present, so are nutrient-loving species such as water horehound.

Cedar bogs are impressive in their diversity of ferns (nine species) and fern allies (six species) and abundance of orchids (four species in three stands). Of all habitats investigated, cedar bogs presented the best habitat for rare lichens. Eight rare lichen species were collected in three bogs, including the first recorded collection of Parmelia revoluta in Minnesota. This new collection is especially significant because the previously known range of this species is several hundred miles to the south.

White cedar has been emphasized as the preferred winter browse for deer in Michigan and Wisconsin. The importance of cedar as a browse species in the Study Area is limited by the small size, isolated occurrence, and poor condition of the stands. These bogs probably provide year round cover for marten, fisher, and snowshoe hare. Although they are uncommon in Minnesota, the bobcat (Lynx rufus) and lynx (Lynx lynx) prefer cedar and spruce lowlands as winter habitat.

FIGURE 18 CEDAR BOG



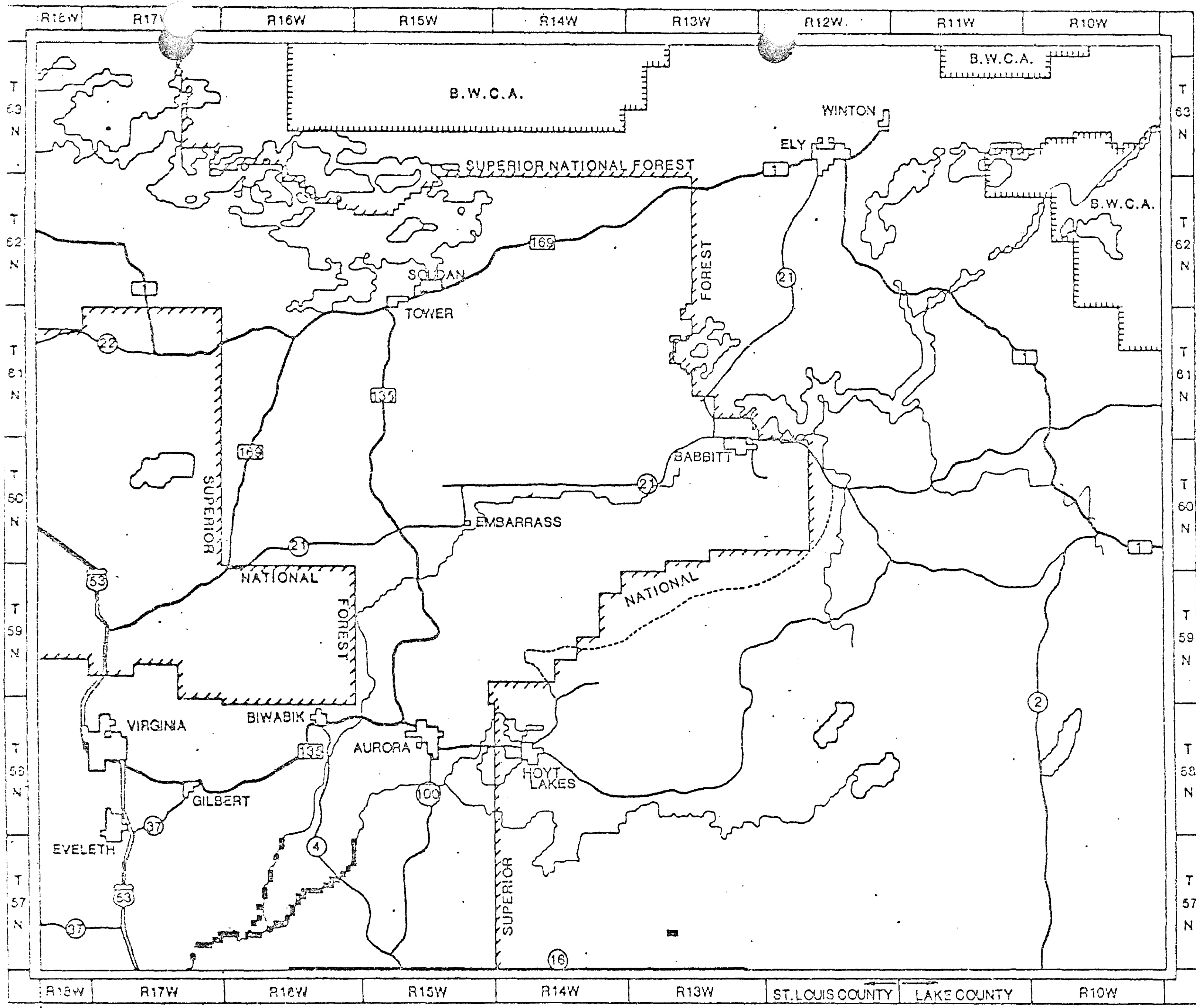
A variety of small mammals were characteristic of the three cedar bogs sampled, including the masked shrew, short-tailed shrew, meadow vole, and red-backed vole. The presence of both the deer mouse (Peromyscus maniculatus) and least chipmunk (Eutamias minimus) is a bit surprising, because both generally prefer drier habitats. The positive correlation of their densities with high percentages of deadfall may help explain their presence in this habitat.

The songbird community of cedar bogs is dominated by the yellow-bellied flycatcher/Connecticut warbler species association that is characteristic of conifer wetlands as a group and discussed in detail with the black spruce community.

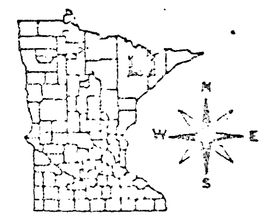
2.5.1.5 Black Ash Lowlands---Black ash communities account for a very small proportion of the Study Area and are widely distributed in small draws and along rivers. These stands are generally so small that they are not observed in the MLMIS inventory (Figure 19). Stands located in the floodplain of the Kawishiwi River are characterized by open canopies and poorly-developed herb and shrub layers (Figure 20a). In such floodplain stands, silver maple (Acer saccharinum) is a frequent canopy-associate of black ash. Annual flooding explains the poor development of the herb and shrub layers and good development of vines.

Figures 19 and 20a

Because ash stands that occupy draws are not subject to flooding, they are structurally more similar to alder carrs than floodplain ash stands (Figure 20b). Ash stands in draws are more likely to have cedar or paper birch as associate canopy species. Such stands have well developed shrub layers dominated by speckled alder and willow. The herb layer is characterized by such species as



LEGEND



KEY MAP

MEQB REGIONAL COPPER-NICKEL STUDY

FIGURE 19

ASH

SOURCE: MLMIS 1978

FIGURE 20A FLOODPLAIN ASH

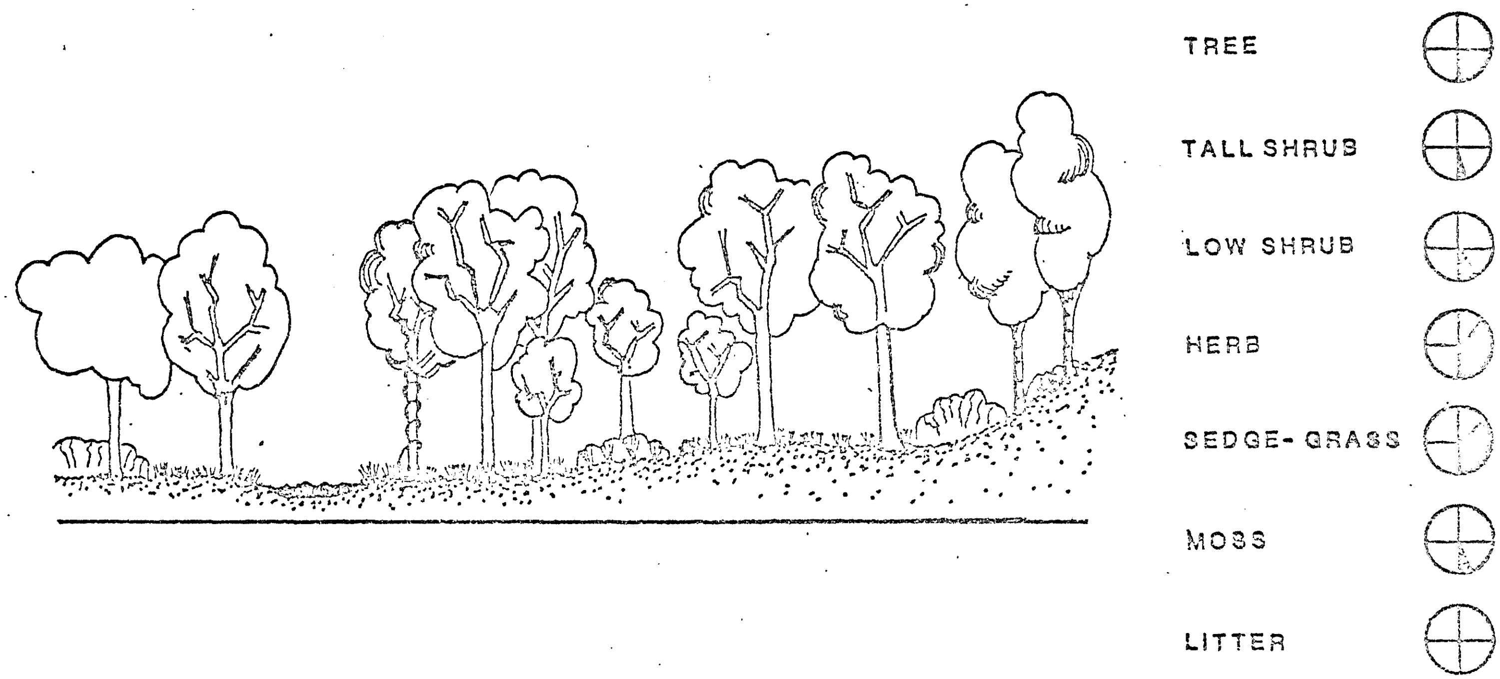
SONG BIRD ASSOCIATION

BLACK CAP CHICKADEE/ GOLDEN CROWNED KINGLET	SPARROW HAWK- BROWN THRASHER	EASTERN WOOD PEWEE- SCARLET TANAGER	CATBIRD/ SWAMP SPARROW	HERMIT THRUSH/ BLACK - BURNIAN WARBLER	YELLOW- BELLIED FLYCATCHER/ CONNECTICUT WARBLER	COMMON FLICKER/ BROWN- HEADED COWBIRD	MOURNING WARBLER/ CHESTNUT- SIDED WARBLER	RED EYED VIREO/ OVENBIRD
			NOT	CENSUSED				

DEER

MOOSE

BEAR



INSECTIVORES

NOT CENSUSED

GRANIVORES

GRAZERS

SMALL MAMMAL ASSOCIATION

SNOWSHOE HARE	RUFFED GROUSE	SPRUCE GROUSE	BALD EAGLE	WOLF	FISHER	MARTEN

IMPORTANT LESS IMPORTANT UNIMPORTANT

the swamp blue aster (Aster puniceus), dewberry (Rubus pubescens), violets, sweet mint (Mentha arvensis) and water horehound (Table 8). Many of these species are common in wet meadows, cedar bogs, and alder carrs.

Figure 20b

The black ash community was not sampled for small mammals, but the literature suggests that the following species are characteristic of black ash communities: woodland deer mouse, red-backed vole, meadow jumping mouse (Zapus hudsonicus), woodland jumping mouse (Napaeozapus insignis), and the American water shrew (Sorex palustris) (Kalin 1976). The water shrew generally prefers stream banks and was not collected in any of the habitats sampled as part of the small mammal census. Young ash stands are used by deer for winter browse and bushy ash stands are used by woodcock for fall cover.

The single ash stand sampled for songbirds (in 1976 only) was too small and heterogeneous to be used as part of the breeding bird study.

2.5.2 Uplands

Uplands form a floristic continuum from those dominated by coniferous species such as pines to those dominated by deciduous species such as aspen and birch. Most of the upland communities contain at least some marketable timber. For this reason, stands of many ages are available for study within each cover type. Cover types that are almost exclusively natural in origin and do not regenerate after harvest are not represented in the younger age classes. The only natural upland community recognized by this Study's community classification is the mixed black spruce-jack pine community.

the swamp blue aster (Aster puniceus), dewberry (Rubus pubescens), violets, sweet mint (Mentha arvensis) and water horehound (Table 8). Many of these species are common in wet meadows, cedar bogs, and alder carrs.

Figure 20b

The black ash community was not sampled for small mammals, but the literature suggests that the following species are characteristic of black ash communities: woodland deer mouse, red-backed vole, meadow jumping mouse (Zapus hudsonicus), woodland jumping mouse (Napaeozapus insignis), and the American water shrew (Sorex palustris) (Kalin 1976). The water shrew generally prefers stream banks and was not collected in any of the habitats sampled as part of the small mammal census. Young ash stands are used by deer for winter browse and bushy ash stands are used by woodcock for fall cover.

The single ash stand sampled for songbirds (in 1976 only) was too small and heterogeneous to be used as part of the breeding bird study.

2.5.2 Uplands

Uplands form a floristic continuum from those dominated by coniferous species such as pines to those dominated by deciduous species such as aspen and birch. Most of the upland communities contain at least some marketable timber. For this reason, stands of many ages are available for study within each cover type. Cover types that are almost exclusively natural in origin and do not regenerate after harvest are not represented in the younger age classes. The only natural upland community recognized by this Study's community classification is the mixed black spruce-jack pine community.

FIGURE 20B ASH IN A DRAW

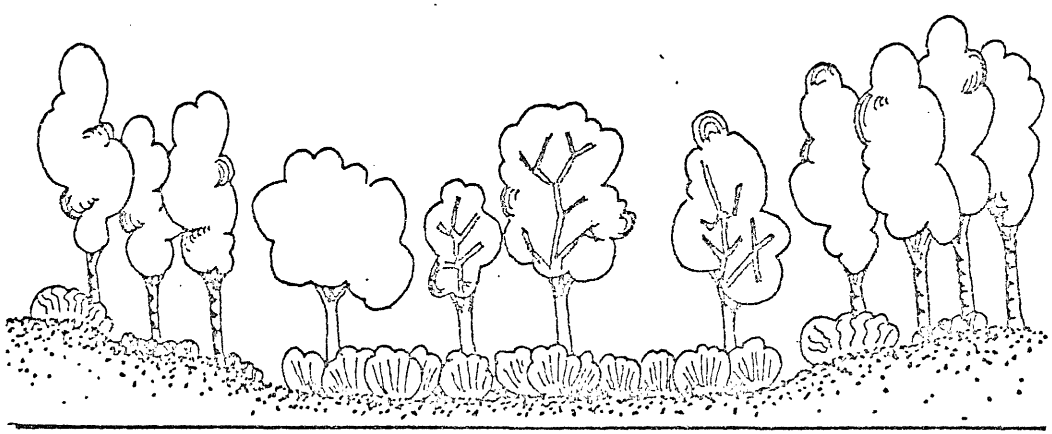
SONG BIRD ASSOCIATION

BLACK CAP CHICKADEE/ GOLDEN CROWNED KINGLET	SPARROW HAWK- BROWN THRASHER	EASTERN WOOD PEWEE- SCARLET TANAGER	CATBIRD/ SWAMP SPARROW	HERMIT THRUSH/ BLACK - BURNIAN WARBLER	YELLOW-BELLIED FLYCATCHER/ CONNECTICUT WARBLER	COMMON FLICKER/ BROWN-HEADED COWBIRD	MOURNING WARBLER/ CHESTNUT-SIDED WARBLER	RED EYED VIREO/ OVENBIRD
			NOT	CENSUSED				

DEER

MOOSE

BEAR



TREE

TALL SHRUB

LOW SHRUB

HERB

SEDGE- GRASS

MOSS

LITTER

NOT CENSUSED

INSECTIVORES

GRANIVORES

GRAZERS

SMALL MAMMAL ASSOCIATION

SNOWSHOE HARE	RUFFED GROUSE	SPRUCE GROUSE	BALD EAGLE	WOLF	FISHER	MARTEN

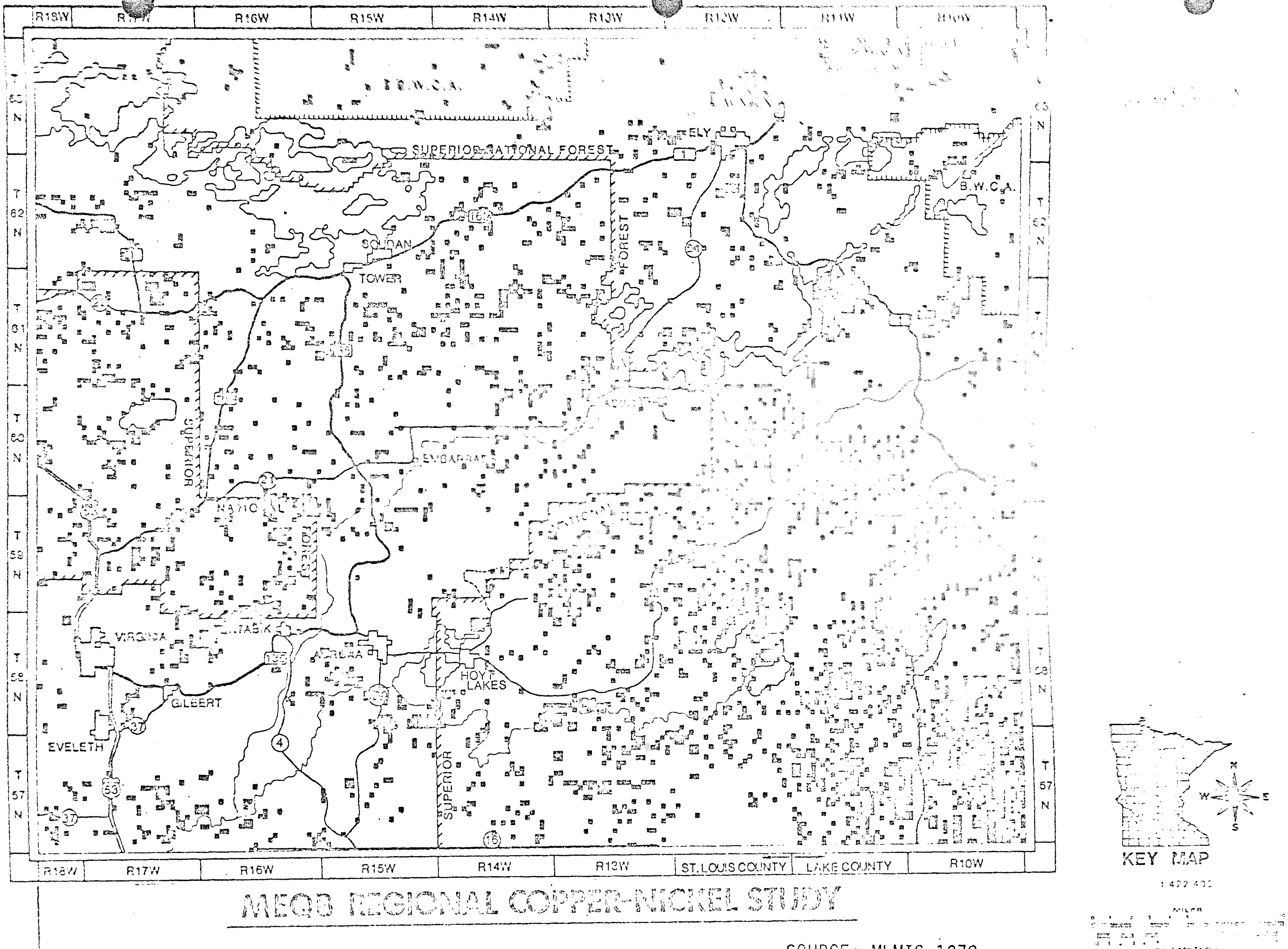
IMPORTANT. LESS IMPORTANT UNIMPORTANT

2.5.2.1 Black Spruce-Jack Pine--The black spruce-jack pine community occurs most frequently on east and west facing slopes between rocky ridges and bogs on thin, sandy-loam soils mainly in the northeast part of the Study Area. This community is generally included by foresters and inventory systems in the spruce-fir forest type which is presented in Figure 21. It is both topographically and floristically transitional between wetland black spruce and upland jack pine communities (Figure 22). Black spruce and jack pine dominate the canopy, with balsam fir and birch as common associates. The importance of balsam fir may have been greater in the past because many of the areas currently in this community type were classified by the Forest Service in 1948 as "restocking spruce-fir."

Figures 21 & 22

The high shrub layer is less dense than in upland deciduous stands but better developed than in pine plantations. Juneberry (Amelanchier spp.), hazel (Corylus cornuta), and mountain ash (Sorbus americana) are the most common members of this layer, whereas wild rose (Rose acicularis) and Labrador tea are the most frequent low shrubs. The most common herbs are blueberry, bunchberry, false lily-of-the-valley (Maianthemum canadense), wild sarsaparilla (Aralia nudicaulis), and large-leaved aster (Aster macrophyllus). The presence of the ladyslipper (Cypripedium acaule), a member of the protected orchid family, is significantly higher in this habitat type than in any other (Table 8).

The black spruce-jack pine community was not sampled during either the small mammal or breeding bird survey. Spruce grouse and ruffed grouse use this habitat year round, but although it is excellent habitat for spruce grouse it is only marginal for ruffed grouse. Black spruce-jack pine stands provide



MEQB REGIONAL COPPER-NICKEL STUDY

FIGURE 21 SPRUCE-FIR

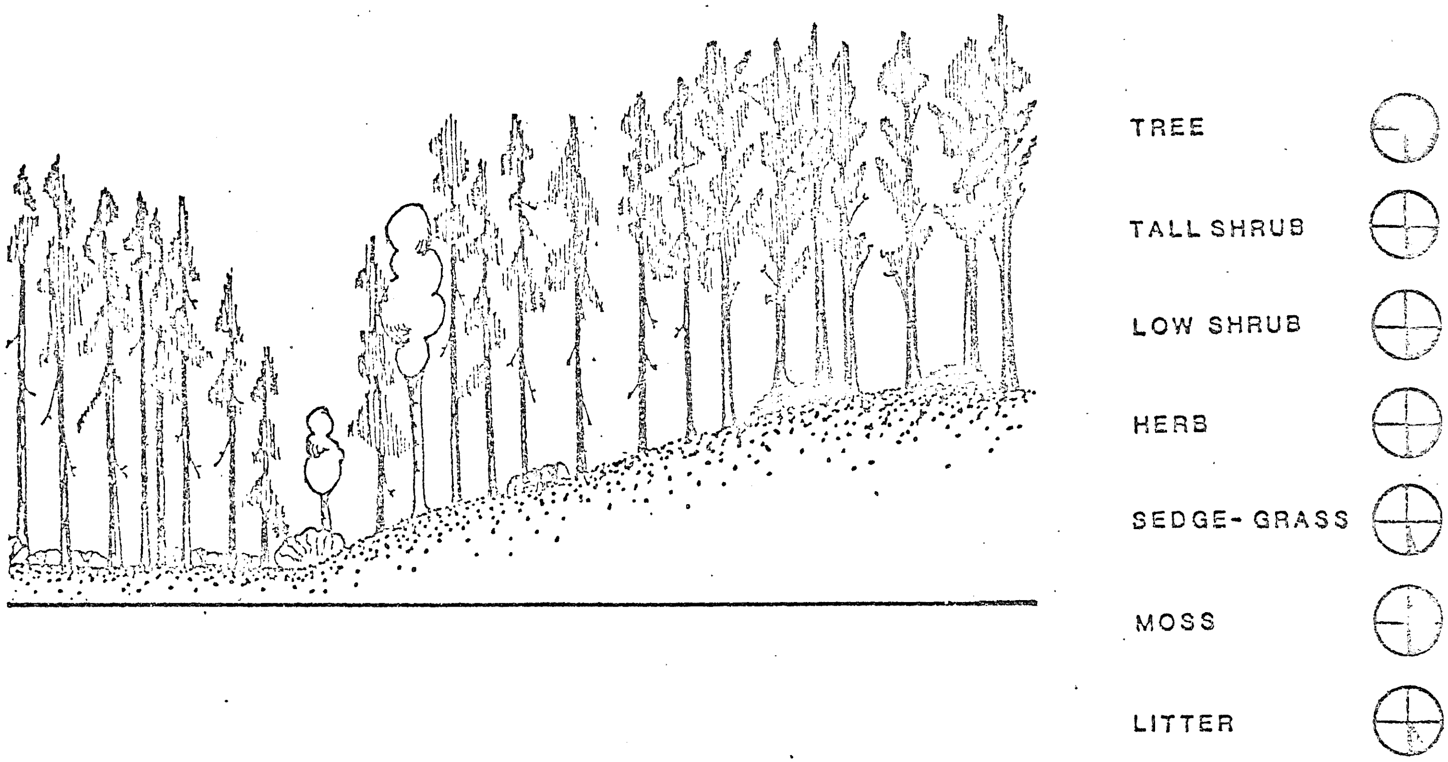
SOURCE: MLMIS 1978

FIGURE 22 BLACK SPRUCE-JACK PINE

SONG BIRD ASSOCIATION

BLACK CAP CHICKADEE/ GOLDEN CROWNED KINGLET	SPARROW HAWK- BROWN THRASHER	EASTERN WOOD PEWEE- SCARLET TANAGER	CATBIRD/ SWAMP SPARROW	HERMIT THRUSH/ BLACK - BURNIAN WARBLER	YELLOW-BELLIED FLYCATCHER/ CONNECTICUT WARBLER	COMMON FLICKER/ BROWN-HEADED COWBIRD	MOURNING WARBLER/ CHESTNUT-SIDED WARBLER	RED EYED VIREO/ OVENBIRD
			NOT	CENSUSED				

DEER | MOOSE | BEAR



INSECTIVORES | GRANIVORES | GRAZERS

NOT CENSUSED

SMALL MAMMAL ASSOCIATION

SHOWSHOE HARE	RUFFED GROUSE	SPRUCE GROUSE	BALD EAGLE	WOLF	FISHER	MARTEN

IMPORTANT LESS IMPORTANT UNIMPORTANT

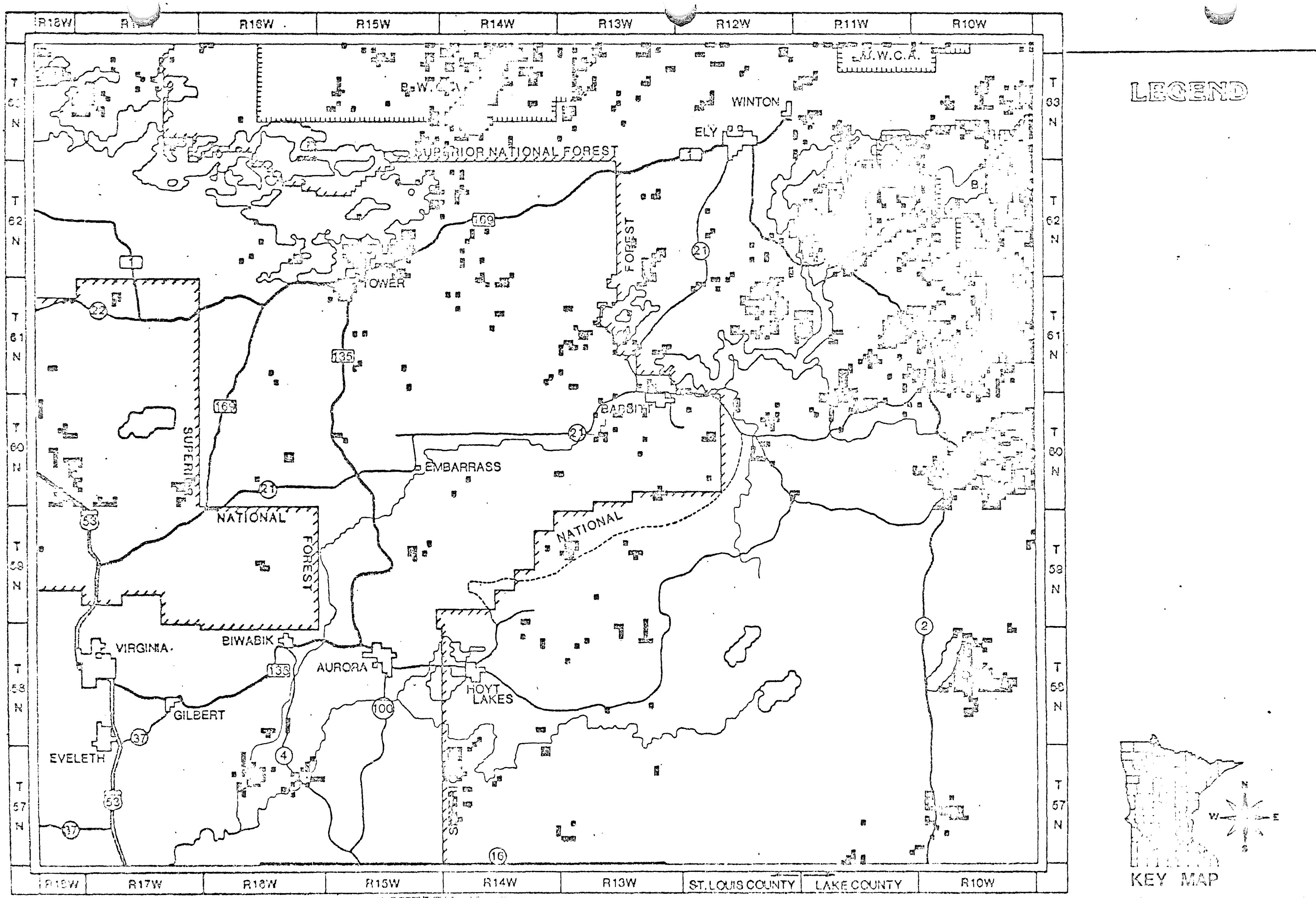
excellent cover for marten and adequate cover for fisher. Fisher populations appear to be concentrated in the portion of the Study Area where this habitat type is most extensively developed, but no causative relationship has been demonstrated. Use by large game mammals is probably restricted to winter use by deer and moose.

2.5.2.2 Jack Pine--The jack pine habitat type is present throughout the Study Area but concentrated in the northeast (Figure 23). Jack pine stands in the southern part of the area lie on either the clay-till soils of the Aurora Till Plain or on the loam soils of the Toimi Drumlin Field. Many of these stands take their origin as plantations postdating the 1936 Palo-Markham-Aurora fire. General Land Office Survey records show that the original pineries in this part of the area were dominated by red and white pine or mixtures of these species with deciduous elements (Figure 4). Jack pine was best developed in the shallow-moraine bedrock province where the few remaining natural stands occur today.

Figure 23

Jack pine is notable for its adaptation to forest fire. Not only are mature trees resistant to ground fires, but the cones are serotinous--that is, they are covered with a waxy substance that does not permit them to open and shed seed unless temperatures reach those attained in forest fires. This adaptation assures that seeds fall on mineral soil where seedlings are most likely to survive.

Because of its adaptation to fire, natural jack pine stands in northeastern Minnesota are even aged, dating from years with a record of extensive forest



MEQB REGIONAL COPPER-NICKEL STUDY

FIGURE 23 WHITE/RED/JACK PINE SOURCE: MLMIS 1978 fires. Stands north of Birch Lake and south of State Highway 1 take their origin in fires of approximately 1910, as do stands in the outwash plain of Glacial Lake Dunka.

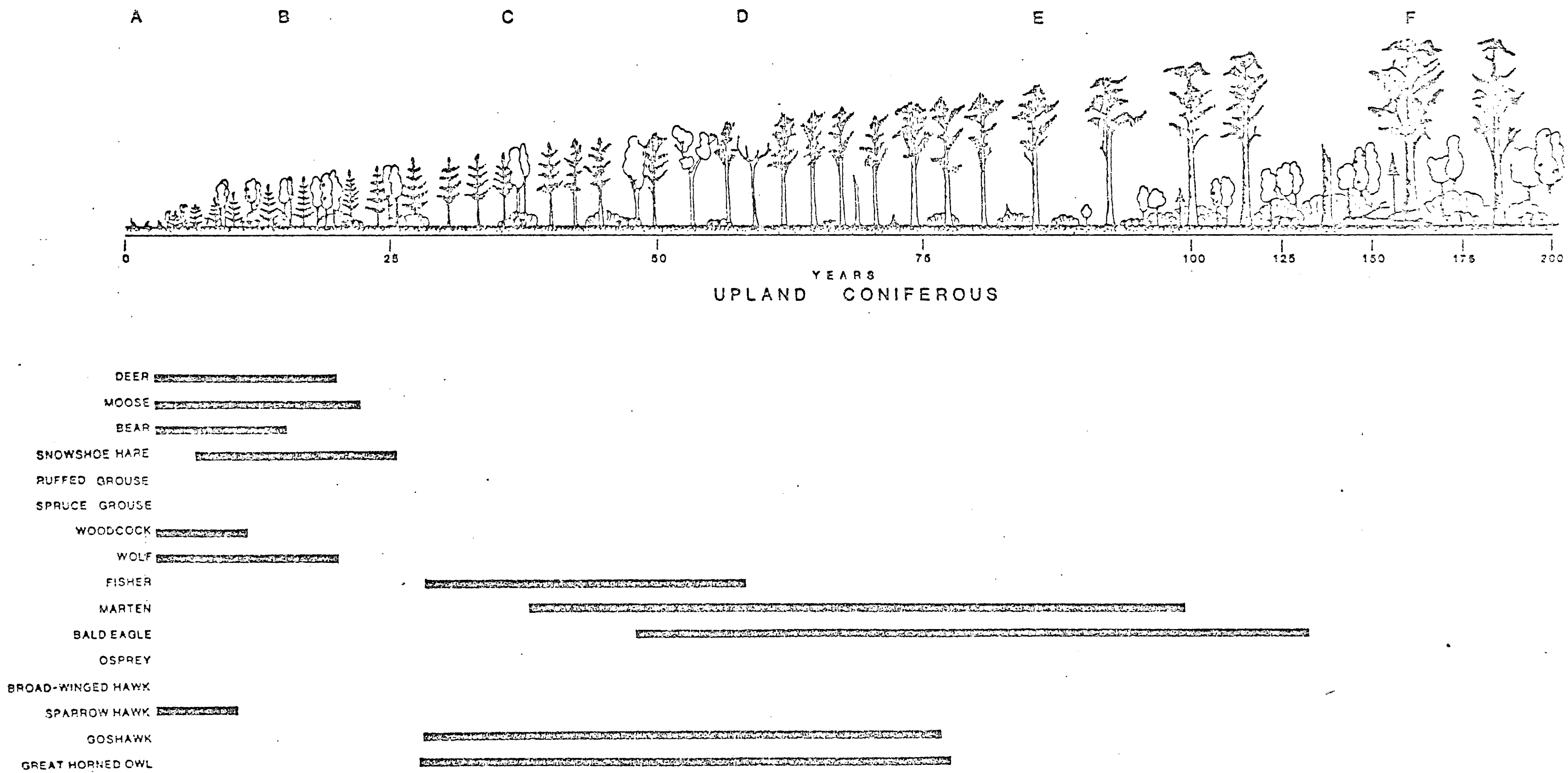
Most jack pine stands sampled by the Copper-Nickel Study are plantations falling into three successional classes: recent clearcuts (less than 8 years); young plantations (8-25 years); and mature stands (over 20 years)(Figure 24). Associated animal species vary with successional stages and are discussed with the appropriate stage below.

Figure 24

Recent Clearcuts--Because jack pine is adapted to regenerate after fire, the best regeneration is assured when management plans include some method of site preparation before reforestation.

Current management practices do not include extensive prescribed burning as a method of site preparation. The effect of forest fire in preparing a mineral seedbed has been simulated, in the past, by rock raking and barrel scarification. Many of the herb species of the forest floor have the capability of reproducing vegetatively for years, of withstanding forest fire or other disturbance, and of blooming only under the conditions of high light that follow such disturbance. Examples of such species are the large-leaved aster and fireweed (*Epilobium angustifolium*). Invasion of herbaceous weedy species such as pearly everlasting (*Anaphalis margaritacea*) and dogbane (*Apocynum androsaemifolium*) depends on several factors. The degree of soil disturbance, distance from seed sources, competition from persistent forest-floor herbs, and rate of regeneration of shade-producing trees all influence the establishment of weedy species.

FIGURE 24 FOREST SUCCESSION AND ANIMAL USE IN UPLAND CONIFEROUS STANDS



The practice of rock raking, which was in favor 5-10 years ago, included bulldozing the forest floor and piling slash in windrows several meters high and wide. The presence of these windrows favored development of a patchy shrub layer, usually dominated by raspberries (Rubus idaeus), along the windrows. The additional structural complexity and food resources added by these windrows are important to wildlife and birds. Regardless of the method of site preparation, plantations established on sites that were formerly occupied by deciduous stands are generally revegetated by large numbers of aspen suckers and require release from competition by use of herbicides or by hand removal of deciduous species (Figures 25 and 26).

Figures 25 and 26

Recent clearcuts were distinguished as faunistically distinct communities for both songbirds and small mammals, but the canopy composition of the recently harvested stand or of the plantation itself was not as important as the present structural characteristics of the clearcuts.

Bird communities of young clearcuts are dominated by species that are not unique to this habitat, whereas birds that are characateristic of open habitats such as the sparrow hawk (Falco sparverius) are not present in great numbers. Although ground nesters contribute the largest proportion to bird density, shrub nesters are much more important in this community than in mature coniferous stands. In some cases almost half the individuals were shrub nesters, reflecting the importance of shrubby windrows (Figure 25). The unimportance of tree nesters and cavity nesters reflects the general dirth of trees in this habitat (Figure 16).

The four conifer clearcuts sampled in 1977 shared three species: the mourning warbler (Oporornis philadelphia), white-throated sparrow (Zonotrichia

FIGURE 25 CLEARCUT

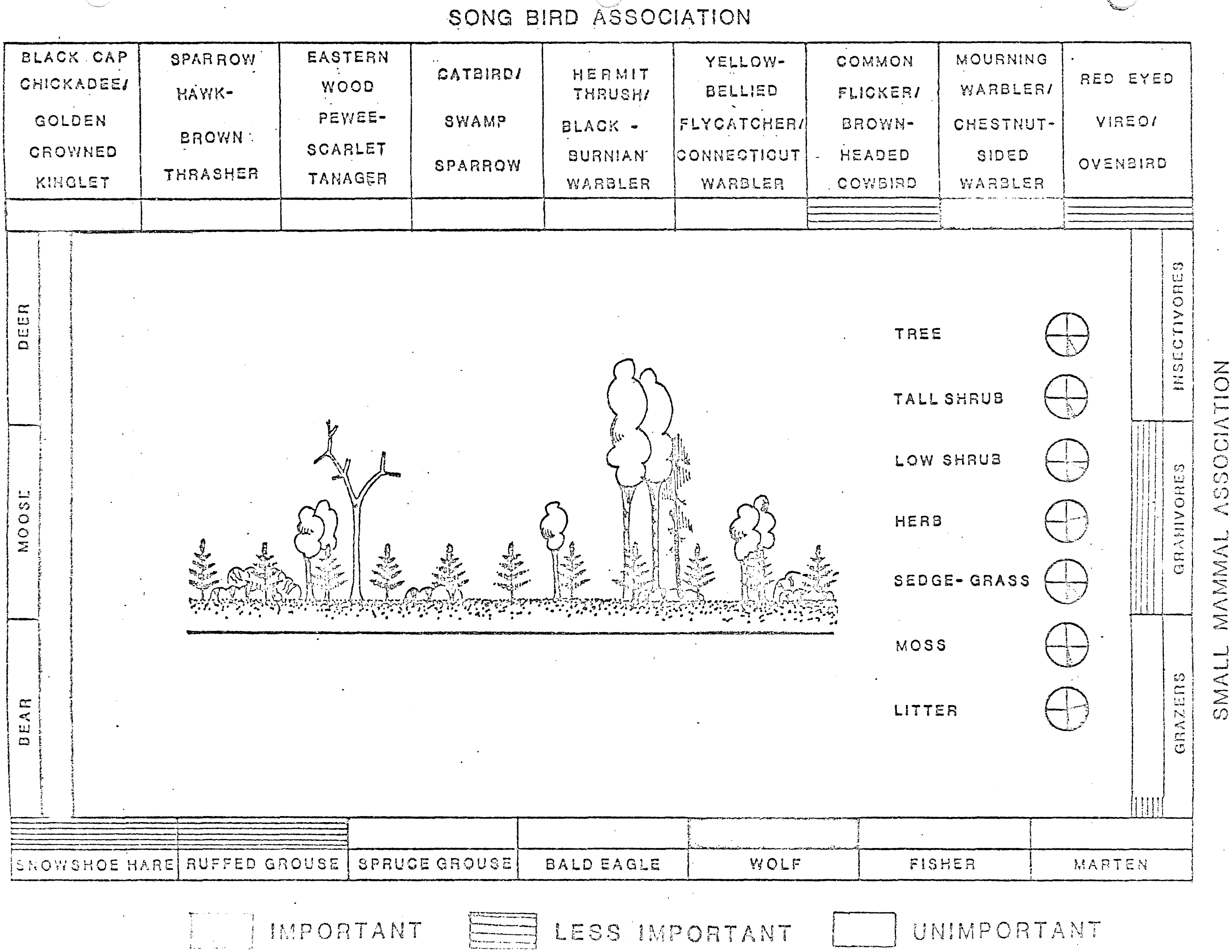
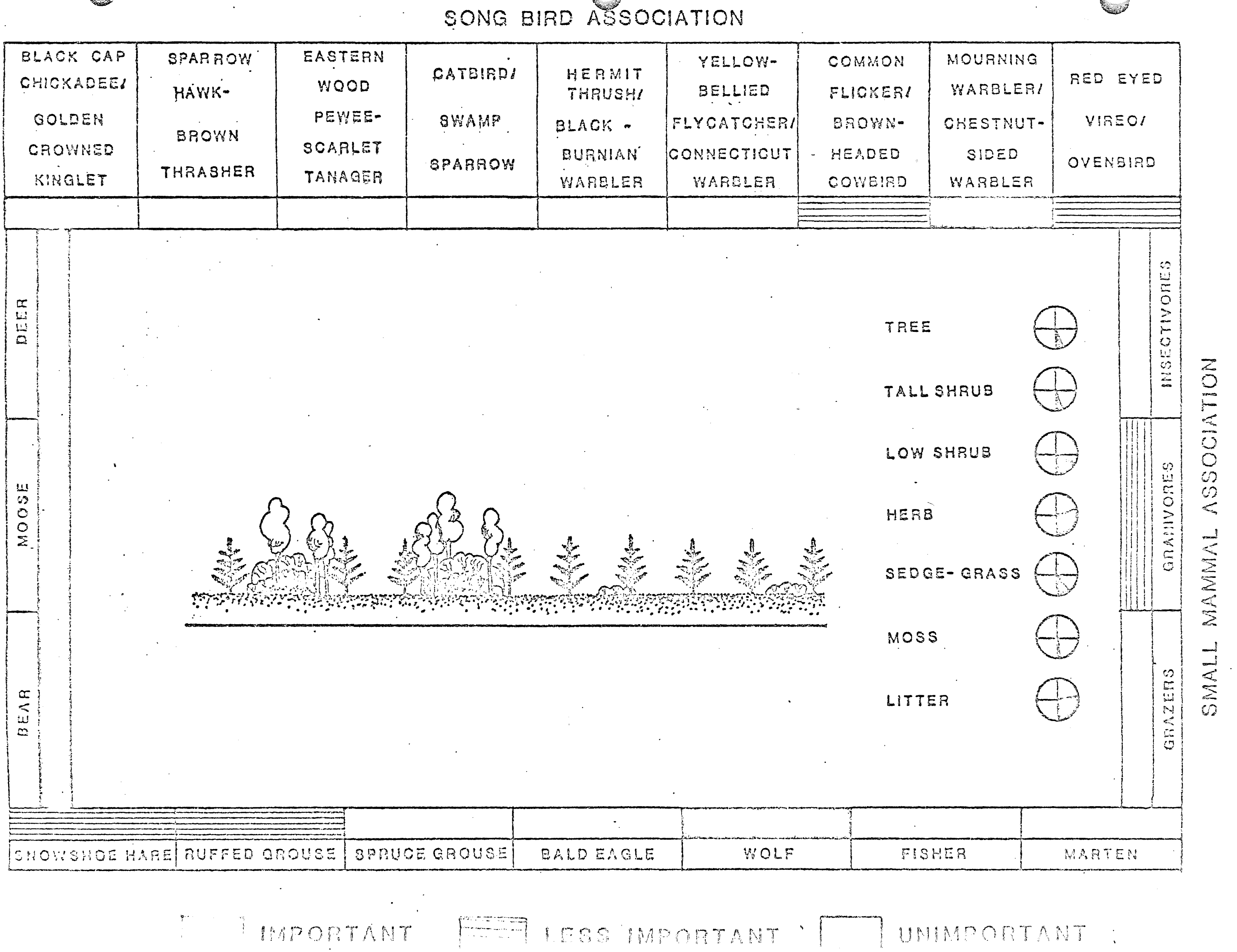


FIGURE 26 CLEARCUT WITH WINDROWS



atricapilla), and chestnut-sided warbler (Dendroica pennsylvanica). The chestnut-sided warbler was the dominant species in three of these four stands.

The only conifer clearcut sampled during the winter-bird survey was atypical because of the presence of several mature trees. The most abundant species were hairy woodpecker (Dendrocopos villosus) and downy woodpecker (Dendrocopos pubescens), species clearly associated with the presence of the trees.

In their earliest stages (1-2 years) the very open nature of recent clearcuts provides a habitat favorable for woodcock throughout their resident season. In the spring recent clearcuts are used by adult males as display grounds. As soon as the young can fly in the summer, females bring their broods from mature deciduous stands to open areas to probe for soil arthropods. In the autumn, clearcuts are used as staging areas for migration. Because woodcock require a long "runway" for take-off, densities are highest in areas where logging roads are available as avenues of escape. The singing-ground census showed that if logging roads remain open, clearcuts may be used as singing-grounds for ten years or more.

Small mammal populations of recent clearcuts and young jack pine plantations were grouped together in the analysis and were more similar to those in young upland stands of other types than to those of mature jack pine plantations. Both the least chipmunk and the woodland deer mouse achieved their highest frequencies in young stands where they were 2-6 times more common than in stands of the corresponding mature habitat. Both species were positively correlated with increasing amounts of deadfall, a common feature of clearcuts and very young plantations. The red-backed vole was also characteristic of young pine plantations, and reached average densities of approximately five individuals per hectare in all plantations sampled. One species, the meadow jumping mouse, appeared to be more characteristic of very young red pine plantations than of jack pine plantations of the same age.

Young Plantations--Although the Study's data do not indicate generally higher populations of small mammals in young plantations than elsewhere, from a forest-management viewpoint small mammals are a serious problem. Aerial seeding is reduced in effectiveness by the depredations of granivorous rodents, especially deer mice. Established young plantations are often damaged by red squirrels (*Tamiasciurus hudsonicus*) that remove the leaders and by other small mammals that girdle stems.

Young plantations that have not been released from deciduous competition offer high densities of young aspen and hazel as browse for moose and deer. The extensive raspberry crops of the windrows and the general stimulation of blueberry crops by high light conditions make such areas an excellent feeding ground for black bears (*Ursus americanus*) during the berry season. Windrows also provide good denning sites for bears.

Young plantations between the ages of approximately 7 and 15 years are generally characterized by pines at heights similar to those of the shrub layer. Presence or absence of deciduous shrub species depends on whether release has occurred. Common deciduous shrub species of jack pine plantations are hazel, juneberry, and aspen. Species composition of the herbaceous layer depends on the type of site preparation that was used and on the development of shade-producing species in the shrub layer. It appears that invasion by and persistence of weed species is greater in plantations where rock raking was vigorous and a higher proportion of forest-floor herb species were destroyed.

Young conifer plantations are more variable than mature stands in both plant species composition and structure. This variability is reflected in the greater variability of the bird community. The avian community of young plantations is not as well defined as that of mature coniferous stands. No two plots were alike in dominant species. Because of the structural variability of the vegetation the highest avian densities in young plantations were more than two times the lowest densities.

Variability in representation of the nesting guilds was greater than in mature habitats, but in general ground nesters were more important than tree nesters. As might be expected, shrub nesters were also more important than tree nesters, reflecting the shrub-like size of the pines.

Characteristic breeding species on all five plantations included the white-throated sparrow, blue jay (*Cyanocitta cristata*), chestnut-sided warbler, and song sparrow (*Melospiza melodia*). Young plantations were not included in the winter bird survey.

Small mammals characteristic of young plantations are generally those of clearcuts.

Mature Stands--Mature jack pine stands are characterized by jack pine canopies with admixtures of aspen, birch, and red pine (Figure 27). Shrub layers are poorly developed. Hazel, juneberry, and Bebb's willow (*Salix bebbiana*) are the most frequent components of the high shrub layer. Rose (*Rosa acicularis*), raspberry, and sweet fern (*Comptonia peregrina*) are frequent in the sparse low shrub layer. Shrub layers are best developed in stands of natural origin like plot G27, a virgin stand that was harvested at the end of the 1977 field season. In general, the herbaceous layer is dominated by high coverages of large-leaved aster, grasses (*Gramineae*), blueberries, strawberries (*Fragaria virginiana*), dewberries, and bunchberries. Rare species are generally members of the orchid family such as coral root (*Corallorhiza maculata*) and lattice leaf (*Goodyera* spp.).

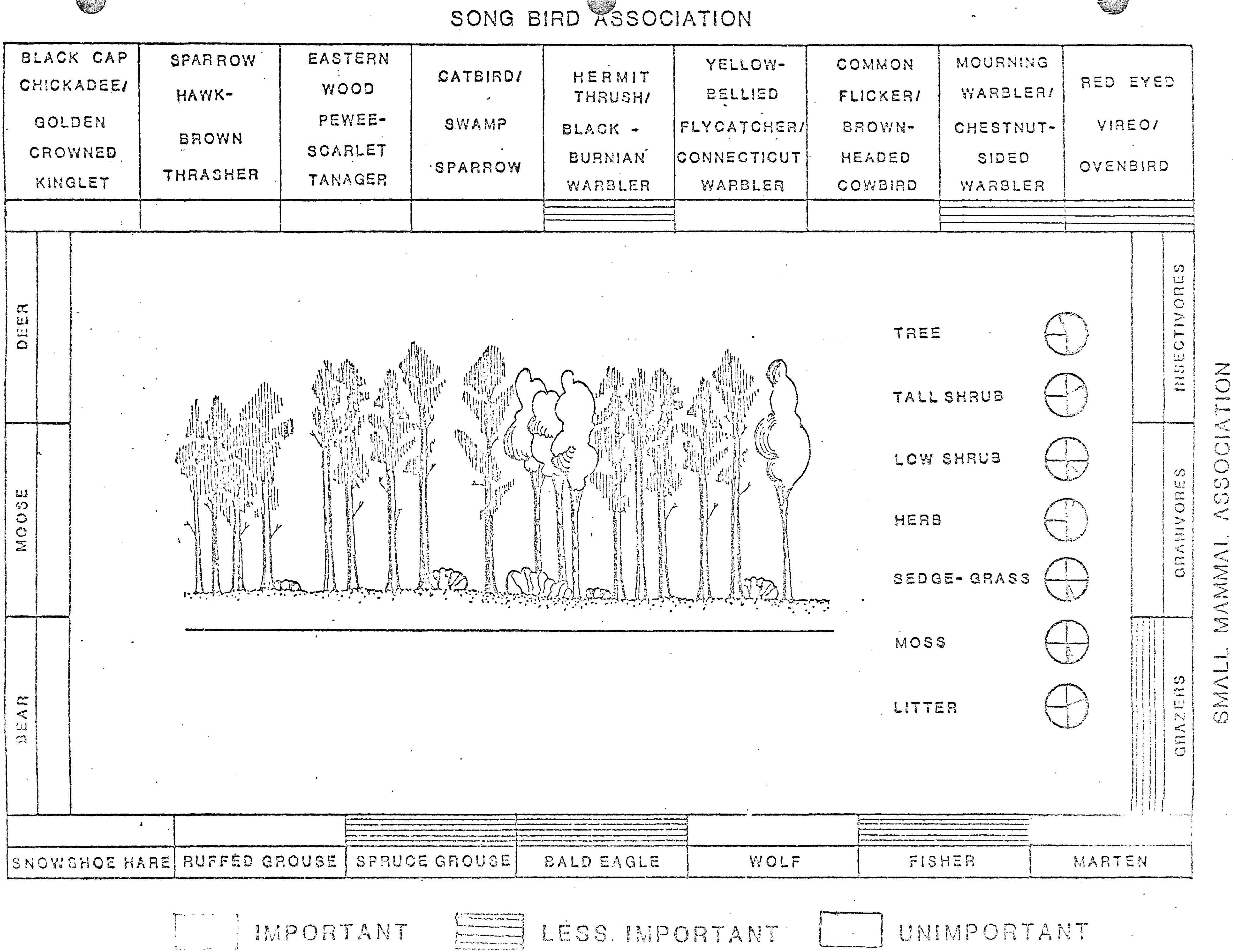
Figure 27

The bird community of mature upland conifer stands was recognized by cluster analysis as faunistically distinct from other bird communities. Within this avian community no distinction was made between birds of mature red pine, jack pine, and white spruce communities.

Breeding bird density of mature conifer stands averages approximately two-thirds that found in mature deciduous communities, with ground nesters contributing over half the individuals. Tree nesters are more important than shrub nesters, whereas cavity nesters are virtually absent (Figure 16). The small proportion of shrub nesters is not surprising in light of the generally low density of shrubs. The relationship of shrub nesters to available shrubs is borne out by their higher proportion (20 percent) in the one stand (G20) with a higher shrub density.

Characteristic bird species of mature coniferous uplands include the hermit thrush (*Hylocichla guttata*), eastern wood pewee (*Contopus virens*), yellow-rumped warbler (*Dendroica coronata*), brown creeper (*Certhia familiaris*), Blackburnian warbler (*Dendroica fusca*), and red-breasted nuthatch (*Sitta canadensis*). The single mature white spruce stand differed from other mature coniferous uplands in density, number of species, and species composition.

FIGURE 27 MATURE JACK PINE



Winter studies in mature conifer uplands yielded the lowest number of observations per five hours of any community sampled. Species observed included the great-horned owl (Bubo virginianus), hairy woodpecker, raven (Corvus corax), black-capped chickadee (Parus atricapillus), downy woodpecker, and black-backed 3-toed woodpecker (Picoides arcticus). The absence of seed-eating finches is worth noting. The cyclic nature of seed production in boreal conifers has a strong influence on population cycles of winter finches, such as the common redpoll (Acanthis flammea), which are notorious for their large yearly fluctuations. Winter finch species were rare throughout the state during the winter of 1976-1977.

Two of the three small mammals characteristic of young plantations are also characteristic of mature jack pine stands. The red-backed vole occurs at the same frequencies but at higher densities in mature stands, whereas the deer mouse occurs with both lower frequencies and densities in mature stands. In 1977 the masked shrew was also characteristic of mature jack pine stands, but this species avoided such dry sites during the summer of 1976.

Porcupine (Erethizon dorsatum) scar studies in Lake and St. Louis counties reveal that porcupine prefer jack pine as winter food. Because studies in Michigan suggest that porcupines selectively eat those species nearest their dens, their apparent preference for jack pine may be related to the proximity of safe, rocky denning sites. In an area where there are high populations of their chief predator, the fisher, safe denning sites become even more important. Fisher populations in northeastern Minnesota are currently high enough to sustain a trapping season. Trap records from the first such season (1977) suggest a concentration of fishers in the northeastern part of the Study Area.

2.5.2.3 Red Pine--Red pine communities in the Study Area are almost exclusively plantations and are scattered throughout the area (Figure 23). On Superior National Forest lands, acreages of red and jack pine are comparable in Lake County, but in St. Louis County acreages of red pine are approximately one third those of jack pine. General Land Office Survey records show that before clearance red pine was mixed with white pine and ran in a band from the Aurora Till Plain northeastward to the east end of Birch Lake but avoided the Shallow Moraine Bedrock Province where jack pine was better developed.

Mature red pine resembles jack pine in its resistance to fire, but it lacks serotinous cones. Good seed crops of red pine occur every 4-7 years, a factor that may have been important historically for the regeneration of red pine stands. Like jack pine, red pine seedlings prefer the seedbed and light conditions that occur following fire. The coincidence of fire and a good seed year is less probable for red pine with its longer cycle of seed production.

Because of the undependability of natural seeding, red pine plantations are usually established by planting or aerial seeding. Before planting, sites are usually prepared by barrel scarification (or formerly by rock raking). Current management guidelines differ somewhat from those of the last 40 years, because they do not encourage conversion of deciduous sites to pine stands. Plantations established on sites formerly occupied by deciduous species such as aspen require release from competition by herbiciding or hand removal. Unlike jack pine plantations, red pine are usually thinned two or three times before their final harvest at 120 to 180 years.

Because of their structural and floristic similarities, recent red pine clearcuts and young red pine plantations share the same songbird and small mammal communities as jack pine stands of the same age. They also provide the same resources for game species such as woodcock.

Mature red pine plantations are similar in structure to mature jack pine plantations, with sparse shrub layers and continuous herb layers (Figure 28). Cluster analysis based on canopy composition recognizes red pine as a distinct type, while lumping jack pine stands with mixed black spruce-jack pine communities. Although their basal areas are low, birch, aspen, spruce, and fir are present in a higher proportion of the stands (Table 8) and occur more frequently in the shrub layer than in jack pine stands. Hazel, juneberry, and Bebb's willow occur at lower frequencies and densities than in the jack pine community, whereas rose and raspberry occur at higher frequencies and densities. Leading herbaceous species in the two communities are similar, but a much larger number of herbs reach their highest percent presence in the red pine habitat. Except for the addition of bracken fern (Pteridium aquilinum) the same suite of species attains highest coverages in the red pine community.

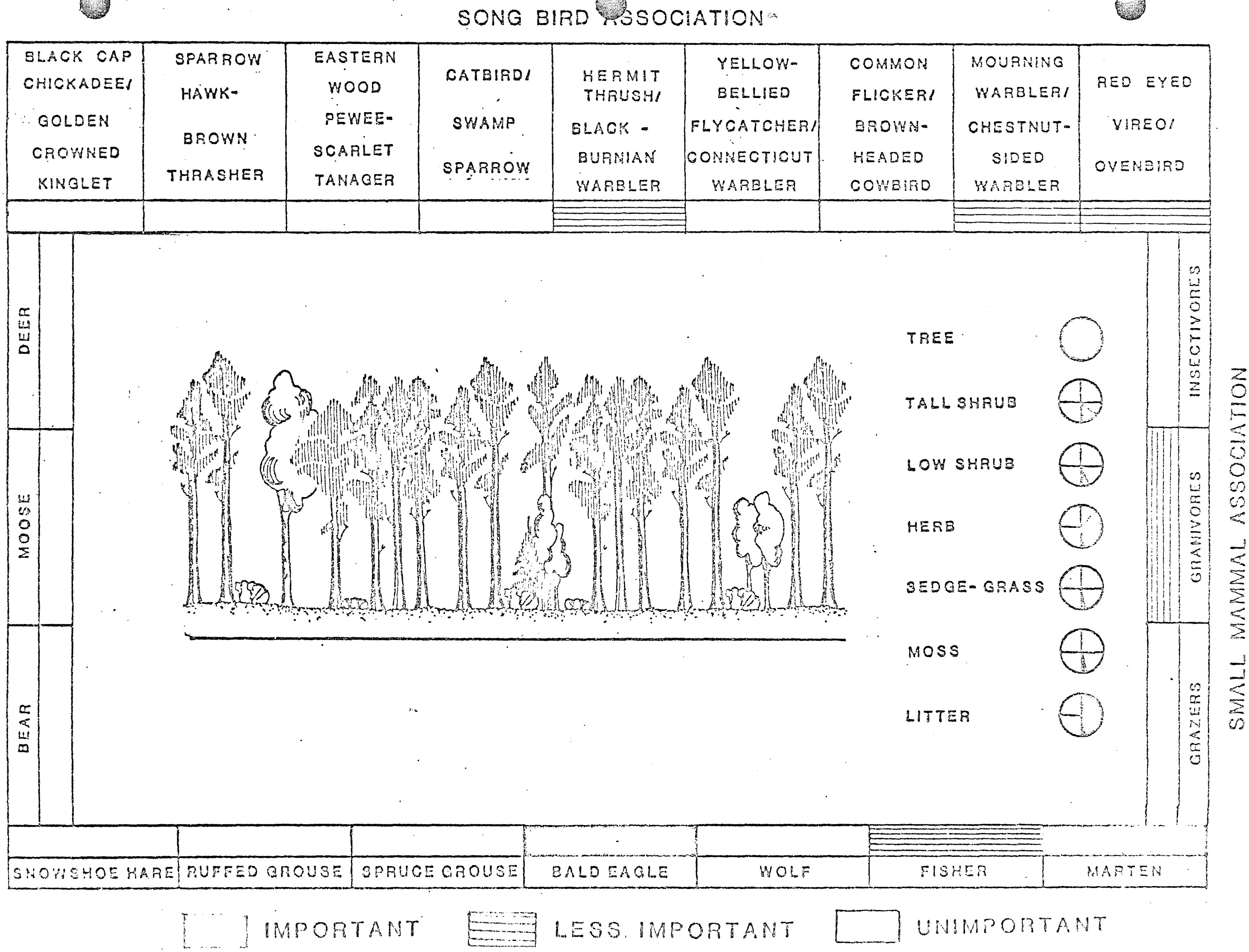
Figure 28

The avian community of mature red pine stands is indistinguishable from that of jack pine.

In addition to the three small mammals characteristic of mature jack pine stands, the least chipmunk and meadow jumping mouse are characteristic of mature red pine stands.

Mature red pine stands provide the same resources for large mammals and raptors as do jack pine stands. Owls and hawks use mature trees as nesting sites, and fisher use the habitat for cover and food. Use by porcupine is not documented

FIGURE 28 MATURE RED PINE



for northeastern Minnesota. Deer use maturing stands for winter cover when other habitats are not available.

2.5.2.4 White Spruce--The white spruce stands in the Study Area are an artifact of forest management and are not considered as one of the eleven major community types. These stands, which are included in the spruce-fir type, in the computerized inventories, do not appear to be as widespread as the computerized inventories indicate (Figure 21)(MLMIS and Minesite). Stands in the shallow-moraine bedrock province are generally dominated by black spruce rather than white spruce, often with jack pine as a coordinate species. Areal extent of natural upland black spruce on national forest lands in Lake and St. Louis counties is between three and four times that of white spruce plantations.

Since 1936 white spruce plantations have been established in a portion of the Study Area southeast of Aurora and in the eastern part of the area near the junction of State Highway 1 and Lake County Highway 2. Three such plantations were sampled as part of this study.

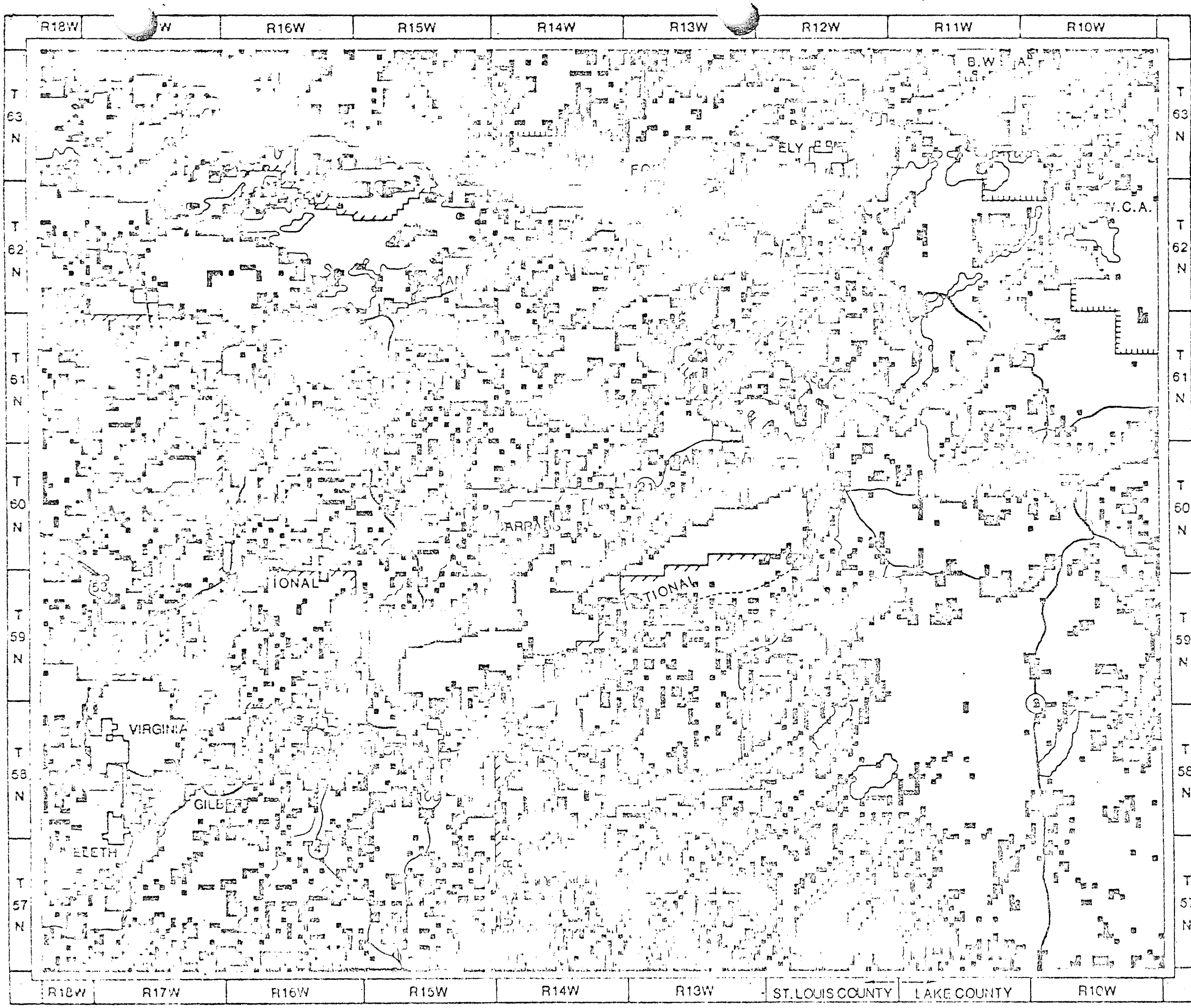
In keeping with the silvicultural recommendation of mineral soil for the establishment of white spruce, both of the younger plantations were apparently rock raked before being planted. Instead of recommending a monoculture, management guidelines for white spruce in the Superior National Forest recommend leaving at least 30 percent aspen-birch with young spruce to aid growth and prevent frost damage. White spruce plantations are normally harvested in 100 years.

Because of their variability and the absence of a canopy in the two younger plantations, cluster analysis based on canopy composition failed to recognize white spruce as a distinct community type. The three stands were not structurally or floristically similar enough to make any generalizations about the community. The mature stand had a patchy distribution of herbaceous species associated with an internal moisture gradient in the plot. The two younger stands (3 and 15 years) were characterized by a patchy distribution of species in all layers associated with the presence of windrows. Species present in all three stands included white spruce in the high shrub layer, Bebb's willow, bush honeysuckle (Diervilla lonicera), false lily-of-the-valley, strawberry, dewberry, pearly everlasting, large-leaved aster, wood anemone (Anemone quinquefolia), early sweet coltsfoot (Petasites palmatus), and fringed blue aster (Aster ciliolatus). One rare species, green malaxis (Malaxis unifolia) a member of the orchid family, was present in the youngest of the three stands.

The poorly drained nature of the three white spruce sites is reflected by the presence of the masked shrew and arctic shrew as characteristic species. The red-backed vole was also characteristic of this habitat. Mature white spruce plantations would appear to offer suitable habitat for spruce grouse and fisher.

2.5.2.5 Aspen-Birch--Deciduous stands dominated by aspen and birch are widespread today throughout the Study Area (Figure 29) and produce the most variable of the community types identified in this study. Admixtures of coniferous species such as fir, black spruce, and jack pine are more frequent north of the Giants Range in the Shallow Moraine Bedrock Province (Figure 2). Sugar maple and basswood are more frequent components of deciduous stands along the Giants Range and to the south of it. In the northern portion of the Study Area basswood is most likely to occur in deciduous stands that are under the climatic influence of large lakes such as Fall, White Iron, and Basswood.

Figure 29



LEGEND

MECC REGIONAL COPPER-NICKEL STUDY

FIGURE 29

ASPEN - BIRCH

SOURCE: MLMIS 1978

General Land Office Survey records show that aspen-birch stands were originally most extensive in the Toimi Drumlin Field, in the Outwash-Moraine Complex province, the Aurora Till Plain, and those parts of the beds of Glacial Lakes Upham and Norwood that were not occupied by bogs (Figure 4). Along the crest of the Giants Range pines were mixed with hardwoods. Although this community was not sampled as part of the Regional Copper-Nickel Study, the higher proportion of maple in stands along the Giants Range is obvious in the autumn.

Both aspen and birch are cold-tolerant, short-lived, "sun-loving" species that are considered to be pioneers in the successional series. In northeastern Minnesota they are replaced by longer-lived or more shade-tolerant species such as white pine, black spruce, and balsam fir. When aspen-birch stands are disturbed by fire or logging, they regenerate vegetatively to form even-aged stands. Aspen forms suckers from the roots, whereas birch forms stump sprouts. Complete removal of the canopy results in better stocking by aspen suckers because residual mature trees inhibit suckering. Deciduous uplands in the Partridge River watershed are an example of the inhibitory effect of residual trees. Serial examination of aerial photos at roughly ten-year intervals reveals that in many parts of townships 59 and 60N., ranges 12 and 13W., scattered mature aspen were left after logging in the 1940s, and reforestation was delayed by several years after cutting. Today these areas support a heterogeneous mosaic of poorly stocked aspen and birch, upland shrubs, and interspersed coniferous plantations.

Two major subtypes of the aspen-birch community were investigated as part of this study: nearly pure aspen-birch stands and aspen-birch stands with fir as a major canopy associate. The aspen-birch community as a whole exhibits high frequencies of coniferous elements, emphasizing the similarity between this community and the mixed coniferous-deciduous community.

Recent Clearcuts--Young aspen-birch clearcuts are more similar structurally and floristically to other young clearcuts than they are to mature aspen-birch stands. Many of the most ubiquitous herbaceous plants are adapted to recurrent natural disturbances, such as fire, and are able to persist after clearcutting.

The structural similarity of deciduous and coniferous clearcuts is reflected in the species composition of the songbird community. Like coniferous clearcuts, deciduous clearcuts are dominated by ground nesters, followed by shrub and tree nesters. The two deciduous clearcuts studied were structurally dissimilar from those coniferous plots having windrows. The absence of shrub-rich windrows may explain the lower maximum densities of shrub nesters in recent deciduous clearcuts.

Characteristic bird species of deciduous clearcuts were the same as those of coniferous clearcuts: the mourning warbler, chestnut-sided warbler, and white-throated sparrow. Species composition varied among tree nesters because they were dependent on residual and neighboring trees. For example, a clearcut (plot G40) surrounded by deciduous upland and having several residual red maples supported the red-eyed vireo (*Vireo olivaceus*), whereas one bordered by coniferous upland (plot G13) with several residual red pines harbored the eastern wood pewee, rose-breasted grosbeak (*Pheucticus ludovicianus*), and chipping sparrow (*Spizella passerina*).

Small mammal populations of recently clearcut deciduous stands are the same as those characteristic of coniferous clearcuts and young plantations and include the woodland deer mouse, least chipmunk, and red-backed vole, as well as the masked shrew.

The value of deciduous clearcuts for game species is similar to that of young plantations. Woodcock use 1-3 year old deciduous clearcuts because their open nature provides escape routes from predators.

Regenerating Deciduous Communities---One year after a deciduous stand in the Study Area has been harvested a dense growth of young aspen usually appears (Figure 30). At 1-2 years, densities of young aspen have been measured in the Study Area as high as 55,000 stems per hectare. If the stand has not been planted to pine and aspen growth is not controlled, the aspens will reach heights of 3 to 5 meters in 4 to 6 years. Three such stands were sampled as part of the 1977 breeding bird survey.

Figure 30

As might be expected, shrub-nesters are the most important nesting guild in the regenerating deciduous community (Figure 16). Almost half the birds in this habitat were shrub-nesters, whereas over one third were ground nesters. Both tree-nesters and cavity-nesters were relatively unimportant. The high density of young aspens in such stands appears to influence not only the higher proportion of shrub-nesters, but also the higher overall avian density of young aspen stands compared with mature stands. Characteristic species of this successional stage include the mourning warbler, red-eyed vireo, and chestnut-sided warbler.

Sapling-size aspen are of extremely high food value for deer, moose, and beaver (Figure 31). These stands retain their value for deer and moose, as the trees grow beyond reach because the shrub layer comes into full development. Hazel, willow, and mountain maple (*Acer spicatum*) become principal winter browse species.

FIGUR 30 ASPEN REGENERATION

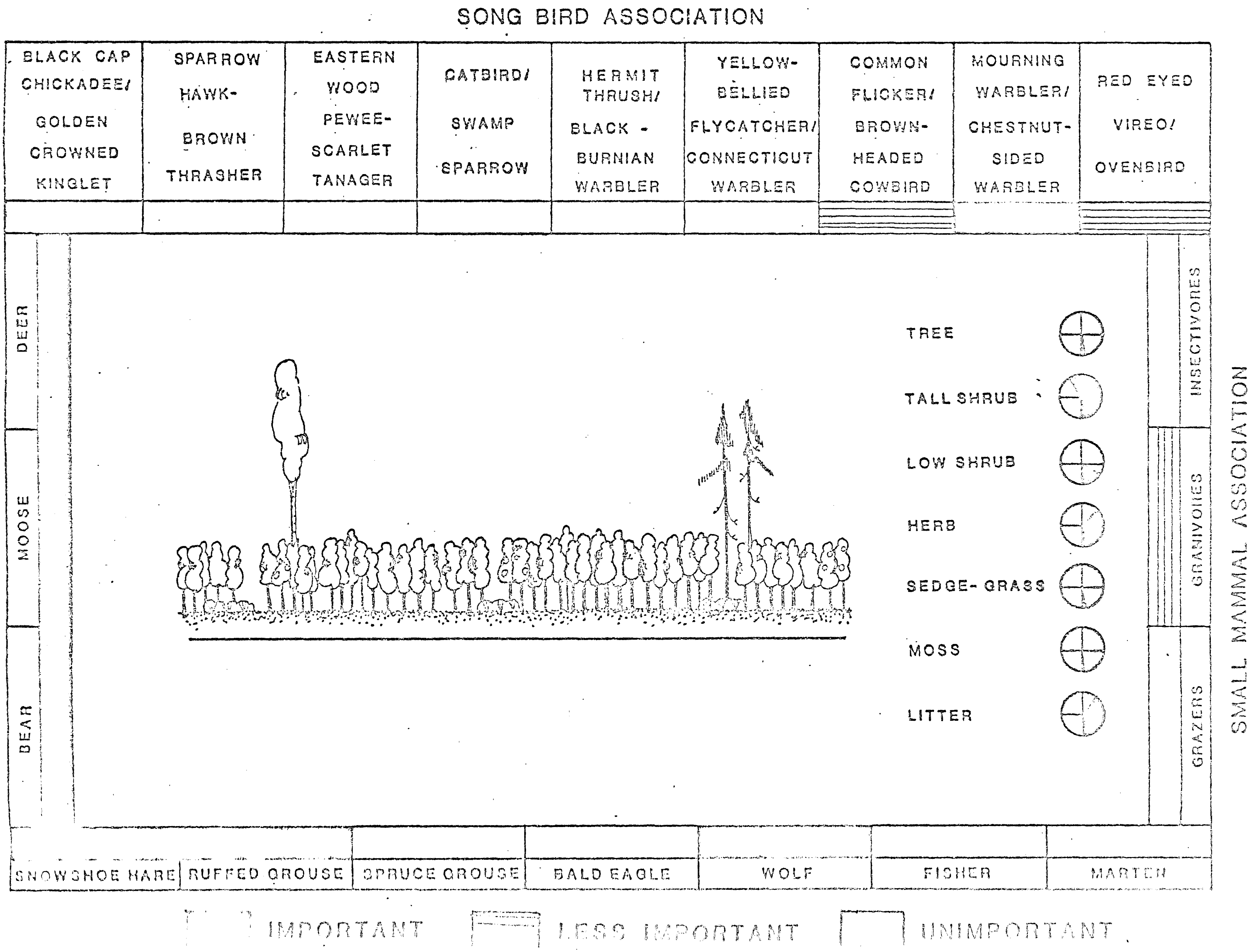


Figure 31

Mature Aspen-Birch--As aspen-birch stands mature, the density of trees is reduced to about two percent of the densities found at the sapling stage (Figure 32). High shrubs continue to be important in mature stands. Hazel, mountain maple, and honeysuckle (Lonicera canadensis) reach their highest percent presence in this community (Table 8). Other prevalent modal species are large-leaved aster, wild sarsaparilla, braken fern, twisted stalk (Streptopus roseus), ground pine (Lycopodium obscurum), and sweet bedstraw (Galium triflorum). The nodding trillium (Trillium cernuum) is the most frequent protected species found in the aspen-birch community. Aspen-birch stands in the Toimi Drumlin Field exhibit a higher frequency of spring ephemerals such as spring beauty (Claytonia caroliniana) and other early spring flowers such as wild ginger (Asarum canadense) and hepatica (Hepatica americana) than at other Study sites.

Figure 32

The bird community of mature deciduous uplands is recognized as a faunistically distinct community. As in all mature communities, ground-nesters were an important component of the community, accounting for an average of almost half the individuals (Figure 16). Shrub-nesters, which accounted for about one quarter of the total density, were more important than in mature coniferous communities but less important than in regenerating aspen stands. The remaining quarter of the population was mainly composed of tree-nesters. Characteristic species of mature deciduous stands were the shrub nesting red-eyed vireo (Vireo olivaceus), the ground-nesting ovenbird (Seiurus aurocapillus), and the ground-nesting veery.

FIGURE 31 FOREST SUCCESSION AND ANIMAL USE IN UPLAND DECIDUOUS STANDS

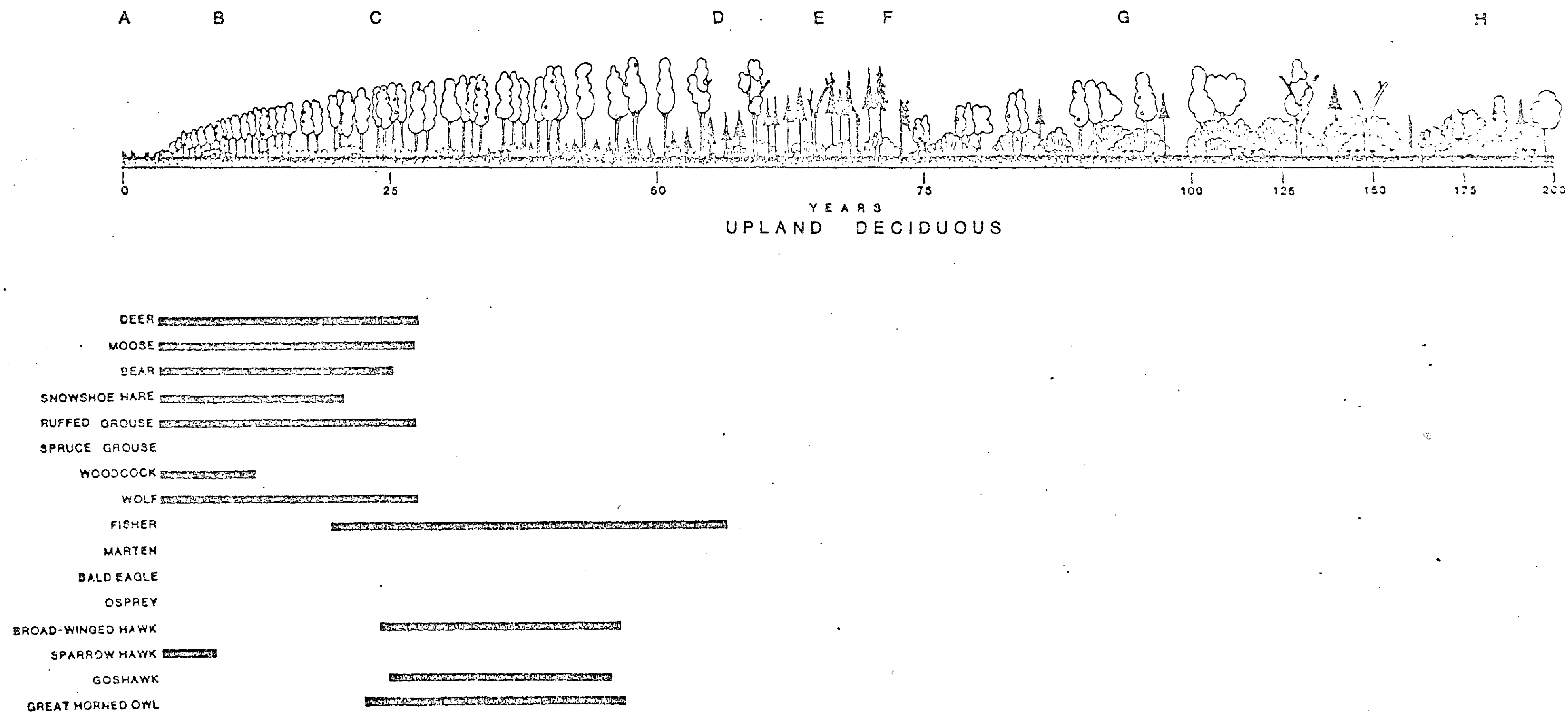
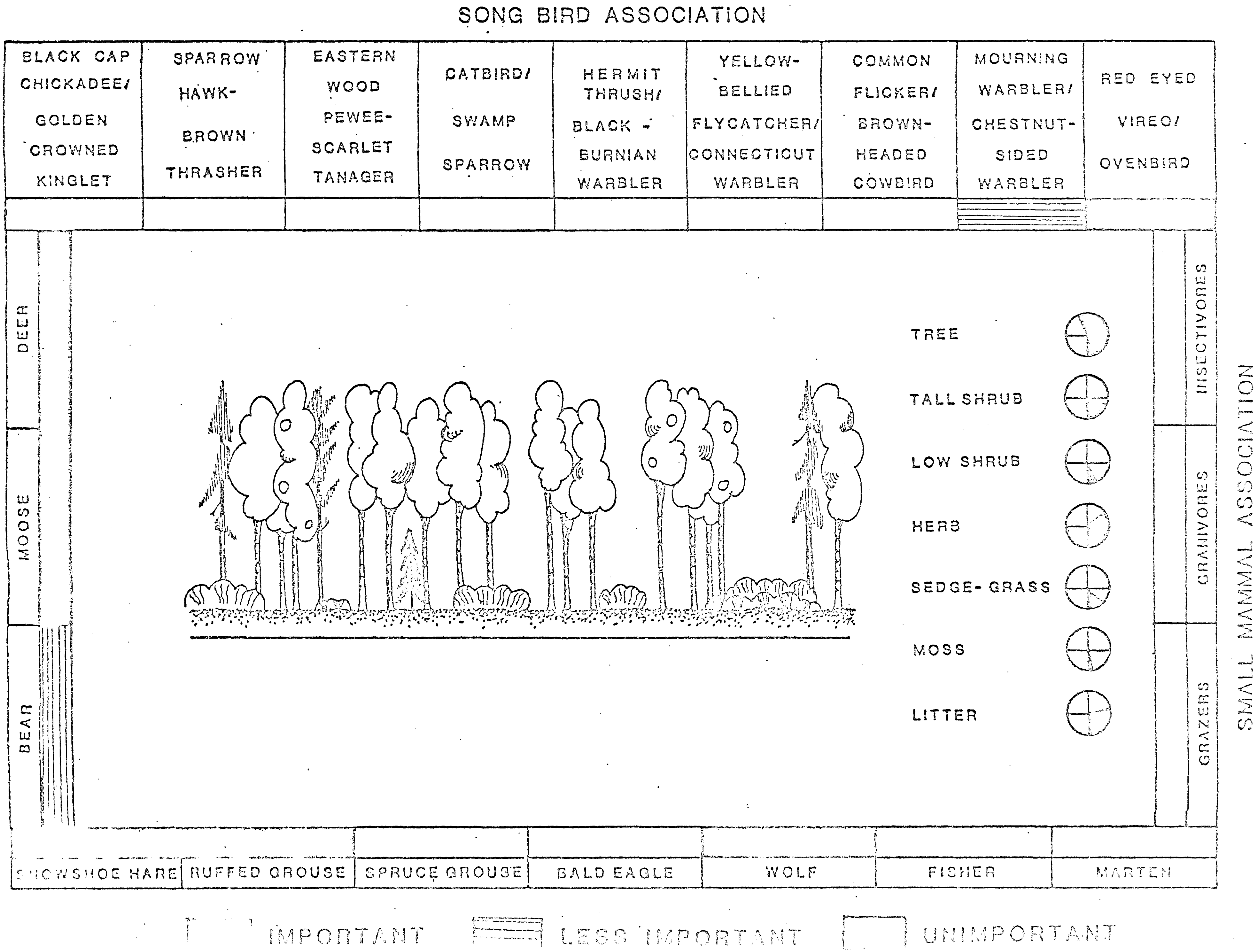


FIGURE 32 MATURE ASPEN



During the winter of 1976-1977 three mature aspen-birch plots were sampled. Together these plots averaged seven observations in a five-hour period, ranking third among the six habitats sampled. A total of six species were observed; of these, three were present in all three plots (the hairy woodpecker, common raven, and black-capped chickadee).

The deciduous stands in the east-central portion of the Study Area are representative of the area logged in the 1940s and only partially reforested. The vegetation is characterized by an open heterogeneous canopy with scattered clumps of live or dead aspen, interspersed patches of plantation, and an almost continuous shrub layer.

The bird community associated with this heterogeneous vegetation was recognized as distinct from other upland bird communities. The vegetation of the two stands sampled in this area was sufficiently floristically dissimilar that one stand was classified as aspen-birch and the other as mixed coniferous-deciduous. In spite of these floristic dissimilarities the avian faunas of the two stands were more similar than those on stands in any other community type. The two stands had fourteen common species with six attaining their highest density and importance value in this community. These species were the blue jay, black-and-white warbler (Mniotella varia), Canada warbler (Wilsonia canadensis), rose-breasted grosbeak, magnolia warbler (Dendroica magnolia), and yellow-bellied sapsucker (Sphyrapicus varius). The high shrub density and general structural diversity of these stands are reflected in the high overall bird density, second only to that of young plantations, and the high species diversity, second to that of alder carr.

Ruffed grouse, the most important game bird in forested areas of the state, reaches its highest densities in the aspen-birch community where it exploits every successional stage. Young stands are used by broods, medium-aged stands by displaying males, and mature stands by nesting females and by both sexes as winter feeding grounds. Buds and twigs of mature aspen constitute the primary winter food of ruffed grouse.

Six small mammal species are characteristic of mature aspen-birch stands. Two of these, the woodland jumping mouse and eastern chipmunk, attain their highest average relative densities in aspen-birch stands. In each case these densities are three or more times higher than densities in all other vegetation types. The chipmunk shows a significant habitat selection not only for the deciduous canopy but also for the associated herb layer dominated by large-leaved aster. The short-tailed shrew is found in densities similar to those in closed tamarack bogs and two to three times higher than in all other habitat types. Both the eastern chipmunk and short-tailed shrew showed significant habitat selection for the dense cover of high shrubs characteristically associated with the aspen-birch canopy.

Mature aspen-birch stands are less important to large mammals than earlier successional stages. The high cover of hazel in mature stands continues to provide summer browse for deer. Stands with concentrations of juneberries receive seasonal use by bears.

Mature deciduous stands with a larger proportion of fir in the canopy have a significantly lower basal area of hazel in the high-shrub layer and lower coverages of large-leaved aster and bracken fern in the herb layer.

Where deciduous communities have fir understories, the woodland jumping mouse and eastern chipmunk occur in lower densities than in similar stands that lack fir.

2.5.2.6 Mixed Coniferous-Deciduous--Deciduous stands in the Shallow Moraine Bedrock Province, especially those north of Birch Lake, often contain a high proportion of fir, black spruce, and jack pine. Although they probably represent one extreme in a continuum from pure aspen to mixed upland stands, cluster analysis based on canopy composition recognizes such stands as a separate community type.

Almost all mixed stands in the releve data set were located in the Kawishiwi watershed. Quantitative data are available from only two stands of this community type and neither is located in the Kawishiwi watershed. For this reason small mammal data for the mixed coniferous-deciduous habitat may not be representative of the community as a whole.

Mixed stands are characterized by higher presence values for black spruce, fir, and jack pine and lower frequencies of birch than are aspen-birch stands (Figure 33). Although spruce is present in more stands and has a higher average basal area, the density of fir is seven times higher, indicating that there are a greater number of smaller fir trees. The shrub layer is less well developed in this community type than in aspen-birch stands. Hazel, juneberry, and mountain ash dominate the tall shrub layer. Bluebead lily, false lily-of-the-valley, and twinflower (Linnaea borealis) reach their highest percent presence in the herb layer of this community. Other important herbs are large-leaved aster and bracken fern.

Figure 33

Although the proportion of trees of each species in different size classes does not suggest a successional relationship between stands of different canopy

FIGURE 33 MIXED CONIFER- DECIDUOUS

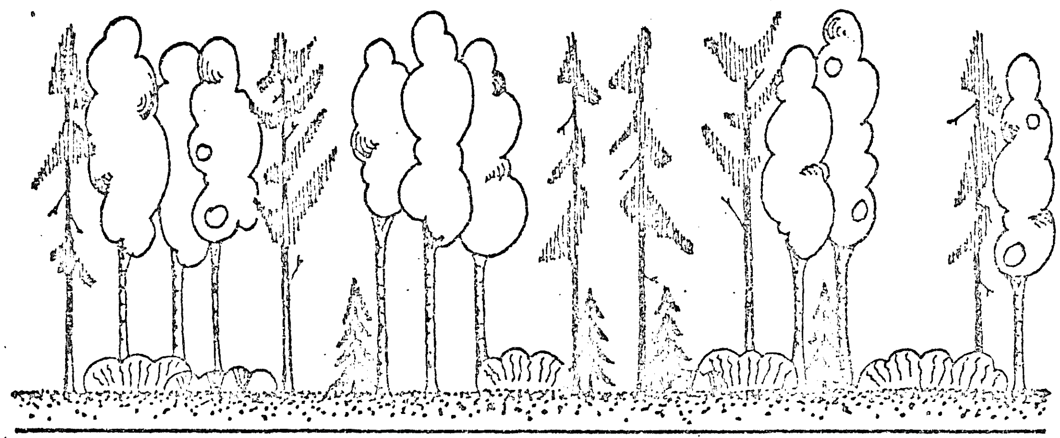
SONG BIRD ASSOCIATION

BLACK CAP CHICKADEE/ GOLDEN CROWNED KINGLET	SPARROW HAWK- BROWN THRASHER	EASTERN WOOD PEWEE- SCARLET TANAGER	CATBIRD/ SWAMP SPARROW	HERMIT THRUSH/ BLACK - BURNIAN WARBLER	YELLOW-BELLIED FLYCATCHER/ CONNECTICUT WARBLER	COMMON FLICKER/ BROWN-HEADED COWBIRD	MOURNING WARBLER/ CHESTNUT-SIDED WARBLER	RED EYED VIREO/ OVENBIRD

DEER

MOOSE

BEAR



TREE

TALL SHRUB

LOW SHRUB

HERB

SEDGE- GRASS

MOSS

LITTER

SMALL MAMMAL ASSOCIATION

INSECTIVORES

GRANIVORES

GRAZERS

SNOWSHOE HARE	RUFFED GROUSE	SPRUCE GROUSE	BALD EAGLE	WOLF	FISHER	MARTEN

IMPORTANT LESS IMPORTANT UNIMPORTANT

types, the mixed coniferous-deciduous community in the northeastern part of the Study Area appears to be the nearest thing to a "climax" community (Figure 31). As is the case with mixed black spruce-jack pine communities, this community may have contained a higher proportion of fir in the past, for large portions of the area in this cover type were classified as "restocking spruce-fir" in the late 1940s.

During the last ten or fifteen years timber guidelines for this community encouraged the conversion of mixed stands to commercially valuable species such as pine. Marketable timber was harvested where feasible, and areas were often prepared by removal of "weed" species, such as aspen and mountain maple, followed by rock raking. An example of such an area is the extensive clearcut north of August Lake.

Characteristic small mammals are similar to those of mature aspen-birch-fir communities, with three out of four species in common. The masked shrew, short-tailed shrew, and red-backed vole are characteristic of both habitats, whereas the pigmy shrew is only characteristic of mixed coniferous-deciduous stands.

The combination of attributes of deciduous and coniferous stands makes mixed stands an attractive habitat for large animals. Ruffed grouse, deer, and moose use these stands in winter. Generally the coniferous component provides cover and the deciduous species provide browse, although moose may browse fir in late winter. Fishers, spruce grouse, and bald eagles favor coniferous species for cover.

The presence of conifers in a deciduous stand adds a new dimension to the resources available for birds. Species that depend on conifers for food, nesting sites, or shelter are added to the community. Several species appear to exploit the aspen-birch community only as the basal area of conifers increases. These birds include the white-throated sparrow, black-capped chickadee, magnolia warbler, yellow-rumped warbler, and winter wren. Within the range of communities where conifers never contributed more than 18 percent of the total basal area, only one species (the chestnut-sided warbler) demonstrated an obvious trend of decreasing density as the basal area of conifers increased.

Winter observations in three mixed uplands containing aspen, birch, white pine, jack pine, and balsam fir included a total of ten bird species. Only three of these species were present in all three plots: the common raven, black-capped chickadee, and gray jay. Together, the mixed uplands had an average of nearly twelve observations per five hours, ranking first among the six habitats sampled. The higher number of observations in this habitat than in the deciduous uplands may be accounted for by the fact that conifers provide more protection from loss of body heat.

2.5.3 Habitat Distribution

Table 6 assigns each of the twelve forest communities recognized by the Regional Copper-Nickel Study to the broader community classification used by the MLMIS inventory. Correspondence between the two systems is least good for non-pine conifer forests and best for elm-ash bottomlands. For the purposes of characterizing songbird and small mammal associations, the MLMIS system appears to be sufficiently detailed, because these populations are more closely correlated with structural attributes and environmental gradients than with floristic composition. The proportion of forested land covered by each community in the Study Area and in Lake, St. Louis and Cook counties is given. Cover types equivalent to those of the Society of American Foresters are also provided.

The aspen-birch community accounts for over 52.2 percent of the Study Area, and 50.6 percent of commercial forest lands in the three counties. This community is best developed in forest areas of the northern two-thirds of the state and extends northwestward into western Ontario and Manitoba.

Second in importance is a group of non-pine conifer habitats that are lumped by the MLMIS classification system into a single spruce-fir community. Twenty-three and one-half percent of the forested lands in the Study Area are assigned this cover type. Black spruce bogs, which account for approximately 10 percent of commercial forest lands in the three county region, are probably the most important component of the spruce-fir type. Wetland black spruce communities are scattered throughout forested areas in the northern half of Minnesota and extend northward into Canada, where they become one of the predominant forest types. Upland black spruce communities are recognized as a local cover type in the Superior National Forest and account for 1.6 percent of commercial forest lands in the forest. Upland black spruce communities are confined to the extreme northeastern part of the state and extend northward into Canada, where they are much more common. The black spruce-jack pine community that the Regional Copper-Nickel Study recognizes in the Kawishiwi watershed is an example of an upland black spruce community. White spruce plantations account for 1.2 percent of commercial forest lands in the three county region. Although upland white spruce stands are common in Canada, natural stands dominated by white spruce appear to be uncommon in Minnesota. White spruce is, however, distributed as a minor canopy associate in upland forests throughout the northern half of the state. Communities dominated by balsam fir are rare in the Study Area, probably because such monospecific communities are highly susceptible to spruce budworm infestations. Large portions of the Kawishiwi watershed were typed by the

Forest Service as restocking spruce-fir in the 1940s, but fir is a minor associate in these stands today. Stands dominated by fir account for 12.5 percent of commercial forest lands in the three county region. Such communities occur naturally in the northern third of the state and extend northeastward into Canada as far as the interior forests of the maritime provinces, where infestations by spruce budworm have been especially severe.

Tamarack and cedar bogs account for a very low proportion of commercial forest lands in the three county region and an equally low proportion of lands in the Study Area. The actual area covered by tamarack may be somewhat higher than that reported for commercial lands, because many tamarack bogs are poorly stocked. Both types of bogs extend southward throughout the forested portion of the northern two-thirds of the state, reaching their southern range limits around the Twin Cities. East of the Study Area, tamarack bogs become more rare in the Gunflint Trail area of the Boundary Waters Canoe Area (Dean 1971). Both tamarack and cedar extend eastward through the Lake States, where cedar becomes a more important wetland community than in Minnesota (Gates 1942). Tamarack extends both eastward and westward throughout the boreal forest of Canada, whereas cedar extends eastward to the maritime provinces.

The MLMIS classification lumps jack, red, and white pine communities into a single pine cover type that accounts for 8.7 percent of forested lands in both the Study Area and the three county region. Because of intense early logging and its susceptibility to white pine blister rust, white pine is now a minor component of the forested landscape throughout most of Minnesota. It accounts for only .009 percent of commercial forest lands in the three county region. Red pine accounts for less than half of the pinelands in the three county region. Jack pine is more important than red pine in the Shallow Moraine

Bedrock Physiographic province. Pine occurs throughout the forested areas of the northern two-thirds of the state and was originally better developed south of the Study Area than in extreme northeastern Minnesota. Similar pine forests extend eastward through the Great Lakes Region in both the United States and Canada.

The elm-ash-cottonwood community defined by MLMIS is represented in the Study Area by ash bottomlands. This distinctive community accounts for less than one percent of the Study Area and less than three percent of the three county region. Floodplain forests are near their northern range limit in northeastern Minnesota but extend southward along rivers throughout the state. As the community is traced southward on the east side of the state, black ash becomes less important and American elm more so. Ash communities in wetlands outside floodplains extend thoughout forested portions of the northern half of the state, but generally occur as small pockets in other vegetation types.

The maple-birch-basswood community described by MLMIS occurs on only .02 percent of the Study Area. Red maple is more common than basswood as an associate canopy species in aspen-birch stands. Basswood is most common in aspen-birch stands in the Toimi Drumlin Field and around large lakes. The maple-basswood community is more extensive near the north shore of Lake Superior where sugar maple, basswood, and yellow birch are the dominant species (Flaccus and Ohmann 1964). Maple-basswood communities are much better developed in south-central Minnesota and reach their greatest importance southwest of the Twin Cities in an area formerly occupied by the Big Woods (Daubenmire 1936). This community is associated with the deciduous forests that extend throughout the eastern half of the United States (Braun 1950) with an increasing number of co-dominant species farther east and south.

2.5.4 Mammals and Birds of Special Interest

Although the animals of the Study Area are an integral part of the ecosystem and cannot be separated from the habitats that support them, the habitat-by-habitat approach to community characterization does not give a complete picture of the importance of each species in the Study Area as a whole. For this reason major herbivores and carnivores are discussed on a species-by-species basis below.

Mammals and birds of special interest fall into two major groups: biologically important species, and economically important species. Biologically important species are rare or endangered (e.g. bald eagle), have ranges largely restricted to northeastern Minnesota (e.g. wolves), or are near their range limits (e.g. lynx). Economically important species are harvested for recreation (e.g. deer) or for profit (e.g. fur-bearers), or cause damage to plantations (e.g. snowshoe hare) or property (e.g. black bear).

Within the ecosystem, biologically and economically important species may be either primary consumers (herbivores) or secondary consumers (carnivores). Herbivores are directly dependent on the vegetation of an area and are therefore more likely to show specific habitat preferences than carnivores (Table 2). Leading economically important herbivores in northeastern Minnesota have overlapping food preferences (Table 9) and generally prefer habitats dominated by regenerating aspen. Within the Study Area, the Toimi Drumlin Field is perhaps the best example of an area that provides habitat for a number of species, because it fulfills the habitat requirements of moose, deer, ruffed grouse, and beaver.

Table 9

TABLE 9 FOOD PREFERENCES OF HERBIVORES AND OMNIVORES

TREES

		TREMBLING ASPEN	PAPER BIRCH	PIN-CHERRY	CHOKE-CHERRY	MOUNTAIN ASH	BLACK ASH	JACK PINE	RED PINE	BLACK SPRUCE	WHITE CEDAR	TAMARACK	BALSAM FIR
OMNIVORE	BLACK BEAR												
	RACCOON												
	STRIPED SKUNK												
HERBIVORE	WHITE-TAILED DEER												
	MOOSE												
	SNOWSHOE HARE												
	RUFFED GROUSE												
	SPRUCE GROUSE												
	WATERFOWL												
	BEAVER												
	MUSKRAT												
	RED SQUIRREL												
	PORCUPINE												

SHRUBS

		HAZEL	BLUEBERRY	RASPBERRY	RED OSIER DOGWOOD	MOUNTAIN MAPLE	BUSH HONEYSUCKLE	JUNEBERRY	WILLOW	SPECKLED ALDER	GREEN ALDER
OMNIVORE	BLACK BEAR										
	RACCOON										
	STRIPED SKUNK										
HERBIVORE	WHITE-TAILED DEER										
	MOOSE										
	SNOWSHOE HARE										
	RUFFED GROUSE										
	SPRUCE GROUSE										
	WATERFOWL										
	BEAVER										
	MUSKRAT										
	RED SQUIRREL										
	PORCUPINE										

HERBS

		GRASS-SEDGE	LARGE-LEAVED ASTER	BUNCHBERRY	STRAWBERRY	BRACKEN FERN	LEGUME	CLOVER	MUSHROOM	OTHER UPLAND HERBS	OTHER LOWLAND HERBS
OMNIVORE	BLACK BEAR										
	RACCOON										
	STRIPED SKUNK										
HERBIVORE	WHITE-TAILED DEER										
	MOOSE										
	SNOWSHOE HARE										
	RUFFED GROUSE										
	SPRUCE GROUSE										
	WATERFOWL										
	BEAVER										
	MUSKRAT										
	RED SQUIRREL										
	PORCUPINE										

OTHERS

		GARBAGE	CARRION	INSECTS	FISH	CRUSTACEANS	AMPHIBIANS-REPTILES	SONGBIRDS	SMALL MAMMALS	AQUATIC PLANTS
OMNIVORE	BLACK BEAR									
	RACCOON									
	STRIPED SKUNK									
HERBIVORE	WHITE-TAILED DEER									
	MOOSE									
	SNOWSHOE HARE									
	RUFFED GROUSE									
	SPRUCE GROUSE									
	WATERFOWL									
	BEAVER									
	MUSKRAT									
	RED SQUIRREL									
	PORCUPINE									

PREFERRED USED NOT USED

2.5.4.1 Herbivores--Although deer and moose utilize similar browse species, direct competition may be affected by forest management practices that favor clearcuts larger than 750 hectares. Township-sized blocks containing approximately fifty percent large cutovers regenerating to aspen and birch are preferred by moose, whereas smaller man-made openings and edges of large cuts are used by deer. Although studies in Newfoundland (Dodds 1960) and Michigan (Bookhout 1965) suggest competition between hare and cervids, exclosure studies by Krefting (1975) in northeastern Minnesota suggest that competition for browse in the Study Area may be relatively low. Where competition does occur it may well be to the advantage of the large game mammals and detriment of hares.

Deer--Of the major herbivores in the Study Area, deer are most widely distributed throughout the state. Deer were not widespread in northeastern Minnesota before the advent of logging and densities have remained low. In the years from 1972 to 1977, between 1,131 and 1,952 deer were harvested in the Study Area, representing 1.7 to 3.2 percent of the statewide harvest taken from 6.2 percent of the state deer habitat. Results of harvest data (Rutske 1975) suggest that the number of deer harvested in northeastern Minnesota decreases from west to east.

Fawn:doe ratios declined 1.8 percent per year (1955-1973) in northern counties where wolves are absent and 3.3 percent per year where wolf predation occurs (Mech and Karns 1977). In areas where wolves are absent, the decline in reproductive rate is attributed to reduction of browse quality as forests mature. In the BWCA and the northeastern part of the Study Area, wolf predation appears to be the limiting factor controlling deer populations. A large proportion of the deer population in the Ely-Harris Lake area is restricted to a 2 km buffer zone between wolf packs (Hoskinson and Mech 1976; Mech and Karns 1977; Mech 1977c).

This and similar buffer zones may be important reservoirs for future repopulation of areas currently devoid of deer. Direct competition between hunters and wolves is limited to areas near roads (Mech 1971).

Moose--Unlike deer, moose were widespread in northeastern Minnesota before the advent of logging and probably reached their maximum populations shortly after the demise of the woodland caribou. Since the advent of logging, and the increase in number of deer, moose populations have fluctuated in response to management activities within the area (Peek 1971). Recent aerial census results indicate that the moose population in northeastern Minnesota has remained relatively stable during the 1970s at about 2,500 animals (MDNR). Centers of high moose densities are the converse of deer population centers. Moose densities increase from west to east and from north to south across the Study Area.

Moose are concentrated in the eastern portion of the Study Area and the Toimi Drumlin Field. The estimated population of 815 animals for the Study Area accounts for 14 percent of the moose in the state and occupies 9.1 percent of the state moose census area. Unlike deer, moose populations do not appear to be suffering from wolf depredation. Because they are not confined to zones between wolf packs, moose have a functionally larger available habitat than deer. Current management practices in the Superior National Forest enhance the habitat for "boreal" animals including moose, beaver, and wolf.

Snowshoe Hare--Snowshoe hares are found throughout the forested area in the northern two-thirds of the state. Populations of hares are subject to extreme periodic fluctuations. The amplitude of the cycle is a function of the survival and reproductive rate within a particular geographic region. Lake States populations fluctuate at about a 10:1 ratio from peaks to lows (Wood and Munroe

1977). Snowshoe hare densities in the forested or shrub communities of the Study Area may range from a density from 10-20/km^2 during population peaks.

Like deer, snowshoe hare reach highest densities in young forested habitats with a dense shrub structure and prefer habitats where they are sheltered from predation. Preferred habitat usually includes some form of coniferous or brushy cover. Major predators of the snowshoe hare include the great horned owl, great grey and barred owls, lynx, bobcat, fox, coyote, wolf, mink, and man.

Beaver--Beaver range throughout central and northeastern Minnesota and are the major herbivorous fur-bearers in the Study Area. Aerial census data indicate that populations have been increasing since 1957 and that the number of colonies per 1.6 km of stream length is slightly higher (.89) in the Ely-Finger Lake area than in the Isabella area (.53)(MDNR aerial census 1976). Colonies range from 1 to 12 individuals with an average of 5.7 animals (Banfield 1974). Like the other large herbivores, beaver prefer habitats abounding in young aspen and maintain high populations along streams in the Toimi Drumlin Field.

Ruffed Grouse--Ruffed grouse occur throughout the forested portion of Minnesota from the Canadian to the Iowa border. The northeastern part of the state has a long history of depressed densities compared to most of the remainder of the state (Gullion 1970; W. Berg, 1976 MDNR, personal communication). Within the eastern part of the Study Area, which accounts for 4.4 percent of the state's grouse habitat, a census in the spring of 1977 revealed a greater density of displaying males in the south than in the north. The higher densities are probably associated with a preference by displaying male ruffed grouse for aspen and aspen-birch habitats. Peak spring breeding densities of ruffed grouse may reach 1 pair/4 hectares in 8 to 25 year old aspen-birch stands, whereas pine stands support densities of only 1 pair/8 hectares. Both of these density estimates may be high; however, regional data are not available.

Spruce Grouse--Spruce grouse (Canachites canadensis) are generally considered to be a bird of the mature coniferous forest dominated by jack pine (Pinus banksiana) and/or spruce-fir (Picea spp. - Abies spp.)(Aldrich 1963). This species is distributed across the boreal forest of Canada and Alaska, with populations in the United States restricted to portions of certain northern states.

Both upland and lowland conifer habitats are used by spruce grouse. The age of forest used by spruce grouse varies. Territorial males used mature closed-canopy stands, whereas nesting females used younger forests (Haas 1974). Moderate amounts of habitat disturbance by logging or fire are not detrimental to spruce grouse, and may, in fact, be beneficial for broods or nesting cover (Haas 1974). Density estimates from Anderson (1973) and Haas (1974) suggest that loss of large tracts of spruce grouse habitat would result in loss of 4 to 5 individuals for every 12 hectares lost.

Waterfowl--Minnesota contributes approximately two percent of the continental waterfowl population. In 1976 and 1977 the breeding duck populations in Minnesota were estimated at 676,000 and 695,000, respectively (Jessen and Parker, MDNR, USFWS, in press). Although the state is relatively well-endowed with wetlands, the forests of northeastern Minnesota contain only a small proportion of prime waterfowl habitat. The mineral resource zone (see Volume 3-Chapter 2) within the Study Area includes approximately 100,000 acres of wetland, all classified as being of "lesser" importance to waterfowl.

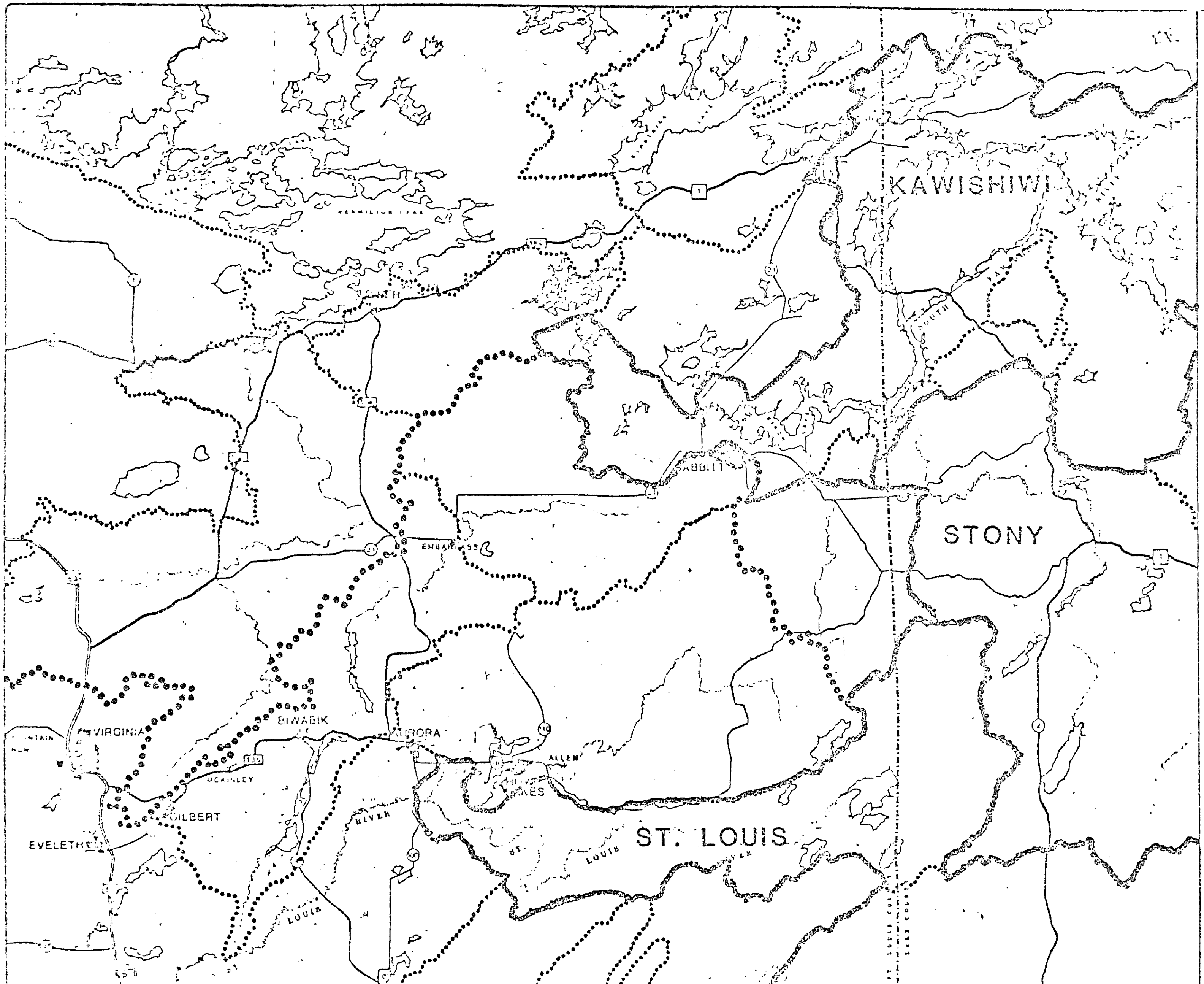
Results of an aerial census conducted by the Copper-Nickel Study, in the spring of 1977, suggest that waterfowl reach their highest concentrations in the southeastern part of the Study Area. The most heavily used watersheds during waterfowl migration are the St. Louis, Stony, and Kawishiwi rivers (Figure 33b). Within these areas the highest duck concentrations on lakes were observed on Stone, Long, Seven Beaver, and Birch lakes. The concentration of waterfowl in lakes and streams in the southern part of the Study Area can be attributed to the shallow depth of the lakes, the slow current of the streams, and the relative abundance of emergent aquatic vegetation. Areas that are important during the migrating season may be equally important during the breeding season. Spring migrants, and presumably breeders, are dominated by mallards, common goldeneyes, ring-necked ducks, blue-winged teal, and black ducks.

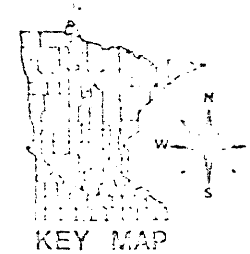
Figure 33b

2.5.4.2 Omnivores--The changing status of the black bear reflects changing attitudes over the past sixty years. Black bears have been protected, unprotected, bountied, and established as a big game animal (present status).

The principal range of black bears in Minnesota is the forested region in the north central and northeastern parts of the state, totaling 55,503 km^2. The Study Area represents 8.3 percent of the state's black bear habitat. Density estimates from Rogers (U.S. Forest Service, personal communication 1978) for northeastern Minnesota suggest that the bear population in the Study Area probably ranges between 825 and 1,268 animals.

Black bears are the major wild omnivore in the Study Area. They prefer upland forests in early successional stages. Although an assortment of mature berries and nuts are their major food sources, Rogers (1977) has found that almost all bears in the Isbella area rely on garbage dumps during some season of the year.





MEQB REGIONAL COPPER-NICKEL STUDY

FIGURE 33B WATERSHEDS IMPORTANT TO WATERFOWL

2.5.4.3 Carnivores--Predators are of special interest because of their generally low densities and competition with man (in some cases) for the same food resources (Table 10). Within the Study Area wolves are the major predators that conflict with the human population because other predators either occur in low numbers (e.g. lynx) or use foods that are of no value to the human population (e.g. owls).

Table 10

Wolves-- The conflict between wolves and man is reflected by the history of the wolf's protection status. In 1950 the Minnesota Department of Natural Resources (MDNR) ceased a wolf control program and bountied the animal. The bounty was ended in 1965. Wolves within the Superior National Forest were protected in 1970 by a U.S. Department of Agriculture decree. The 1973 Endangered Species Act granted wolves full protection throughout that time, but increasing populations and their return to their previous range has prompted a recent change (spring 1978) to allow authorized trapping or shooting of nuisance animals suspected of killing livestock in certain regions of the state.

The last thriving population of timber wolves in the contiguous United States resides in northern and northeastern Minnesota. Mech (U.S. Forest Service, personal communication 1978) estimates a population of 1,250 wolves in the lower 48 states, with 1,200 of the animals in northeastern Minnesota. In recent years wolves have expanded to areas outside of the Superior National Forest to include 78,000 km^2 of northern Minnesota. It appears that the Study Area contains 7 percent of the current wolf range, but if human activities increase elsewhere in northern Minnesota and wolf range is once again limited to the Superior National Forest, the Study Area would represent 29 percent of available wolf habitat.

TABLE 10 PREFERRED FOODS OF CARNIVORES

PREY

PREDATORS	WHITE-TAILED DEER	MOOSE	BEAVER	WATERFOWL	SNOWSHOE HARE	RUFFED GROUSE	SPRUCE GROUSE	SMALL MAMMALS	SONG BIRDS	FISH	AMPHIBIANS - REPTILES	INSECTS	EARTHWORMS
TIMBER WOLF	I	M	M										
FISHER	M				I			I		M		M	
MARTEN								I	M			M	
RIVER OTTER								M		I	M	M	
MINK								I		I	M	M	
BOBCAT	M				I			I					
LYNX	M	M		M	I	M	M	M					
WOODCOCK												M	I
BALD EAGLE				M				M		I			
OSPREY										I			
BROAD-WINGED HAWK					I	I		I	M		M		
SPARROW HAWK								I	M			I	
RED-TAILED HAWK				M	I	M		I					
GOSHAWK					I	I	M	M	M				
COOPER'S HAWK					M	I	M	M	I				
SHARP-SHINNED HAWK						M	M	M	I				
MARSH HAWK								I	M		M	M	
GREAT HORNED OWL				M	I	I	M	I	M				
BARRED OWL					M	M	M	I	M				
LONG-EARED OWL								I	M				
SHORT-EARED OWL								I	M				
SAW-WHET OWL								I	M				

I = INTENSIVELY USED

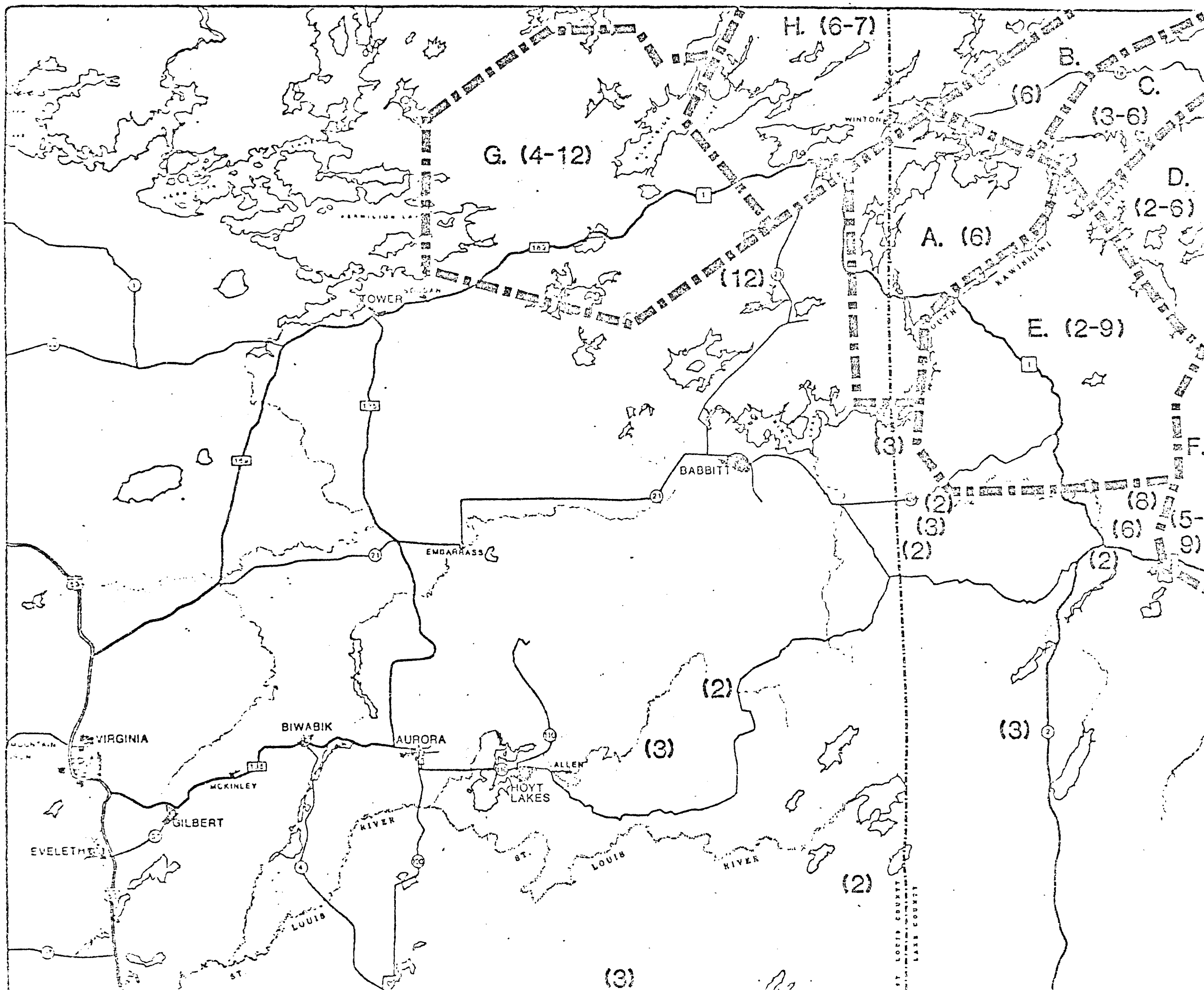
M = MODERATELY USED

(blank) = SELDOM USED

The estimated wolf population of the Study Area is 154 to 200 animals, 13 to 17 percent of the state's population. Densities are highest in the northeastern part of the Study Area as can be seen from Figure 34, a map of known wolf territories in the Study Area. Mech and Karns (1977) report a reduction of wolf populations in the Interior Zone of the BWCA where deer populations have been decimated by wolves. The declining wolf population is attributed to death of pups by malnutrition (Van Ballenberghe and Mech 1975; Mech 1977), combined with mortality caused by intrusion of members of one pack on the hunting territory of another (Mech 1977b, 1977c). The availability of preferred deer habitat in the Toimi Drumlin Field suggests that wolf populations in that area may rise if human activities are not increased. Because of decreasing deer populations, it is doubtful that present wolf densities of 1 wolf per 26-34 km^2 in the Study Area will be maintained. Moose populations are not an alternative prey and cannot maintain high wolf populations.

Figure 34

Raptors--Like wolves, birds of prey (raptors) come into conflict with man in highly populated areas. Although the majority of their prey items are not valuable to the human population, hawks, owls, eagles, and ospreys are subject to illegal shooting in agricultural areas. Raptors, considered more common in the northern part of the state, include the broad-winged hawk (*Buteo platypterus*), great horned owl (*Bubo virginianus*), and goshawk (*Accipter gentilis*). Bald eagle and osprey are fish-eating species that prefer mature coniferous habitat. The 39 known eagle nests in the Superior National Forest account for 5 percent of known bald eagle nests in the United States. Twelve of the 39 nests are located in the northern part of the Study Area where mature

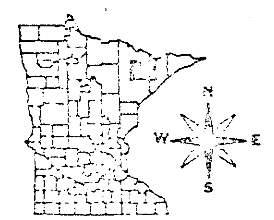


LEGEND

- TERRITORIES OF NAMED PACKS (A-H)
- (#) - NUMBER OF WOLVES IN PACK, OR SIGHTINGS

A. BIRCH LAKE PACK
B. PAGAMI LAKE
C. GREENSTONE LAKE
D. QUADGA LAKE
E. HARRIS LAKE
F. JACK PINE
G. GLENMORE LAKE
H. NEWTON LAKE

SOURCE: MODIFIED FROM MECH, 1973 U.S.D.A. FOREST SERVICE RESEARCH PAPER NC-97



KEY MAP

1:422 400

MILES

KILOMETERS

FIGURE 34

MEQB REGIONAL COPPER-NICKEL STUDY

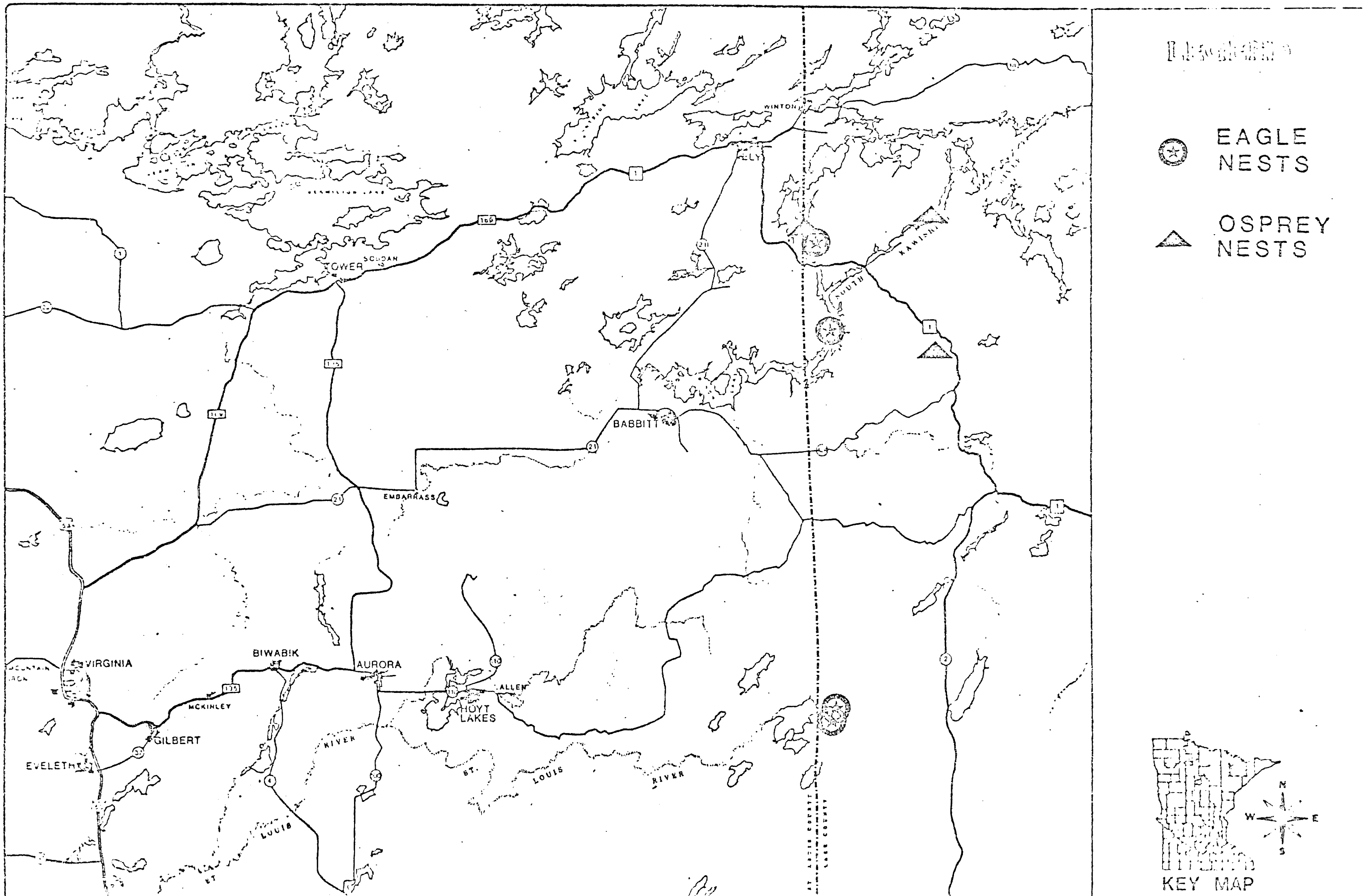
APPROXIMATE LIMITS OF KNOWN WOLF TERRITORIES IN STUDY AREA conifer stands and open water are common (Figure 35). Twenty-three active osprey nests have been recorded in the Superior National Forest, with eight of these nests in the Study Area.

Figure 35

Fifteen species of raptors were observed by the field team in the Study Area. The most commonly observed species were the broad-winged hawk, sparrow hawk, and red-tailed hawk, all diurnal species that are easily observed. Along with the marsh hawk, the sparrow hawk and red-tailed hawk are considered to be the most common breeding raptors in Minnesota (Green and Janssen 1975).

Upland deciduous and coniferous stands generally provide more favorable habitat for raptors than do lowland forest types. Aspen-birch communities/mixed conifer-deciduous stands, preferably with a diversity of natural openings, provide favorable habitat for such migratory raptors as the broad-winged and red-tailed hawks, and sparrow hawks, as well as year-round resident goshawks and great horned owls (Bubo virginianus). Young to medium-aged habitats (less than 30 years) support the largest number and variety of prey biomass, whereas older stands provide trees with branching structures suitable for securing nests.

Otter--River otter are distributed over half of the northern half of the state (107,323 km^2), and are most common in the northeast, where the Study Area accounts for 4.8 percent of the state's habitat. Otters are concentrated near water because fish are their major prey. Otter populations are expected to remain stable because of low seasonal trapping limits and public ownership of the most intensely populated portions of otter range.



MEQB REGIONAL COPPER-NICKEL STUDY

FIGURE 35 KNOWN RAPTOR NESTS NEAR MINERALIZATION

Lynx and Bobcat--The principal range of the lynx in North America is in the forested regions of Canada and Alaska, and only dips into the contiguous United States in the western mountainous states, the Great Lakes, and New England regions (Banfield 1974). Even in the principal range to the north this predator is a solitary, low density species.

Resident lynx range in Minnesota extends from Lake-of-the-Woods to Cook County along the Minnesota-Canadian border and includes 15,300 km^2 with 23.8 percent in the Study Area. During population influxes into the state from Canada, the Minnesota range is extended to 69,600 km^2. Such influxes usually occur one or two years after cyclic population lows of snowshoe hares (Henderson 1977).

Bobcats are more common and more widespread than lynx and expanded into northeastern Minnesota from the hardwood region after clearing of the conifer forests (Henderson 1977; Rollings 1945). The present distribution is north of a line from Anoka to Kittson counties. The Study Area encompasses 5.7 percent of the total range of bobcat in the state.

Fishers and Marten--Fisher range extends into the northern United States, but the principal range is in Canada. Populations in Minnesota are concentrated in the northern counties where suitable conifer and conifer-deciduous forests occur. The Study Area accounts for 15.2 percent of statewide fisher range.

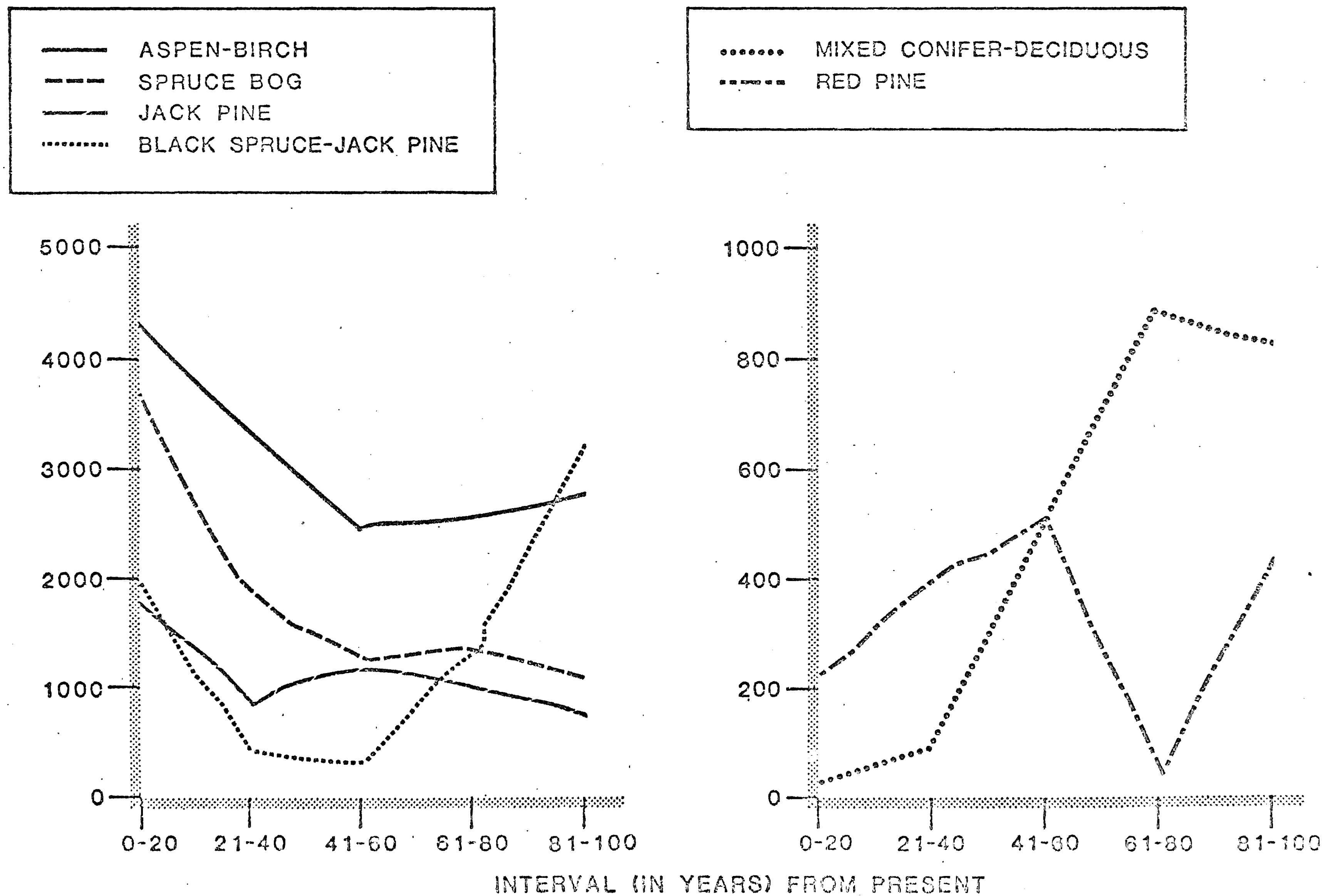
Marten, a close relative of the fisher, are more limited in distribution and occur in much lower densities than fishers. Populations have apparently been rising since the late 1960s (Mech and Rogers 1977). Several authors believe that either the BWCA is acting as a reservoir from which population expansions occur (Mech and Rogers 1977), or the increase is due to high densities of marten in Ontario and subsequent emigration into the United States (Karns 1978, personal communication). It appears that the Study Area accounts for 26.7 percent of marten range in Minnesota. Within the Study Area, prime marten and fisher habitat occurs in the Shallow Moraine Bedrock Province in the northeastern part of the area.

2.5.5 Projections for the Study Area in 1985

Plant communities develop slowly and, in the absence of copper-nickel mining development, few noticeable changes will occur in terrestrial ecosystems of the Study Area. The most significant alterations would occur where extensive harvesting of mature forests is undertaken. Of particular importance in this regard is an area that the U.S. Forest Service (USFS) refers to as the Baird Sale. Under a contract that was signed in 1966, the USFS is attempting to harvest mature and overmature jack pine stands that are concentrated in an area south and east of Birch Lake. By the time that logging is complete, as many as 13,174 acres of forested lands will be harvested and more than 159,900 cords of jack pine will have been removed. It is likely that many of the lands affected by this sale will regenerate to species other than jack pine. Projected harvests, based on the Regional Study's succession model, suggest that the largest harvests of jack pine for the next 100 years are those occurring at present (Figure 36). The model is based on current management practices and assumes that a constant percentage of all lands will be harvested in each era, but that the species composition of the harvest will depend on available timber within marketable size-classes. The assumptions of this model are discussed in section 2.3.3.1.

Figure 36

FIGURE 36 PROJECTED HARVESTS*(HA.) BASED ON THE REGIONAL STUDY'S SUCCESSION MODEL**



*The area included in the model is the portion of Division 1 east of Rabbit (Figure 45) **SOURCE: Sloss 1978

In addition to timber cutting, other factors will act to change existing terrestrial ecosystems. Of particular importance is the potential for intensified forest management on state and federally owned lands.

Legislation recently passed in the U.S. Congress will halt all timber harvesting in the Boundary Waters Canoe Area (BWCA). The consequences of this action will be twofold. First, the forest products industry will be forced to look elsewhere for the softwoods needed to make pulp for high quality papers. Inventories of timber resources now being completed by the MDNR, Division of Forestry, indicate that significant amounts of balsam fir are available and can be used as a substitute for jack pine and black spruce. Balsam fir is little used as a pulp-wood species in Minnesota at present, and increased utilization could significantly increase timber harvesting in the spruce-fir vegetation type.

In addition to increased harvesting of softwoods in the Study Area, both state and federal forestry agencies are currently planning to intensify management of lands for the production of softwoods. Much of the Study Area that currently supports hardwoods formerly supported stands of pine and spruce and could be converted back to conifer production. It seems, therefore, that softwood species could be expanded in areal coverage at the expense of hardwoods. However, the impacts of intensified forest management would not be obvious until 1985-2015, when the hardwoods that currently occupy these sites can be harvested.

In addition to altered forest management practices, planned expansion of taconite mining would significantly impact terrestrial ecosystems of the Study Area. Activities that are currently planned would potentially require more than 20,000 acres of land. Most of these lands are forested and taconite mining could remove these lands from forest production for many years. Removal of these lands would place an additional requirement for intensified management on unaffected lands, although the harvest of timber on lands to be mined could reduce the short-term impacts of mine-land removal.

The cumulative effect of BWCA legislation and expansion of taconite mining may be to place increased emphasis on the intensive management for timber production on the remaining lands (see Volume 5-Chapter 6). Intensified management would tend to favor softwoods over hardwoods and result in a conversion of mixed stands to those of predominantly pine species.

2.6 SUSCEPTIBILITY OF REGION TO IMPACTS

2.6.1 Ecosystem Susceptibility

The susceptibility of an ecosystem to any impact depends on the susceptibility of its component soils, vegetation, animals, and the interactions between these components.

For example, the impact of logging activities on aspen-birch forests on clay soils of the Aurora till plain province differs from that in the shallow moraine bedrock province in several ways. On thinner, drier soils in the north, scattered residual birch are more subject to dieback caused by higher soil temperatures after logging. Heavy equipment is more likely to scalp the thin soils making regeneration by persistent forest floor herbs less likely. The coarser texture of the soils is more likely to cause excessive drainage producing drought stress to the vegetation. On the till plain the clay soils are more subject to compaction by heavy equipment. Their ability to retain moisture favors the regrowth of aspen and birch over planted conifer species. Weedy species of the mint and buckwheat families are more likely to invade open areas because of the higher soil moisture. Forests are more likely to be susceptible to fungal diseases because of the moister forest floor. Populations of deer using such areas after 4 or 5 years are likely to be higher than in the north because wolf populations are lower in the Aurora till plain.

2.6.2 Soils

Susceptibilty of soils varies with their texture, the mineral composition of the parent material, proportion of organic matter, water retention capacity, cation exchange capacity, base saturation, buffering capacity, and the type of vegetation overlying them. Within the Study Area, soils range in texture from clays to sandy-loam and sandy soils, in pH from 4.5 to 6.5, in cation exchange capacity from 15.2 to 119.1 milliequivalents/100g and in base saturation from 14.5 to 62.7 percent. Attributes of the major soils in the Study Area are discussed in Volume 3-Chapter 1. Differences between soils are reflected in Table 11 in which susceptibilities to various impacts are shown for the various soils.

Table 11

Organic soils generally have a higher cation exchange capacity than mineral soils, thus affecting their ability to bind ions rather than the ions leaching out in groundwater or being taken up by plants. Among mineral soils, clays have a higher cation exchange capacity than sandy soils. The buffering capacity of the soil, or its ability to resist changes in pH, is generally proportionate to the cation exchange capacity. Buffering is least at extremes of pH and constant in the pH range from 4.5 to 6.5, suggesting that soils in this range are least likely to be affected by factors such as acid rain. At low pH values aluminum, iron, manganese, copper, and zinc are more soluble and hence more available to plants. Amounts of these ions that are toxic to plants at low pH are less available near neutrality because they precipitate and become insoluble.

Decomposition of litter is apparently inhibited by accumulation of heavy metals. In a study of metal loadings and litter decomposition in soils downwind of the Copper Cliff (Ontario) smelter, Freedman (1976) found slower rates of decomposition where metal loadings were high. Because the concentration of metal in litter depends not only on the loading but on the weight of the litter, soils in the Study Area with lower litter weights can be expected to exhibit a greater relative increase in metal concentration and a concomitantly greater increase in the time required for litter decomposition than those with deeper litter layers.

TABLE 11

SUSCEPTIBILITY OF SOILS TO IMPACTS

- SLIGHTLY SUSCEPTIBLE
- MODERATELY SUSCEPTIBLE
- SEVERE SUSCEPTIBILITY
- ? IMPACT UNKNOWN

	IMPACT									
	NATURAL IMPACTS					ANTHROPOGENIC IMPACTS				
SOIL ASSOCIATION *	DROUGHT	FLOODING	SEEDLING MORTALITY	PLANT COMPETITION	EROSION	ACIDIFICATION	ACCUMULATION OF HEAVY METALS IN LITTER.SLOWED DECOMPOSITION	HEAVY METALS READILY LEACHED OR AVAILABLE	COMPACTION BY HEAVY MACHINERY	DIFFICULT RECLAMATION BECAUSE LITTLE TOPSOIL AVAILABLE
1. ONTONAGAN-BERGLAND							?			
4. AHMEEK-RONNEBY							?			
5. NEWFOUND-NEWFOUND										
6. UNNAMED-TOIVOLA							?			
7. TOIVOLA-UNNAMED-CLOQUET										
8. MESABA-BARTO										
9. CONIC-INSULA						?	?	?		
10. QUETICO-BEDROCK OUTCROP							?			
11. INDUS-WILDWOOD						?	?			
12. TAYLOR-INDUS						?	?			
17. NEBISH-MOOSELAKE-SHOOKER						?	?	?		
25. CORMANT-SHAWANO						?	?	?		
26. MENAGHA-CUTFOOT						?	?	?		
31. ALLUVIAL						?	?	?		
34. SPOONER-UNNAMED-BAUDETTE						?	?	?	?	
35. MESABA-BARTO										
41. CLOQUET-EMMERT						?	?	?		
48. NEMAJI-NEWSON						?	?	?	?	
49. UNNAMED-HIBBING						?				
50. HIBBING-UNNAMED						?				
57. GREENWOOD						?	?			
58. MOOSELAKE						?	?			
59. WASHKISH-LOBO						?	?			

* see Volume 3 Chapter 1 and Patterson and Aaseng 1978 for further details

2.6.3 Vegetation

Susceptibility of vegetation to impacts varies with structural attributes, species composition, health of the dominant species, physiological adaptations of dominant species, and site characteristics. Examples of the influence of structure are the susceptibility of shallow-rooted species, such as fir, to wind damage and the higher incidence of both hypoxylon canker of aspen and birch dieback in open-grown or thinned stands. Impacts on vegetation are summarized in Table 12.

Table 12

The synergistic effect of natural stresses, disease, and pollution varies from species to species and site to site. "Off-site" forest species on soils that do not provide optimum growing conditions are more subject to stress from drought or disease (Hypoxylon canker in aspen; cytospora canker in aspen, birch dieback, and shoestring root rot in most species). A review of plant diseases in the Study Area, the causal agents, hosts, and importance (Zeyen and Groth 1978) provides the background for understanding possible effects of increased air pollution. A second report (Zeyen 1978) presents the likely effects of pollutants on plant-disease interactions. The effects of pollutants on plant disease may be two-fold. For obligate parasites (i.e. those requiring living hosts) low concentrations of pollutants such as SO_2 may reduce the incidence of disease. White pine blister rust is the most important factor limiting the reestablishment of white pine in the Study Area and in neighboring Ontario. The importance of species composition of the forest as a whole is illustrated in this case by the necessity of an alternate host, the gooseberry (Ribes spp.) in order for the causal fungus to complete its life cycle. Studies by Linzon (1958) in

TABLE 12 SUSCEPTIBILTY OF VEGETATION TO IMPACTS*

	NATURAL IMPACTS							ANTHROPOGENIC IMPACTS							
	DROUGHT	FLOODING	FIRE	DISEASE	INSECT EPIDEMICS	WIND DAMAGE	OVER BROWSING	CONVERSION TO FARM LAND	CLEARCUTTING	SELECTIVE CUTTING	OPEN PIT MINING	TAILINGS BASINS	ACID RAIN	HEAVY METAL LOADING	SO_2 DAMAGE
SHRUB CARR															
ASH															
CEDAR															
TAMARACK															
BLACK SPRUCE															
BLACK SPRUCE-JACK PINE															
JACK PINE															
RED PINE															
ASPEN-BIRCH															
ASPEN-BIRCH-FIR															
MIXED CONIFER-DECIDUOUS															

NOT SUSCEPTIBLE OR EFFECT UNKNOWN

ADAPTED TO IMPACT RECOVERS NATURALLY

SUSCEPTIBLE

MOST SUSCEPTIBLE

* Ratings include allowances for probable locations of mining areas and the distribution of community types in Study Area.

Ontario suggest that the incidence of white pine blister rust may actually be reduced by SO_2 fumigations at concentrations of approximately 700 ug/m^3. On the other hand, facultative parasites (those that can live on dead material) commonly attack only those plants that are already under stress. Pollutants generally increase the incidence of such diseases. SO_2 has been observed in several cases to increase the incidence of shoestring root rot (Zeyen and Groth 1978). Air pollutants can be expected to cause the greatest increase of disease in those plants most susceptible to direct damage. The SO_2 sensitivity of major vegetation types in the Study Area is included in Table 12 (susceptibility of vegetation to impacts). Those habitats dominated by the most sensitive species can be expected to show the greatest increase in incidence of disease from synergistic effects of air pollution.

The interaction of a major resource and a pathogen is well illustrated by the case of white pine blister rust. The disease has so reduced the importance of white pine in the area that susceptibility of white pine to any other impacts has become a moot question. On the other hand, red and jack pine are important species, especially from a management point of view. Should the strain of scleroderris canker now present in New York reach Minnesota, the Study Area would be very susceptible and it is likely that all the red pine (.9-3% of the area) and a large proportion of the jack pine would be obliterated.

The genetic composition of a species may have an important effect on its susceptibility to impacts. Trembling aspen, which grows in clones (clumps of individuals with the same genetic composition) exhibited varying responses to the 1976 drought from clone to clone. Such physiological differences between plants of different genetic composition are likely to exist for many kinds of stress responses, including disease and pollution.

The importance of disease resistant strains is well understood in agricultural crops, but is equally relevant in forestry. Research by Ahlgren (1948 to present) is directed toward breeding a blister-rust resistant strain of white pine for northeastern Minnesota. Studies by Goodman, Pitcairn, and Gemmell (1973) on soils contaminated with heavy metals emphasize the usefulness of metal-tolerant clones of grass (Agrostis tenuis, Agrostis stolinifera, Festuca rubra, Festuca ovina, and Anthoranthum odoratum) for revegetating mine spoil.

Susceptibility of the vegetation to impacts is also dependent on the amount of a vegetation type (or a dominant species) that is generally available and its usefulness to the human population. Within the Study Area both cedar and ash communities are of limited areal extent. Upland cedar is virtually non-existent. Because of their very rareness, these habitats are of special concern wherever development, logging, or mining are likely to impinge upon them. Both communities are important for rare lichen species, and cedar bogs harbor a large number of fern allies and orchids. Some vegetation types are not rare per se, but become so in conjunction with physiographic influences. For example, south-west facing slopes of pine stands are most likely to harbor prairie species (e.g. hoary puccoon, Lithospermum canescens at G26), north facing ravines provide sheltered habitats for ferns such as Woodsia spp., and cold bogs are likely locations for disjunct boreal plants (cloudberry, Rubus chamaemorus on a bog near Basswood Lake; northern comandra (Geocaulon lividum at plot T05). It appears from the herbarium records that most collections of the arctic raspberry (Rubus acaulis) have been made in the old beds of glacial lakes, a factor that may explain the occurrence of this species in the Dunka sandplain and not in other spruce and tamarack bogs of the Study Area.

2.6.4 Animals

The existing distribution of populations and their regenerative capacities are additional factors influencing the susceptibility of biological components (especially animals). Susceptibilities of animals to impacts are summarized in Table 13. These susceptibilities are based on the following assumptions. Direct impacts are those in which mining-related activities immediately affect the animals by destroying habitats of affecting their behavior. Because direct land use is not expected to be habitat specific, it is expected to affect the habitats of all animals. Although noise is not habitat specific, only certain animals are likely to respond adversely. Indirect impacts are those experienced by the animals secondhand. For example, when browse species are injured by air pollutants less browse is available for deer, hares, and other species. Increased population pressures result in greater mortality of raptors and bears as "nuisance" animals and indirectly in greater mortality of game species during the hunting season.

Table 13

Deer in the northern part of the Study Area are most susceptible to stress because of the heavy predation pressure. Less habitat is available to them because they use buffer zones between wolf territories. Direct destruction of these buffer zones would leave the deer more vulnerable than destruction of equal acreages of the same habitat in areas within the wolves' territories. Furbearers in the Study Area are not very susceptible to direct impacts (such as logging or mineland acquisition) other than that of trapping because their preferred stream and shoreline habitats in township 61 and northward are protected by the Shipstead-Newton-Nolan Act.

TABLE 13 SUSCEPTIBILITY OF ANIMALS TO IMPACTS

		WOLF	MARTEN	EAGLE/OSPREY	SONG BIRD	SMALL MAMMAL	MOOSE	DEER	BEAR	LYNX	BOBCAT	FISHER	OTTER	BEAVER	SPRUCE GROUSE	RUFFED GROUSE	WOODCOCK	SNOWSHOE HARE	WATERFOWL
LOCALIZED	DIRECT LAND USE (MINE, TAILINGS, WASTE ROCK, ETC.)	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
	SEEPAGE	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		
	NOISE	D		D															
	VISIBLE EFFECTS (DEATH, YELLOWING, ETC.) OF AIR POLLUTION ON VEGETATION	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		
	SUBTLE EFFECTS (REDUCED PRODUCTIVITY, ETC.) OF AIR POLLUTION ON VEGETATION	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I			
	HEAVY METAL LOADING (WATER, SOIL, ETC.)	I	I	I							I	I	I				I		
REGIONAL	VISIBLE EFFECT (DEATH, YELLOWING, ETC.) OF AIR POLLUTION ON VEGETATION																		
	SUBTLE EFFECTS (REDUCED PRODUCTIVITY, ETC.) OF AIR POLLUTION ON VEGETATION																		
	ACID PRECIPITATION			I			I						I						
	PRESENCE OF INCREASED HUMAN POPULATION	D								D									
	CONFLICT WITH INCREASED HUMAN POPULATION		I	D			I	I	D										
	INCREASED HUNTING PRESSURE							D	D										

D = DIRECT IMPACT   I = INDIRECT IMPACT   (blank) = IMPACT UNKNOWN OR NONE

A serious threat to small mammals is the bio-accumulation of toxic materials. Molluscs are known to accumulate metals, especially when both sediment and water contain high metal concentrations. Some metals like copper and nickel would not be accumulated by such animals as raccoons, whereas others, like cadmium, are also accumulated by mammals. Unlike molluscs, fish regulate essential elements such as copper and zinc, and some fish regulate cadmium. Because of this regulation, it may be that fish-eaters are less susceptible to the cumulative effects of metals in the food chain than are mollusc-eaters.

A similar process of accumulation along the food chain may operate in the case of browsers. Certain plants differentially concentrate trace elements; for example, samples of leaves from blueberries, leatherleaf, and hazel in the Study Area differentially concentrate manganese to levels an order of magnitude higher than the lowest recorded levels for species in the Study Area (willow, aspen, and wild pea). Dwarf birch (*Betula pumila*), aspen, birch, and willow appear to concentrate zinc differentially. Aquatic plants are known to concentrate several elements differentially, and it has been demonstrated (Jordan et al. 1973) that the higher concentration of sodium in aquatic plants fills a special need in the diet of moose. In general, mammals have metabolic provisions for the elimination of excess essential elements such as copper and zinc, but ingestion of browse rich in such elements as nickel might constitute a potential danger for some animals.

Direct habitat destruction by logging development and mining is probably more important to large mammals than accumulation of trace elements in the food chain. Those habitats that are most restricted in areal extent and are used most exclusively would suffer the greatest impact. For example, loss of the black spruce-jack pine habitat in the Kawishiwi watershed would almost obliterate the preferred habitat of marten and fisher within the Study Area, whereas loss of a comparable acreage of aspen-birch forest would be a less important loss to animals favoring it (deer, ruffed grouse) because nearly fifty percent of the Study Area is in this community type.

Although the Minnesota wolf population has reoccupied areas of northern and north-central Minnesota outside the Superior National Forest, the behavioral response of wolves to increasing human populations is to retreat to inaccessible areas. Should the human population of northeastern Minnesota expand, wolves might be likely to contract their range either into the more remote parts of the Superior National Forest or the big bog west of the Study Area and north of Red Lake. Changes in the range of wolves could be expected to result in increased deer populations in areas deserted by wolves and possibly reduced deer populations in areas occupied by wolves. Coyote and fox populations could be expected to rise in areas vacated by wolves.

The susceptibility of small mammal populations to environmental impacts is understood to only a limited extent. Because of the large litter size of small mammals, direct habitat loss may not be as important to regional populations of most small mammals as to larger animals. Such small mammals as the rock vole and southern bog lemming, which occur in restricted habitats, could be obliterated if their habitats were destroyed.

Schlesinger and Potter (1974) report that small mammals appear to accumulate lead and cadmium in natural ecosystems. The physiological effects of such accumulation are not well studied. Studies by Schroeder and Mitchener (1971) showed a lowered male/female ratio, increased mortality and resorption of fetuses in rats exposed to 5 ppm of nickel in their drinking water over three generations.

Extrapolation of such laboratory findings to the field situation requires caution, because seed-eating mice adapted to dry conditions, such as the deer mouse, drink very little water.

2.6.5 Impact Zones and Divisions

Because the animal populations are so closely tied to vegetation types, it is possible to examine potential impacts within the Study Area on the basis of divisions and zones within which responses to impacts should be similar.

Seven terrestrial biology divisions are useful in conceptualizing widespread regional impacts on terrestrial communities, such as the impacts caused by air pollution, intensified forest management, or broad range changes in wolf populations. The locations of these divisions are shown in Figures 45a-g. The proportion of major habitats within divisions is presented in Table 14.

Table 14

Direct impacts of copper-nickel mining are more easily assessed by means of seven development zones. Direct habitat alterations, seepage and noise, are more likely to influence communities along this belt than areas more distant from potential mining operations.

The seven development zones (also referred to as the "direct impact zones") are arbitrary divisions of a 6-mile wide band along the zone of copper-nickel mineralization. The band was divided along discontinuities in mineralization so that each of the seven resulting zones contains a potential locus of mining activity, generally reflecting the possible extent of a single mining operation. Current mineral rights holdings, company interests, watershed divides, and vege-

Table 14. Distribution of MLMIS cover types within divisions.*

COVER TYPE	DIVISION 1 ha.	DIVISION 1 % of div.	DIVISION 1 % of type in Study Area	DIVISION 2 ha.	DIVISION 2 % of div.	DIVISION 2 % of type in Study Area	DIVISION 3 ha.	DIVISION 3 % of div.	DIVISION 3 % of type in Study Area	DIVISION 4 ha.	DIVISION 4 % of div.	DIVISION 4 % of type in Study Area
White Pine-Red Pine-Jack Pine	24,017	33	50	3,951	15	8	470	2	1	1,651	3	3
Spruce Fir	9,732	14	8	11,806	44	9	3,983	20	3	15,239	29	12
Elm-Ash-Cottonwood	0	0	0	0	0	0	0	0	0	0	0	0
Maple-Birch-Basswood	16	0.0	14	0	0	0	0	0	0	0	0	0
Aspen-Birch	31,563	44	11	7,579	28	3	6,073	30	2	31,709	30	11
Unproductive**	1,555	2	6	810	3	3	1,344	7	5	2,348	7	9
Nonforest***	5,004	7	8	2,575	10	4	8,210	40	14	1,862	41	3
Total	71,887			26,721			20,080			52,809		

*See maps, Figures 45a-45g.
**Includes both uplands and lowlands.
***Nonforest includes all other land uses such as mining, residential, agricultura, and water.

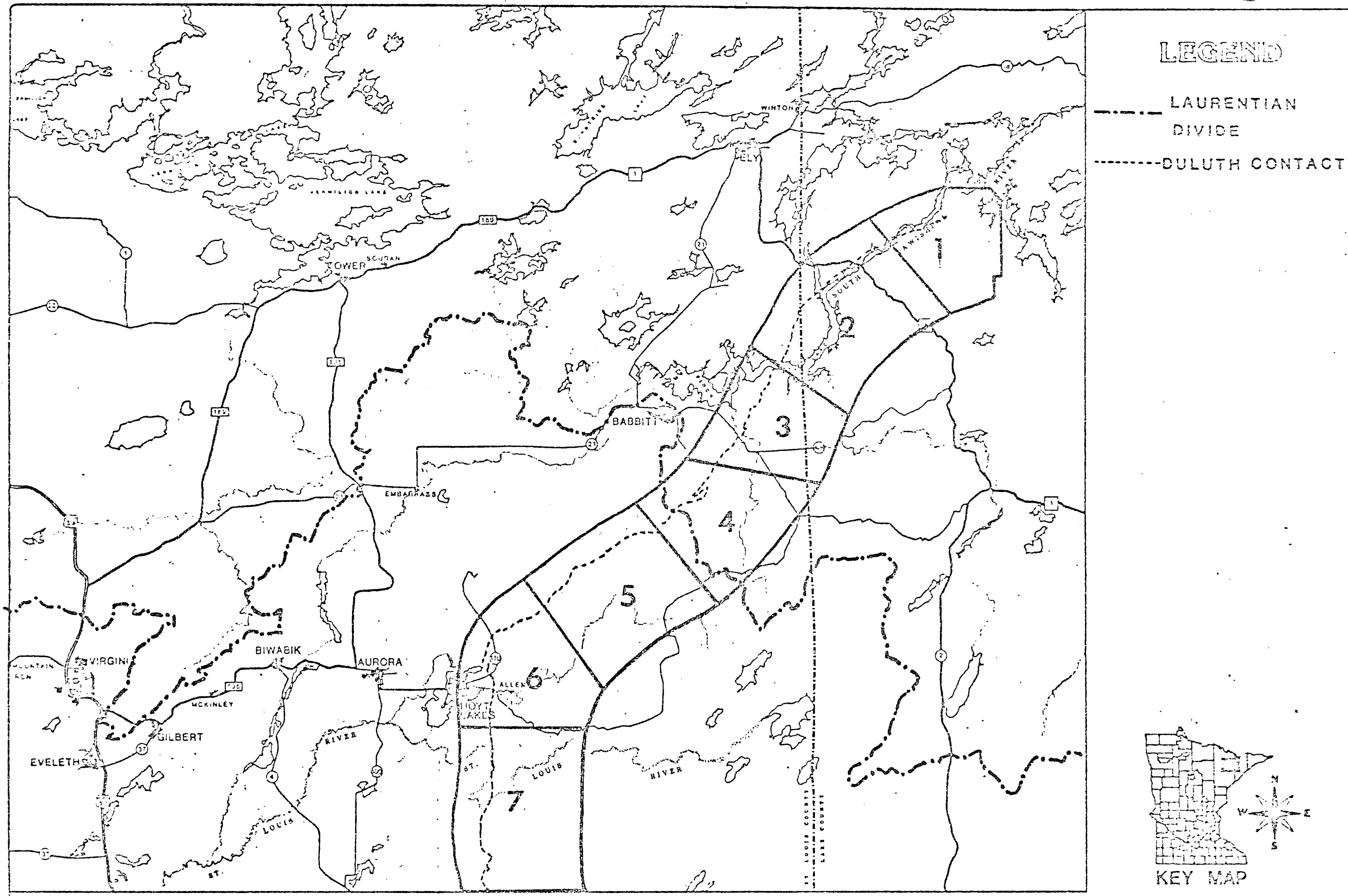
Table 14 continued.

	DIVISION 5			DIVISION 6			DIVISION 7				
COVER TYPE	ha.	% of div.	% of type in Study Area	ha.	% of div.	% of type in Study Area	ha.	% of div.	% of type in Study Area	TOTAL IN STUDY AREA	PERCENT OF STUDY AREA
White Pine-Red Pine-Jack Pine	1,910	4	4	3,998	2	8	11,930	9	25	47,927	8.7
Spruce Fir	22,922	47	18	53,614	26	41	12,416	10	10	129,712	23.5
Elm-Ash-Cottonwood	0	0	0	761	0	98	16	0	2	777	0.1
Maple-Birch-Basswood	16	0	14	0	0	0	81	0	72	113	0.0
Aspen-Birch	18,082	37	6	102,760	51	36	90,668	70	31	288,434	52.2
Unproductive	907	2	4	16,155	8	63	2,639	2	10	25,758	4.7
Nonforest	4,986	10	8	25,480	13	43	11,299	9	19	59,416	10.8
Total	48,823			202,768			129,049			552,137	

tation boundaries were not used to designate the zones. The seven development zones are illustrated in Figure 37, and the area of each habitat within zones is presented in Table 15. The community attributes of these seven development zones are presented in Table 16 and discussed below. Vegetation maps of the seven zones are presented in Figures 38 to 44. Susceptibilities of ecosystem components are summarized by zone in Table 17.

Figure 37, Tables 15, 16, and 17

Zone 1 lies adjacent to the BWCA on the east side of the Kawishiwi River and generally includes the watershed of Filson Creek (Figure 38). The zone is distinguished by its high proportion of jack pine. Thirty-two percent of all jack pine in the direct impact belt lies in this zone (Table 15). Within this zone there is a greater admixture of conifers in the aspen-birch stands than elsewhere in the area. Extensive portions of aspen-birch forests immediately adjacent to the BWCA (near Nickel Lake) have been logged in the last 30 years. Plantations along the Spruce Road range in age from 30 to 5 or fewer years and are exclusively red and jack pine. Remnants of mature white pine stands are scattered near the Spruce Road and the Kawishiwi River. The floodplain ash community is well-developed in a narrow band along both shores of the Kawishiwi River. Two plant communities within zone 1 are near their range limits. The black ash-silver maple floodplain community is approaching its northern limit (the Quetico, Ontario region), whereas the Upland black spruce-jack pine community is at its southern limit. Although distributions of all species in a community do not end abruptly where the community ceases to be recognized as a functional unit, it is the case that individual species may also be near their range limits. The distribution of a species stops where the environment is no



MEQB REGIONAL COPPER-NICKEL STUDY

FIGURE 37 DEVELOPMENT ZONES

Tabl[illegible]5. Proportions of community types in seven development zones*

	ZONE 1				ZONE 2			ZONE 3			ZONE 4		
	ha. in BWCA	Total ha in zone	% of zone	% of this type all zones	ha in zone	% of zone	% of this type all zones	ha in zone	% of zone	% of this type all zones	ha in zone	% of zone	% of this type all zones
Shrub Carr (inc. marsh)		105	1.5	2.9	525	4.3	14.6	396	4.5	11.01	248	3.1	6.9
Ash		2	.03	5.9	2	.02	5.9	2	.02	5.9	7	.08	21.0
Cedar		0	0	0	15	.10	4.4	96	1.1	27.9	11	.14	3.2
Tamarack (inc. nonprod. swamp)		11	.20	1.6	32	.26	4.9	146	1.7	22.4	0	0	0
Black Spruce (inc. mixed black spruce-fir-cedar	139	475	6.8	4.5	1,258	10.4	11.9	1,280	14.0	12.1	1,606	19.9	15.2
Spruce-Fir (mainly upland spruce inc. black spruce-jack pine in zones 1 & 2)		122	1.7	5.3	770	6.3	33.6	206	2.3	8.9	419	5.2	18.2
Jack Pine	764	901	12.9	33.2	765	6.3	28.2	443	5.0	16.3	186	2.3	6.9
Red Pine		98	1.4	10.5	24	.20	2.6	482	5.5	48.9	40	5.0	4.3
Aspen-Birch (inc. aspen-birch-fir)	901	3,527	50.4	11.6	5,858	48.2	19.8	2,198	25.0	7.2	1,766	21.9	5.8
Mixed Conifer-Deciduous		390	5.6	12.3	858	7.1	27.1	744	8.5	23.5	958	11.9	30.3
Clearcut & Young Plantation	42	687	9.8	8.2	1,306	10.8	15.6	1,773	20.2	21.1	1,628	20.1	19.4
Industrial & Residential (inc. mining)		0	0	0	2	.02	.03	1,191	13.6	40.4	1,211	15.0	41.1
Water	430	679	9.7	35.7	730	6.0	38.4	225	2.6	11.8	0	0	0
TOTAL		6,997			12,145			9,182			8,080		

*zones are the copper-nickel development zones shown in Fig. 37.

Source: MLMIS

Table 15 continued.

	ZONE 5			ZONE 6			ZONE 7			TOTAL AREA IN THIS COMMUNITY IN DIRECT IMPACT BELT
	ha in zone	% of zone	% of this type all zones	ha in zone	% of zone	% of this type all zones	ha in zone	% of zone	% of this type all zones	
Shrub Carr (inc. marsh)	539	4.8	14.9	862	8.7	23.9	921	7.0	25.6	3,596
Ash	0	0	0	0	0	0	21	.16	61.8	34
Cedar	126	1.1	36.6	18	.01	5.2	78	.60	22.7	344
Tamarack (inc. nonprod. swamp)	243	2.2	37.2	57	.58	8.8	162	1.2	24.9	651
Black Spruce (inc. mixed black spruce-fir-cedar	4,218	37.6	32.2	1,829	18.5	17.3	2,442	15.0	23.1	13,108
Spruce-Fir (mainly upland spruce inc. black spruce-jack pine in zones 1 & 2)	484	4.3	19.3	260	2.6	11.3	241	1.8	9.6	2,502
Jack Pine	191	1.7	7.0	210	2.1	7.7	14	.1	.5	2,710
Red Pine	0	0	0	14	.14	1.5	278	2.1	29.7	936
Aspen-Birch (inc. aspen-birch-fir)	3,774	33.6	12.4	4,903	49.5	16.1	8,362	63.6	27.5	30,399
Mixed Conifer-Deciduous	210	1.9	6.6	11	.1	.3	3.4	.03	.1	3,163
Clearcut & Young Plantation	1,136	10.1	13.5	1,379	13.9	16.4	487	3.7	5.8	8,396
Industrial & Residential (inc. mining)	278	2.5	9.4	263	2.7	8.9	0	0	0	2,945
Water	24	.21	1.3	104	1.0	5.5	139	1.1	7.3	1,901
Total	11,223			9,910			13,148			70,685

TABLE 16 IMPORTANT CHARACTERISTICS OF ZONES *

ZONE	RARE AND UNIQUE FEATURES: HABITAT	PLANT	WOLF	MARTEN	EAGLE/OSPREY	SONG BIRD	WILDLIFE: MOOSE	DEER	BEAR	FISHER	BEAVER	RUFFED GROUSE	SOILS: ERODIBLE	SUSCEPTIBLE TO HEAVY METALS	LOW BUFFERING CAPACITY	DIFFICULT TO RECLAIM	IMPACT SUSCEPTIBILITY**
1																	HIGH
2																	HIGH
3																	MEDIUM
4																	LOW
5																	MEDIUM
6																	MEDIUM
7																	MEDIUM

SIGNIFICANT OCCURRENCE

* Developmental zones Figure [illegible] ** see Table 17

TABLE 17

SUSCEPTIBILITY OF COMPONENTS WITHIN DEVELOPMENT ZONES*

HABITAT	PLANTS	SOIL	WOLF	MARTEN	EAGLE/ OSPREY	SONGBIRDS	SMALL MAMMALS	MOOSE	DEER	BEAR	LYNX	BOBCAT	FISHER	OTTER	BEAVER	SPRUCE GROUSE	RUFFED GROUSE	WOOD-COCK	SNOWSHOE HARE	WATER-FOWL

* Development zones Figure 37

longer suitable for the species where it is outcompeted by its associates, or where the species has never colonized. Species near their range limits are likely to be exposed to different pressures from natural selection than those near the center of the range, creating genetic variations at the periphery of the range. Aside from the inherent value of allowing natural diversity to maintain itself, the usefulness of genetic variants as breeding stock for disease resistant or winter hardy plants has also been recognized.

Figure 38

Zone 1 has a high rating as wildlife habitat because roughly one-quarter of the best marten habitat (mature upland conifers) in the Study Area is located within the zone. Although deer populations in the northeastern part of the Study Area are low, the zone is especially important because of the high concentration of winter deer yards along the east shore of Birch Lake in a buffer between two wolf packs. Such buffer zones may be important as centers of repopulation for deer in this part of the area.

One plant rare in Minnesota, the large-leaved sandwort (Arenaria macrophylla), was collected at releve site T30 in this zone. One of the 8 known osprey nests in the area is located on the north arm of the Kawishiwi River near the BWCA boundary. Roughly one-fourth of the best marten habitat is included in this zone, along with a high concentration of winter deer yards lying just on the east side of Birch Lake between the Heart Lake and Crockett Lake wolf packs, whose territories overlap with the impact zones.

Ninety-three percent of the area in zone 1 lies on soil association 8, loamy to sandy-loam soils of the Mesaba-Barto group. The remaining soils belong to soil association 58, organic soils of wetlands.

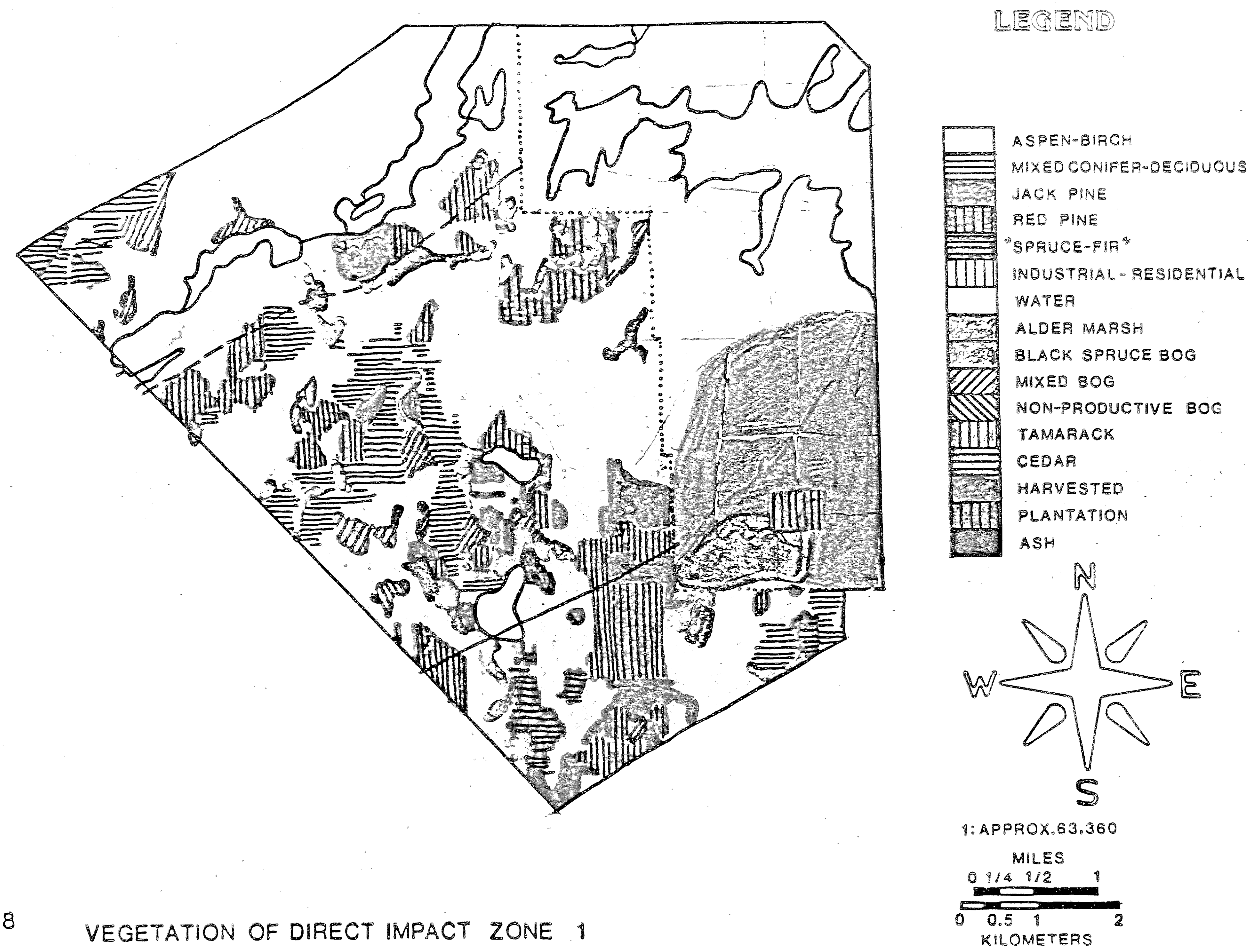


FIGURE 38 VEGETATION OF DIRECT IMPACT ZONE 1

Zone 2 lies along the north arm of Birch Lake and swings east as far as Harris Lake (Figure 39). As in zone 1, there is considerable admixture of conifers in the deciduous uplands, especially on the east side of Birch Lake north of Denley Creek, where spruce budworm damage is apparent. Over one-fourth of all mixed stands in the development zones lie within this zone (Table 15). Large portions of this zone are included in the Baird Sale and can be expected to be reforested in jack and red pine in the near future. White pine is virtually absent from the natural forests in this zone. The ash community is present in restricted pockets along the shores of Birch Lake.

Figure 39

Mature conifer uplands within the zone account for nearly half the best marten habitat in the area. Over one-third of all upland spruce (fir-jack pine) in the development zones lies within this zone. The Keeley Creek Research Natural Area (S14, T61N, R11W) provides excellent examples of the upland black spruce-jack pine community, mainly dominated by spruce and an example of overmature aspen that may serve as an example of forest succession in this part of the area. The Harris Lake osprey nest lies within 1/2 km of the impact zone.

Soils of this zone are the same associations as found in zone 1, with 95 percent of the area on upland association 8, and 5 percent on organic association 58.

Zone 3 occupies the uplands south of Birch Lake and the bed of glacial lake Dunka including the extensive wetland system located along USFS 424 and along the Dunka River (Figure 40). Pine in the area consists almost entirely of red and jack pine plantations ranging in age from less than 5 years to approximately 70 years. Over one-fourth of all red pine within the development zones lies in

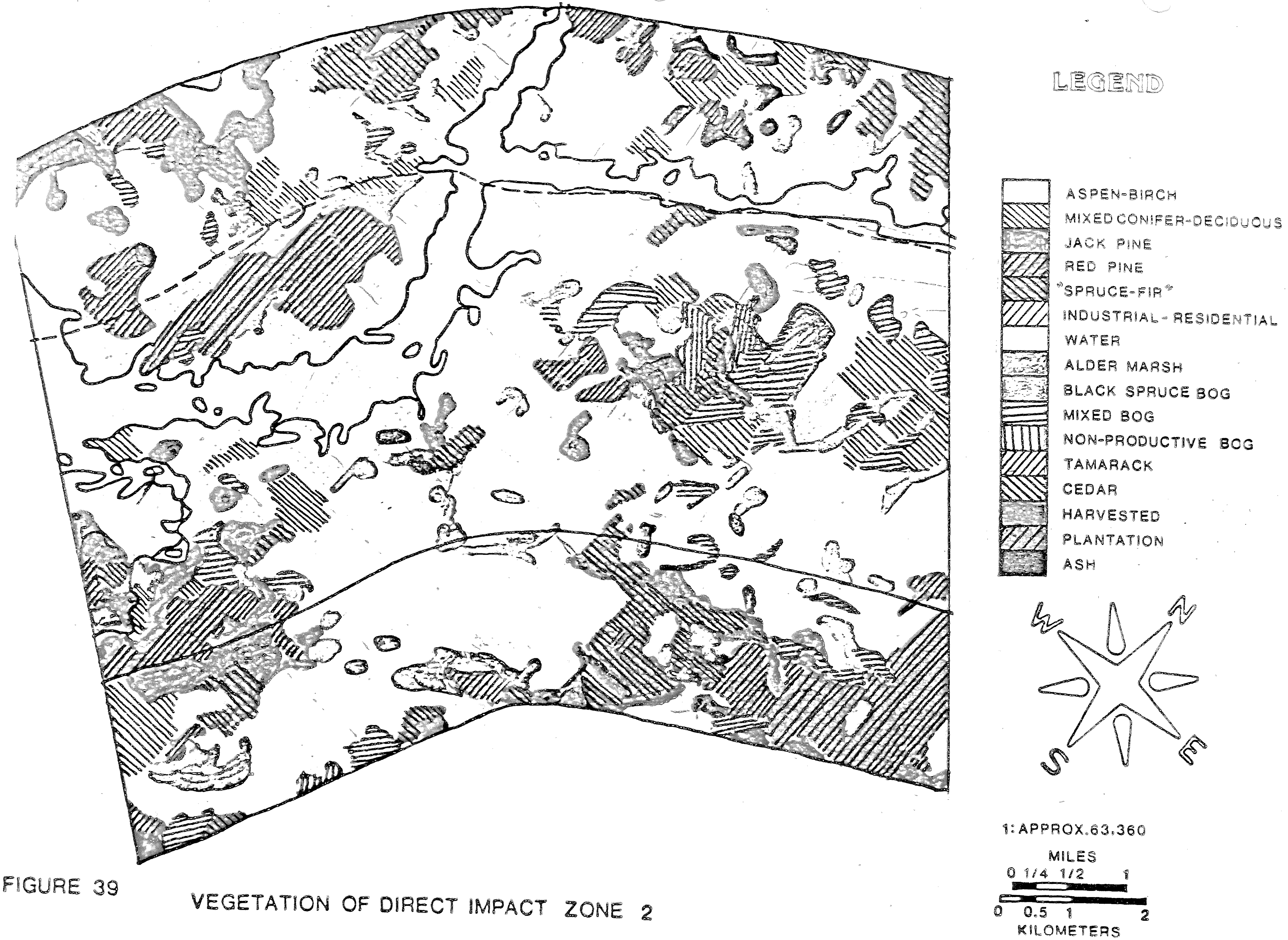


FIGURE 39

VEGETATION OF DIRECT IMPACT ZONE 2

this zone (Table 15). Aspen-birch stands lie mainly just south of Birch Lake and west of the Erie railroad tracks. Portions of the area just south of Twenty Proof Creek cut in the 1930s have regrown to an open upland brushland which may be included in the "aspen-birch" classification. The Dunka wetlands contain ash, cedar, tamarack, and spruce communities which have been disturbed by periodic logging.

Figure 40

Because of their history of disturbance and accessibility to ongoing disturbance these wetlands are probably of less inherent natural value than the more inaccessible wetlands in zones 5 and 6, and certainly of less value than the extensive Seven Beavers wetland in the southeastern part of the Study Area.

Soils of zone 3 are more complex than in zones 1 and 2, reflecting the more complicated glacial history of the area. The predominant soil association (62%) is the Mesaba-Barto association (8) which prevails in zones 1 and 2, but association 7 (Toivola-Unnamed-Cloquet) accounts for 24 percent of the area. Association 5, the Newfound-Newfound coarse-loamy association underlies the pine stands south of the Dunka wetland and accounts for four percent of the area in the zone. Less important upland soils are the Menagha-Cutfoot association (26) and the Mesaba-Barto undulating association (35), each accounting for three percent of the zone. The twelve percent of the zone underlain by organic soil association 58 gives a good estimate of the true amount of wetland vegetation in the zone. Six percent of the area in this zone is accounted for at the present time by taconite mines.

Zone 4 straddles the Laurentian Divide and contains the upper reaches of the Dunka watershed (Figure 41). A large portion of the area in this zone is

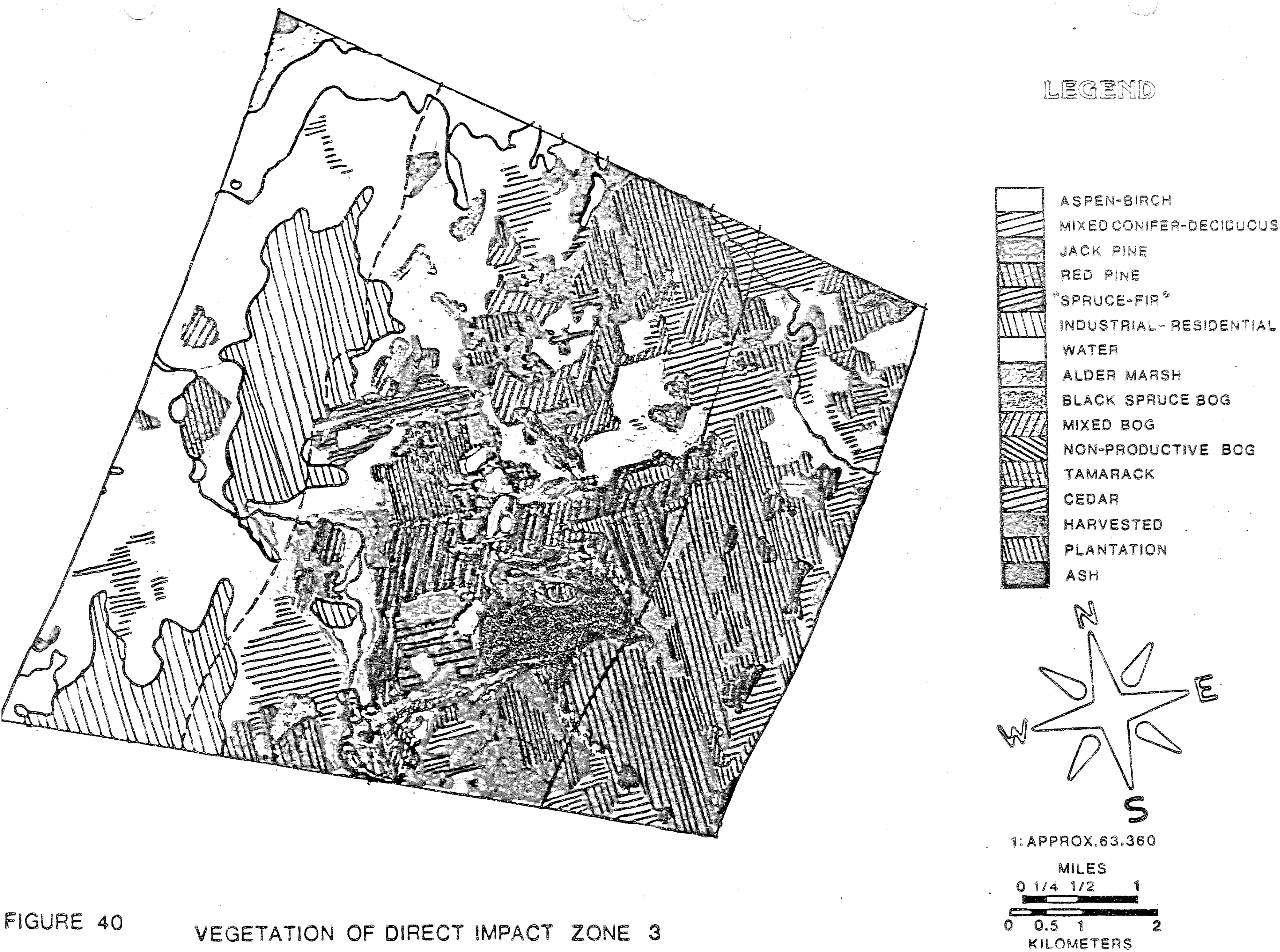


FIGURE 40 VEGETATION OF DIRECT IMPACT ZONE 3

currently taken up by a variety of taconite mining land uses with twelve percent occupied by open pit mines. Aspen-birch is the dominant vegetation type, accounting for 33 percent of the area. Aspen-birch forests in this portion of the Study Area are often fairly open, verging on upland brush communities, of very heterogeneous species composition and patchy structure. The major concentration of upland spruce is in the upper reaches of the Dunka River where stands logged in the 1930s and 1940s have the appearance of mature stands today. The proportion of the area in pine is low (2%) reflecting the post-logging history and large proportion of private ownership. Pine plantations are present both north and south of the Erie Restricted Road and account for almost one-fifth of all plantations in the direct impact belt (Table 15).

Figure 41

The good development of wetland conifer bogs along the upper reaches of the Dunka River is one of the best contiguous areas of habitat for the unique bird community of conifer lowlands and accounts for approximately 15 percent of all spruce bog in the direct impact belt.

The Mesaba-Barto undulating to hilly association (8) accounts for 44 percent of zone 4, with the Mesaba-Barto undulating association (35) accounting for another 3 percent. The Toivola-Unnamed-Cloquet association (7) accounts for 13 percent of the zone and the Newfound-Newfound association 11 percent.

Zone 5 lies mainly in the watershed of the Partridge River. Despite the relatively small portion of the zone in red pine (7.2%), this area accounts for almost half of all red pine within the direct impact belt. The zone is dominated by aspen-birch on the uplands (33%) and spruce (15%) and open conifer (16%) bogs in

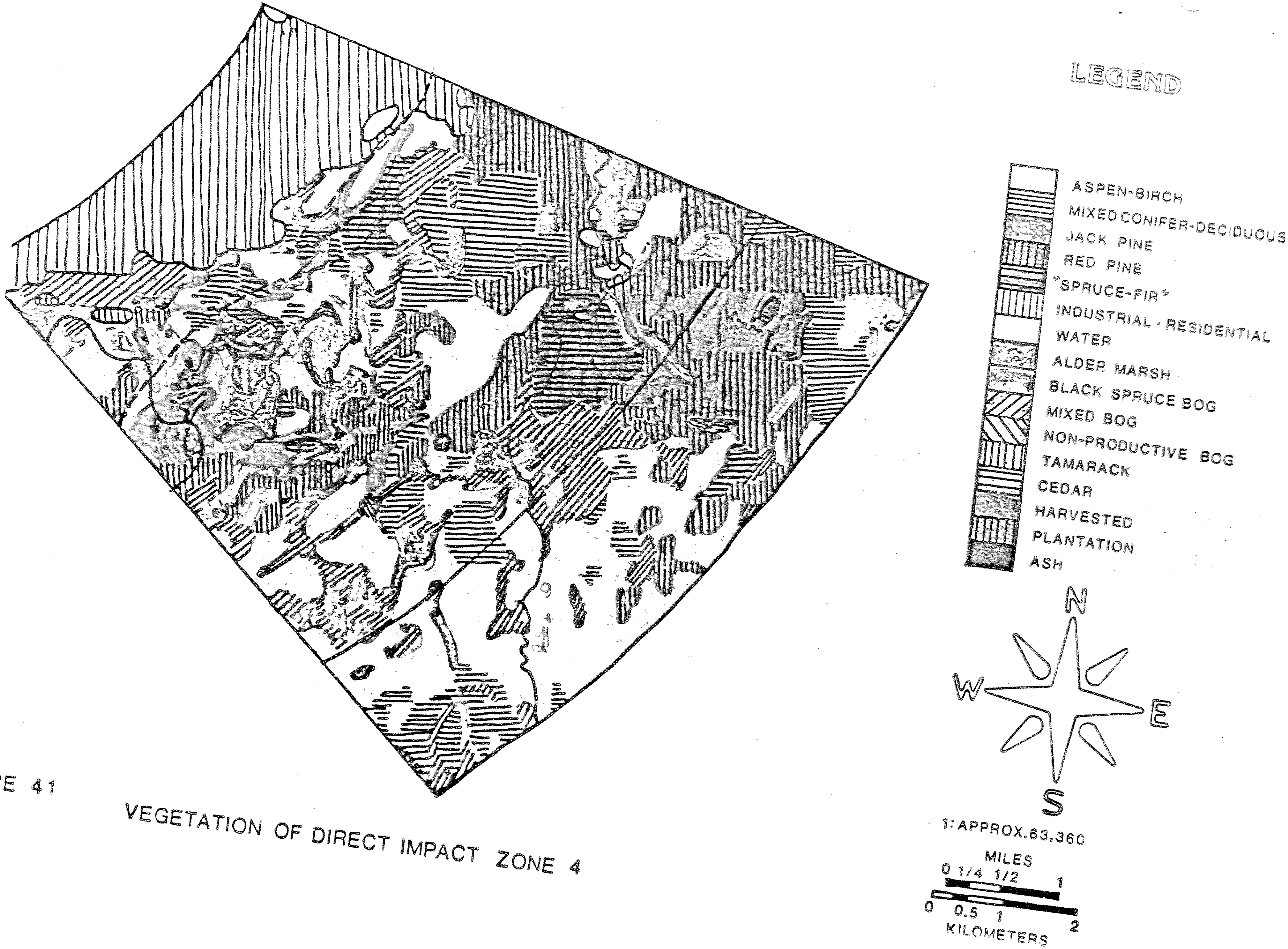


FIGURE 41

VEGETATION OF DIRECT IMPACT ZONE 4

the wetlands (Figure 42). Approximately 80 percent of all open conifer wetlands in the development zones lie within this zone. As is the case with zone 4, the most unique habitat feature is the extensive area of conifer wetland preferred by a unique assemblage of birds. Although the proportion of the zone occupied by cedar bogs is small (2.3%) over half of all cedar in the direct impact belt lies within this zone.

Figure 42

Soil association 8 accounts for 42 percent of the area, association 5 for 24 percent. Soil association 7 is less important than in zones 3 and 4. Roughly three percent of the area is currently accounted for by open pit taconite mines.

Zone 6 lies mainly in the lower reaches of the Partridge River just east of Hoyt Lakes (Figure 43). Approximately 20 percent of the area is currently taken up by land uses related to taconite mining. Aspen and birch account for the largest proportion of upland forests (50% of the area), with pine accounting for another 2 percent. Wetlands account for roughly 25 percent of the area and conifer bogs provide the most unique habitat feature within this zone. Nearly one-fourth of all shrub carr within the direct impact belt lies within this zone (Table 15). Newfound soils (association 5) predominate on uplands with zone 6, accounting for 69 percent of the zone. Association 7 accounts for an additional 4 percent of upland soils. The zone differs from zones 1-5 in the absence of association 8.

Figure 43

Zone 7 lies southeast of Hoyt Lakes on the Toimi Drumlin Field and the Aurora till plain province and is dominated by aspen-birch (64% of the zone)(Figure 44).

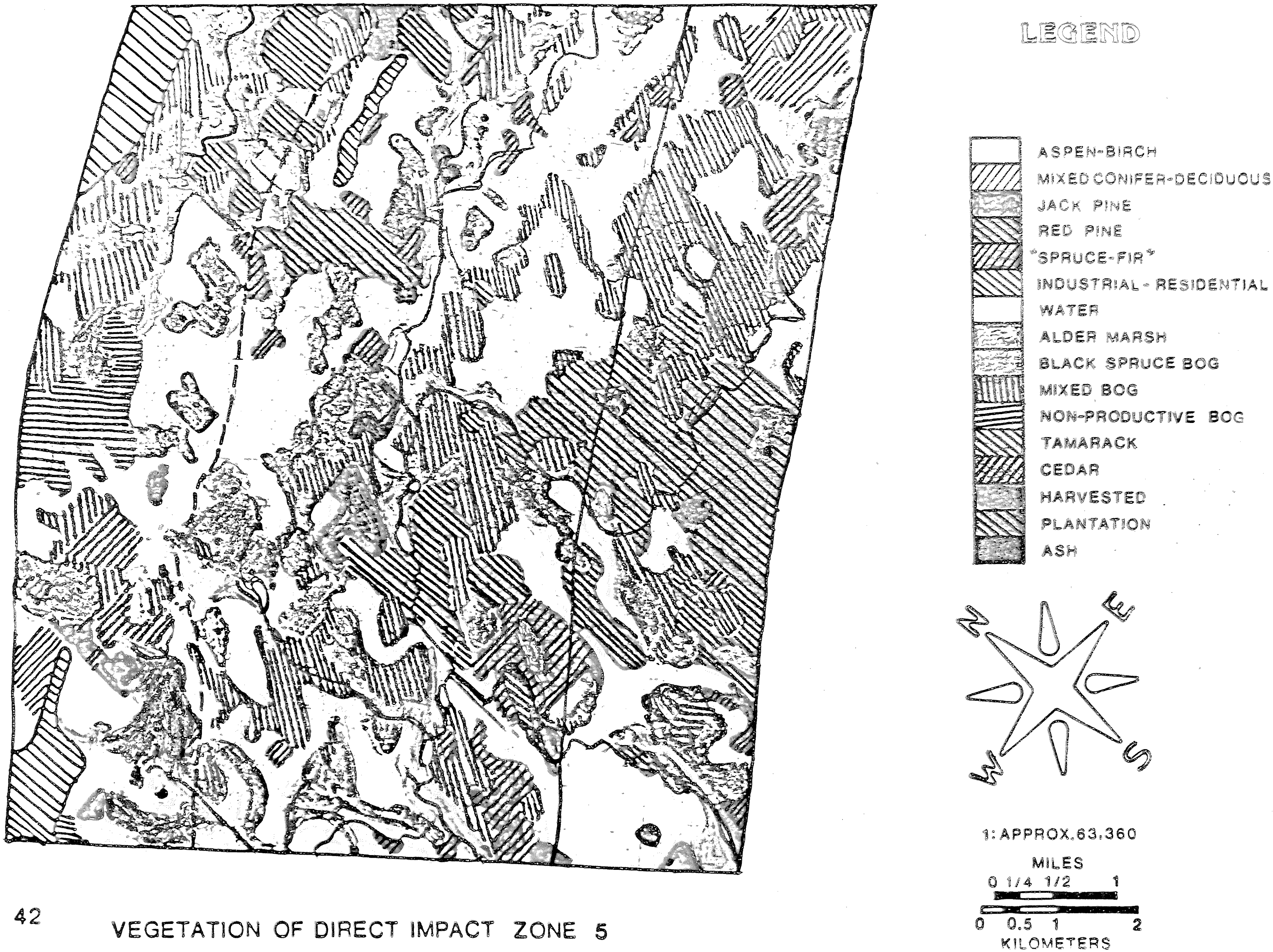


FIGURE 42 VEGETATION OF DIRECT IMPACT ZONE 5

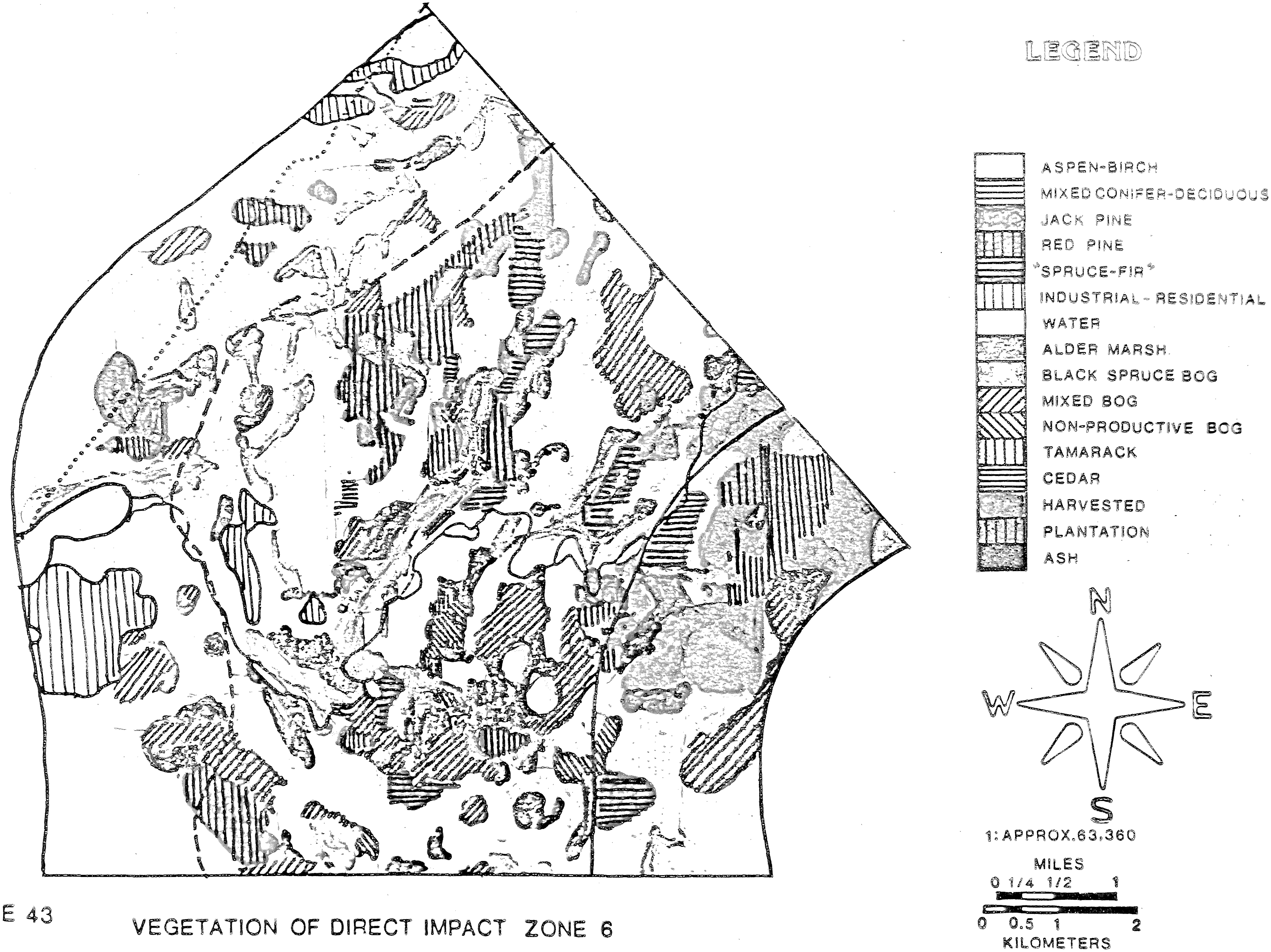


FIGURE 43 VEGETATION OF DIRECT IMPACT ZONE 6

Over one-fourth of all aspen-birch within the development zones lies in this zone. Deciduous stands in this zone are relatively pure, often contain herbs characteristic of forests farther south, and have thin litter layers, suggesting that current rates of decomposition must be rapid. Because the zone was burned by the 1937 Palo-Markham-Aurora fire, forests are even-aged. The two percent pine is accounted for by jack and red pine plantations either dating from shortly after the 1937 fire or planted within the last fifteen years. Lowland spruce is often open and occurs in draws between drumlins, especialy in areas not consumed by the fire. In burned areas such draws are more characteristically occupied by alder carr, which reaches its best development in this zone. In general, the zone provides the best habitat in the Study Area for such game species as deer, moose, woodcock, and ruffed grouse. However, in comparison with statewide habitat for these species it would have only a poor to fair rating.

Figure 44

Seventy percent of the area lies on soil association 5, the association most likely to be susceptible to loading by heavy metals because of its present shallow litter layer (see Volume 3-Chapter 1). Wetlands lie on two organic soil associations, 58 and 57 (22 and 6% of the area, respectively). Very little of the development zones (less than 1%) lies on association 50, the clayey Hibbing soil that should have a good capacity to bind heavy metals.

Seven terrestrial biology divisions were distinguished within the Study Area on the basis of forest cover type and soil associations (Figure 45 and Table 14). The MLMIS resource base was used to classify each 40 acre cell of the area on the basis of vegetation (which should reflect the complex susceptibility of the

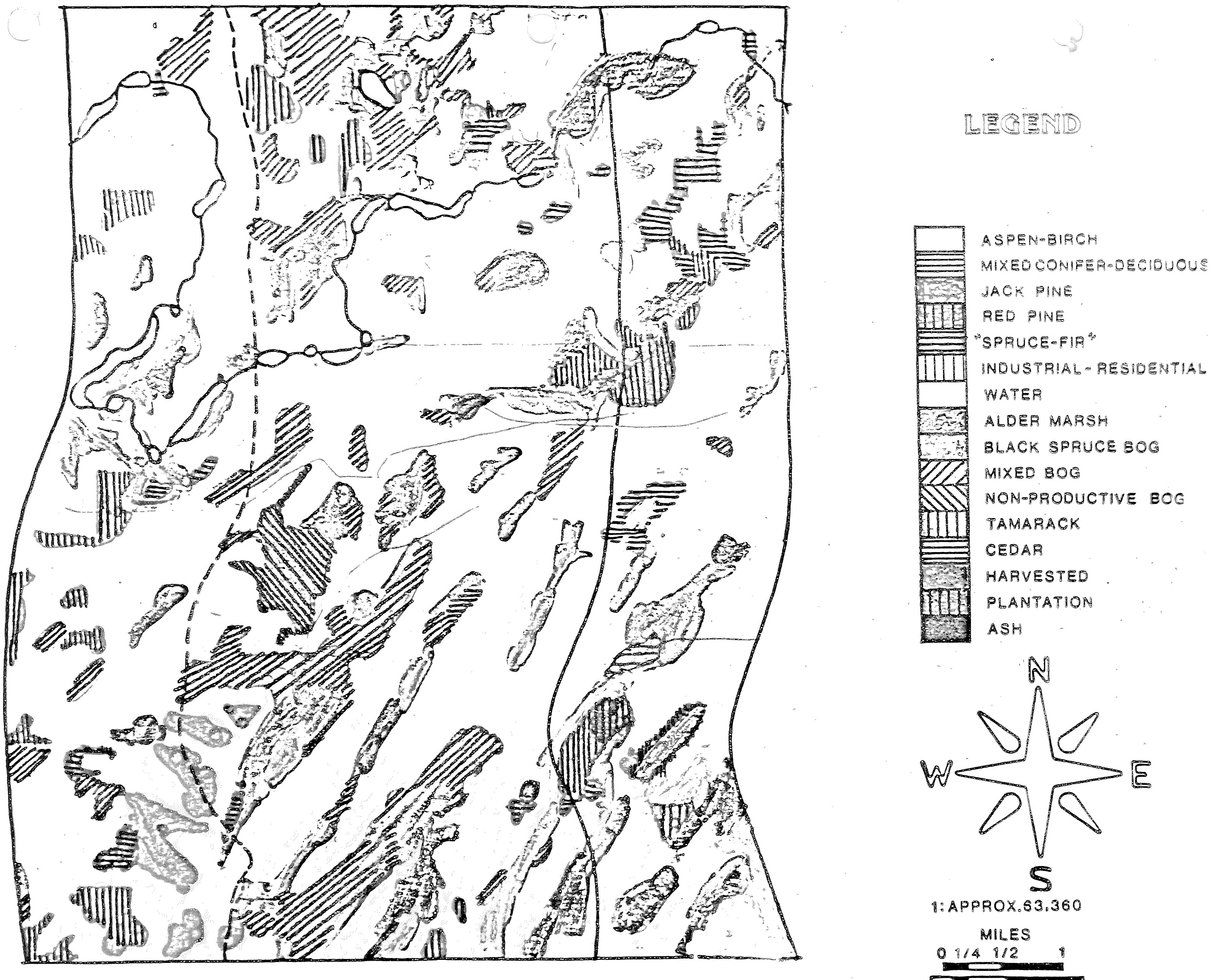


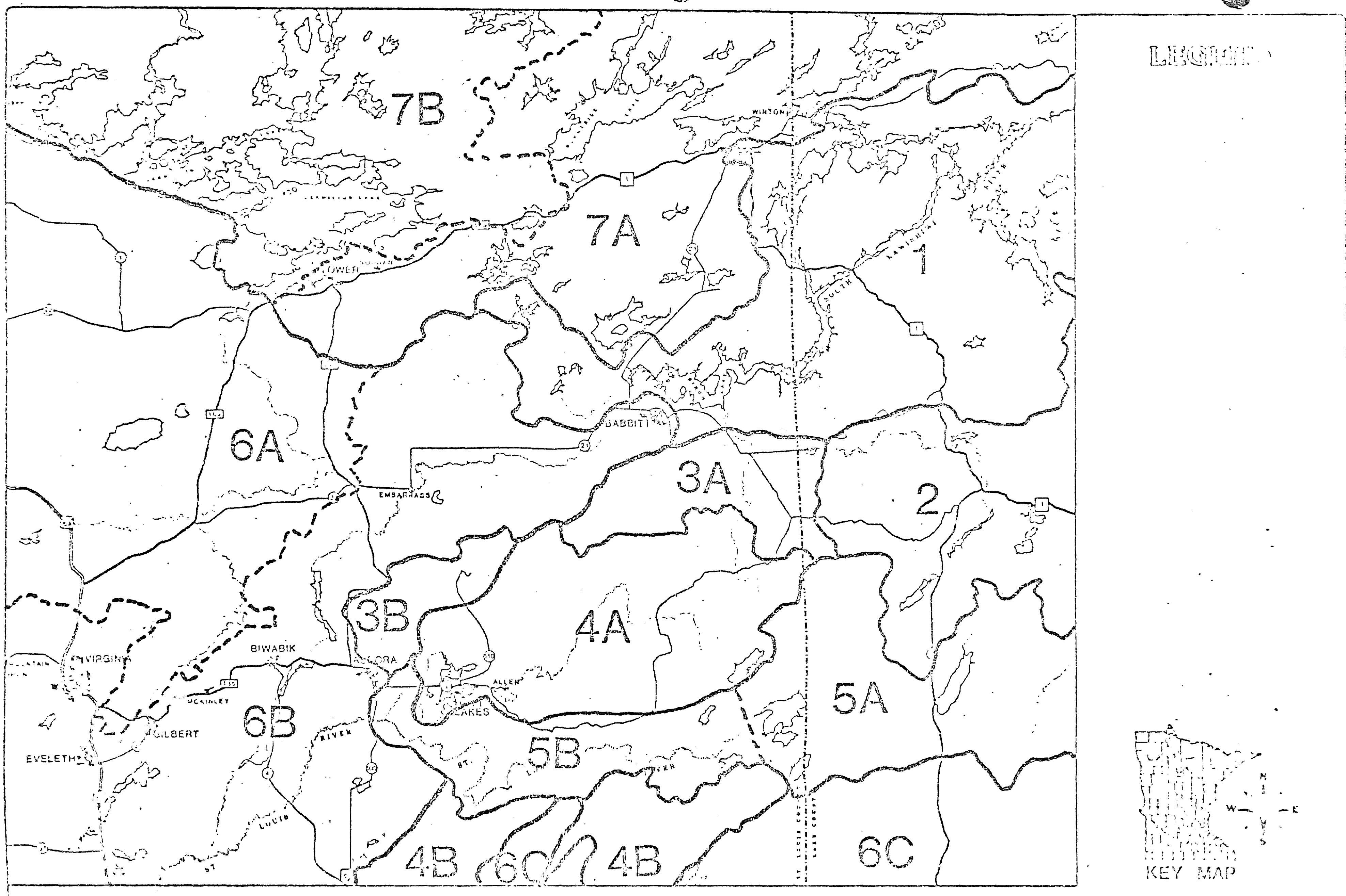
FIGURE 44 VEGETATION OF DIRECT IMPACT ZONE 7

biological components) and soil type (which should reflect susceptibilities accountable to soil texture, cation exchange capacity, and other parameters shown in Table 11). A mechanical clustering technique (Orloci 1967) was used to group watersheds with the most similar community and soil characteristics. A brief description of each of the seven terrestrial biology divisions follows. In some cases, differences within divisions were great enough to require separation of the division into areas that will respond differently to some but not all impacts. The differences between these subdivisions were not great enough to allow distinctions on the basis of soil and vegetation characteristics. Susceptibilities of components within the seven divisions are summarized in Table 18.

Figure 45, Table 18

Division 1 (71,887 ha) lies north of the Laurentian Divide in the area surrounding Birch Lake and the Kawishiwi River. Over 50 percent of all pinelands in the Study Area lie within this division, despite the fact that the dominant vegetation type is aspen-birch (Table 14). The coarse-loamy to loamy soils are generally shallow with nearly two-thirds in the Mesaba-Barto Association.

Division 2 (26,721 ha) includes the Stony River watershed in the east-central part of the Study Area. Spruce-fir (44%) and aspen-birch (28%) dominate the vegetation (Table 14), and account for about equal proportions of the Study Area total for these types. Although the percentage of pine within the division is second only to that of Division 1, the total acreage is much smaller than in zone 7, so that only 8 percent of all pinelands in the Study Area lie within the division. Soils are predominantly undulating to steep and sandy, but one-

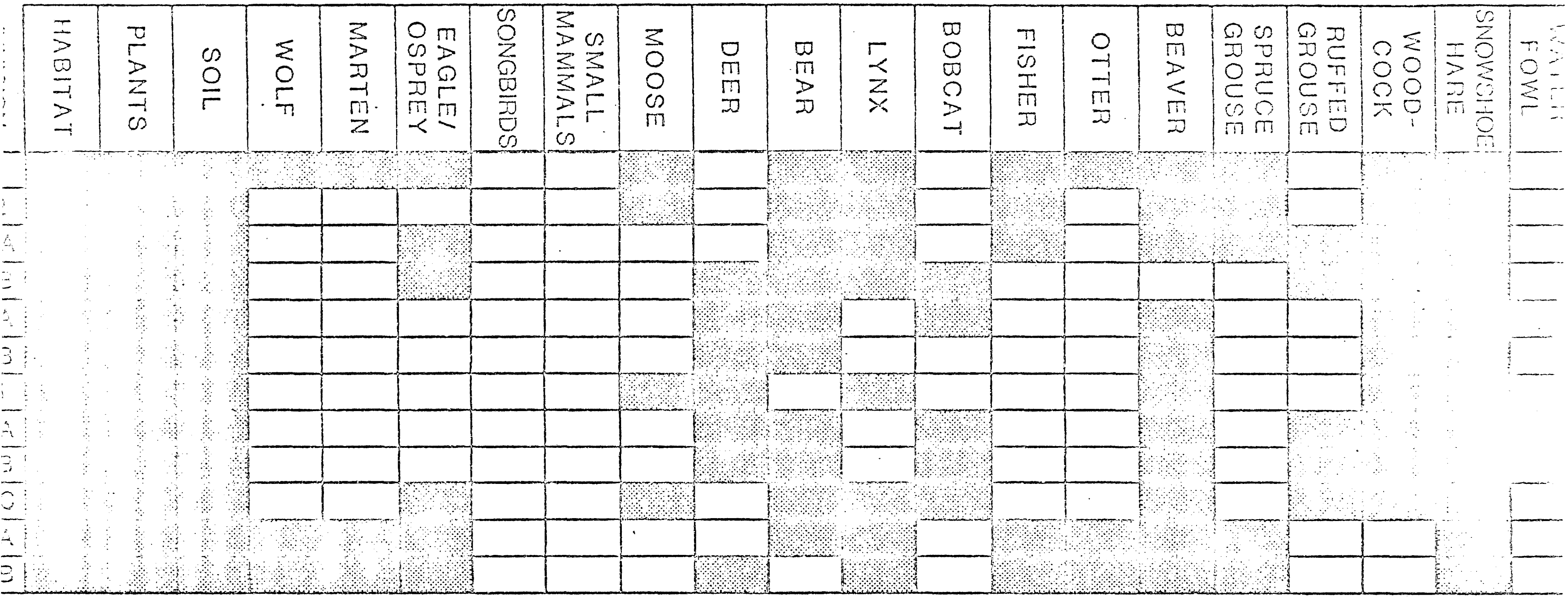


MEQB REGIONAL COPPER-NICKEL STUDY

FIGURE 45 TERRESTRIAL BIOLOGY DIVISIONS

TABLE 18

SUSCEPTIBILITY OF COMPONENTS WITHIN TERRESTRIAL BIOLOGY DIVISIONS



SUSCEPTIBLE

NOT AS SUSCEPTIBLE

SUSCEPTIBILITY OF ANIMALS IS BASED ON THEIR ABUNDANCE WITHIN THE DIVISION AND THE EFFECT THAT IMPACTS ON THE POPULATION WITHIN THE DIVISION WOULD HAVE ON THE POPULATION OF THE STUDY AREA AS A WHOLE.

third of the area lies on organic soils in the Seven Beaver-Sand Lake Outwash Province.

Division 3 (20,080 ha) includes nearly 40 percent non-forested area with 31 percent of the surface covered by mine land. Portions of the Dunka and Partridge River watersheds are included in the division because it straddles the Laurentian Divide. Aspen-birch (30%) and spruce-fir (20%) dominate the uplands and lowlands, respectively. Soils of the area are diverse and include undulating coarse-loamy soils, steep sandy soils and organic soils.

Division 4 (52,809 ha) contains much of the Partridge River watershed and is dominated by aspen-birch (30%)(Table 14) and spruce-fir (29%). The division contains the highest proportion of Newfound soils, characteristic of the Toimi Drumlin Field and nearly one-fourth organic soils underlying spruce-fir and "unproductive" wetlands between drumlins.

Division 5 (48,823 ha) extends from Greenwood and Seven Beaver lakes on the east through the watershed of the St. Louis River on the west. Because of the extensive wetlands on the east, the area is dominated by spruce-fir (47%)(Table 14) and organic soils. Uplands are dominated by aspen-birch (37%).

Division 6 (202,768 ha) is the largest division and accounts for the highest proportion of most cover types (Table 14). It lies in the southwestern part of the area drained by the Pike, Sandy, Lower St. Louis, Little Fork, and parts of the Partridge and Embarrass rivers. The zone has disproportionately high acreages of elm-ash-cottonwood (Figure 5, Table 14), unproductive, and non-forested lands. Ninety-eight percent of all elm-ash-cottonwood communities in the Study Area are concentrated along the Lower St. Louis River as it traverses the bed of Glacial Lake Upham. Acid, organic soils are common in lowland areas with undulating-sandy to coarse-loamy soils in the uplands.

Division 7 (129,049 ha) covers most of the northwestern quarter of the Study Area and includes the Northern, Two River, Bear Island, and Shagawa watersheds (Figure 33b). The division is dominated by upland forests, especially aspen-birch. As is the case in the other most northerly division (1), pinelands are important in division 7, which contains 25 percent of all pinelands in the Study Area. Because extensive stands dominated by maple, birch, and basswood are rare, the MLMIS inventory indicates that 72 percent of all northern hardwoods stands lie within division 7. It should be noted, however, that the component species and small stands of this forest type are normally found on the shores of large lakes in division 7 and in the southwestern part of the Study Area. Two-thirds of division 7 is underlain by undulating to hilly, shallow coarse-loamy soils.

2.7 PHILOSOPHY OF APPROACH TO IMPACT ASSESSMENT

To this point, emphasis has been placed upon describing in detail the components of terrestrial ecosystems of the Study Area. In this section potential stresses are reviewed and impacts to these ecosystems are predicted on the basis of various stress response studies. Studies that have been conducted take the form of either literature reviews or experiments conducted by the Study. Only an overview of these studies is possible in this report, and for more information the reader is directed to the more comprehensive first level reports listed in the bibliography.

Ecosystems never exist in the total absence of factors that disrupt their structure or function. For the purposes of this discussion, an impact is an abnormal disruption of structure and/or functioning of the ecosystem which can be measured not only in the laboratory but in the field. Factors that alter ecosystems may be either short-term and catastrophic (e.g. fire, windstorms, floods, and major construction or mining projects), or longer lasting and more subtle in their effects (e.g. diseases of non-epidemic proportions or air pollutants at low concentrations). Many of these factors occur naturally. Fires and other climate-related disturbances have affected organisms since life began. As a result, ecosystems and their components have evolved strategies for coping with disturbance. As examples, jack pine trees have serotinous cones that open after fires, roots of aspen trees sprout vigorously after the destruction of aerial stems by fire or wind storm, and many species have evolved an ability to grow in areas where soil oxygen is low because of periodic flooding. Similarly, deer and ruffed grouse are dependent on the disturbances that create young successional forests dominated by aspen and birch.

Examples of adaptation are even found in areas subjected to chronic pollution. In England, moths have been observed to adapt their body color in response to air pollution-related changes in lichen flora on bark. This melanistic response has been studied by Kettlewell (1956) and Bishop and Harper (1970) and represents a classic example of species adaptation. An example of adaptation to naturally occurring air pollution has been reported by Hutchinson and Havas (1977) who describe the ecosystems of Smokey Hills, N.W.T., Canada. Sulfur-laden fumigations from burning lignite deposits have persisted for at least 1000 years and have caused terrestrial and aquatic ecosystems of the surrounding tundra to become strongly acidified. Although the ecosystems are greatly simplified, especially with respect to species diversity, a biota has developed that is tolerant of the extremely harsh conditions.

The speed with which the industrial activities of man dominate the environment of an area rarely allows sufficient time for adaptation of ecosystems, however, and it is the consequences of the resultant ecosystem destruction that are the subject of this section of the report. Specifically, the Study is concerned with the various stresses placed upon terrestrial ecosystems by copper-nickel mining development. Stresses that have been identified as being important include land appropriation, noise, seepage of polluted water from stockpiles and tailing basins, and air pollution. Some of these stresses (e.g. land appropriation and noise) already exist in the Study Area as a result of taconite mining. Other stresses are unique to copper-nickel mining and either are not present in the area or occur only to a limited extent. For example, the study of potential seepage problems was limited to the examination of a single white cedar bog near a small stockpile of copper-nickel-bearing ore at Erie Mining's Dunka Pit near Babbitt.

It would have been impossible to conduct stress-response studies for all the ecosystem components that were studied, so this impact analysis relies heavily upon the assumption that ecosystem components interact and are interdependent. This is especially true for animals. Therefore, it was assumed that the impacts of mining development on most animals would occur as a result of habitat alterations rather than in the form of direct, pollution-related stresses. Certainly the bioaccumulation of heavy metals by top carnivores is a potential problem, but accumulation in the food chain begins with plants, and top carnivores may not remain in the altered habitats long enough for the effects of bioaccumulation to be observed. Similarly, noise is more likely to affect animals than plants, but alterations in the structure of the vegetation (as a result of land appropriation or air pollution) may change the noise levels perceived by animals.

Because of the dependence of animals on plant communities, initially emphasis is placed on the importance of potential stresses on vegetation. If development-related changes in vegetation can be demonstrated, assessment of effects on wildlife then becomes a matter of interpreting the effects of habitat alteration on animal species or groups of species.

In the evaluation of development-related stresses, the concept of reversibility is an important consideration. Given that change is a normal facet of all ecosystems, alterations caused by man's activities can not be necessarily assumed to be detrimental. The compatibility of sound forest management practices and wildlife management has been clearly demonstrated in recent years. Because many ecosystems are adapted to intermittent natural disturbances, such as fire, they possess an ability to recover. The speed with which succession progresses after deforestation varies with the type of community and the nature of the disturbance. Therefore, it is the mining-related activities that drastically and permanently alter ecosystems to some less productive state that are of greatest concern. Some stresses (e.g. air pollution) may be avoidable to begin with. Other activities which are essential to the mining process (e.g. the construction of waste stockpiles or tailing basins), require consideration of potential mitigating factors.

With respect to natural ecosystems, mitigating processes may take the form of stress prevention or of reclamation. Construction of baffles to reduce noise levels from ventilating fans and choice of smelter sites to avoid accidental fumigation of sensitive species or soils are examples of preventative measures. For example, within the Study Area, most vegetation types are susceptible to damage from SO_2 fumigation, but those species most able to reproduce vegetatively have a greater capacity to recover from single or occasional incidents than those dependent on regeneration from seed. Smelter sites immediately adjacent to aspen communities would thus have less long-term impact than would such sites adjacent to pines. In addition to the susceptibility inherent in the species, there are differences in susceptibility depending on topographic position. Plants on hills are more subject to fumigation under normal climatic conditions than those of flatlands, which are only vulnerable under conditions of inversion (Volume 3-Chapter 3).

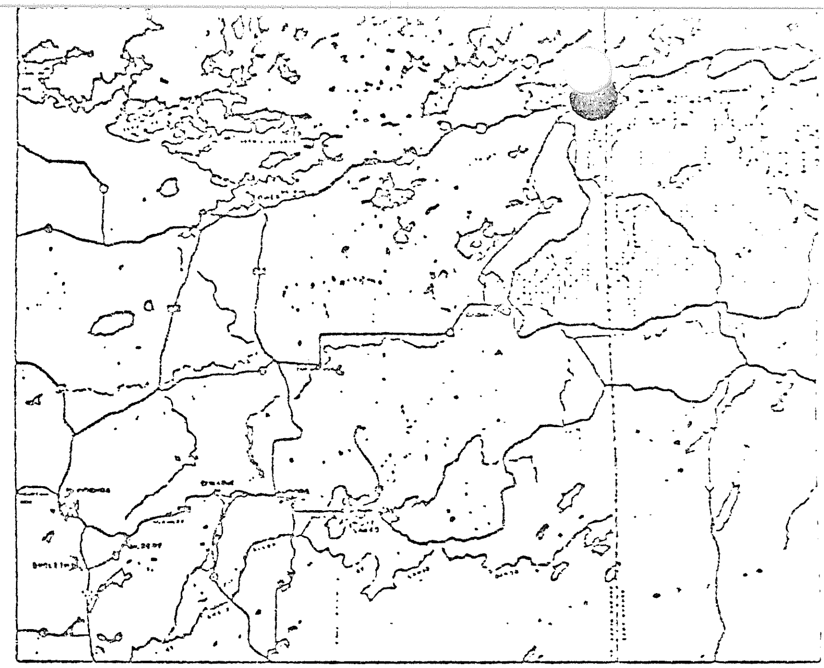
The differential susceptibilities of species, discussed in section 2.9.1.2, were taken into account when the effects of air pollution were simulated by the Regional Study's forest succession model. Pines were considered more susceptible than aspen and birch because of the regenerative capacities of the latter. It was assumed that repeated fumigations would result in reduction of this regenerative capacity and replacement of forest communities by less sensitive species. For the purposes of this modeling, it was assumed that air pollution levels would be great enough to cause physiological (Class III damage-see section 2.9.1) rather than merely subtle damage (Class II). Air pollution levels great enough to cause Class III damage, similar to those found at Sudbury, Ontario, are not expected in the Study Area based on the models presented in Volume 3-Chapter 3; therefore, this "polluted" forest succession model should be used to consider the trends of change that might occur rather than the extent of change. Figure 46 illustrates a trend toward early successional stages, these must be regarded as an exagerated case of potential changes, due to the worst case nature of the modeling assumptions (see Sloss 1978 and section 2.3.3.1 for further details of modeling assumptions).

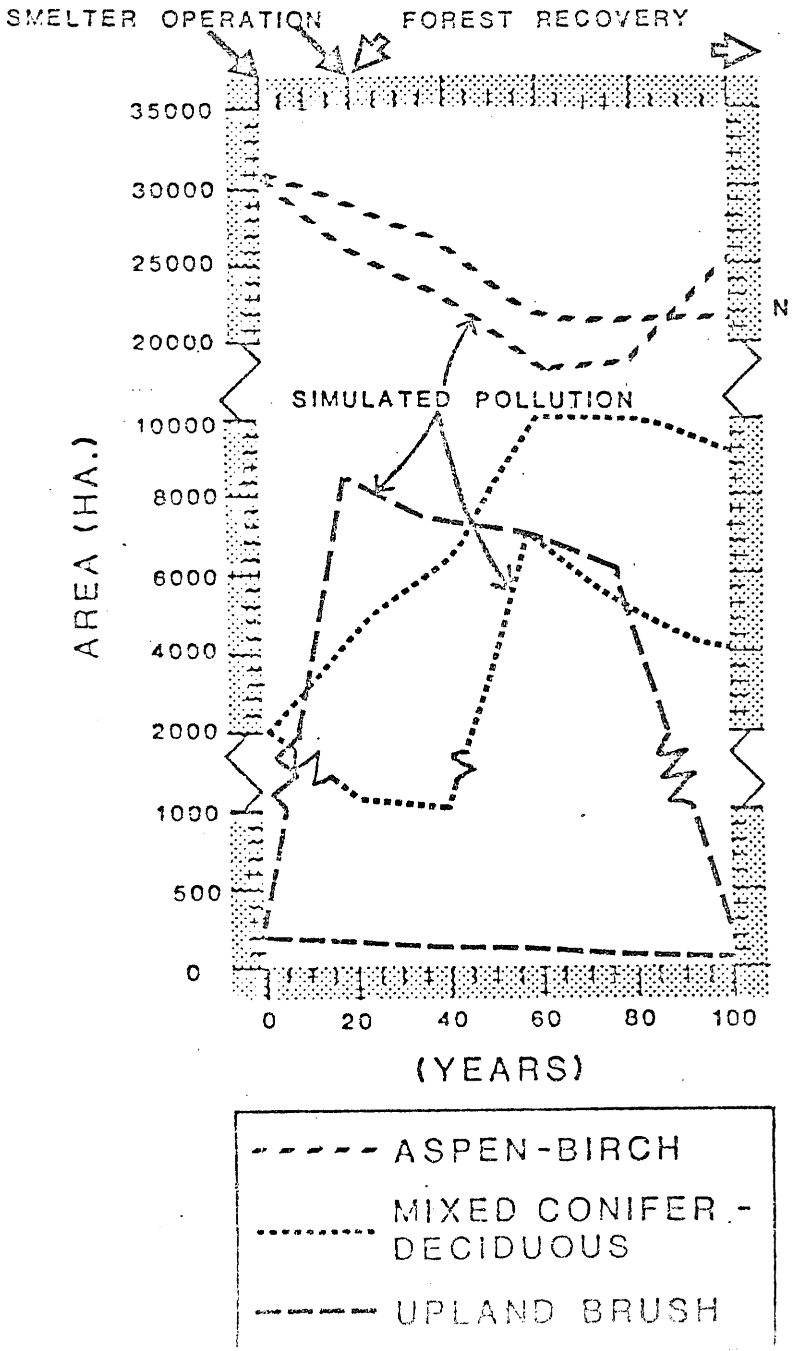
Figure 46

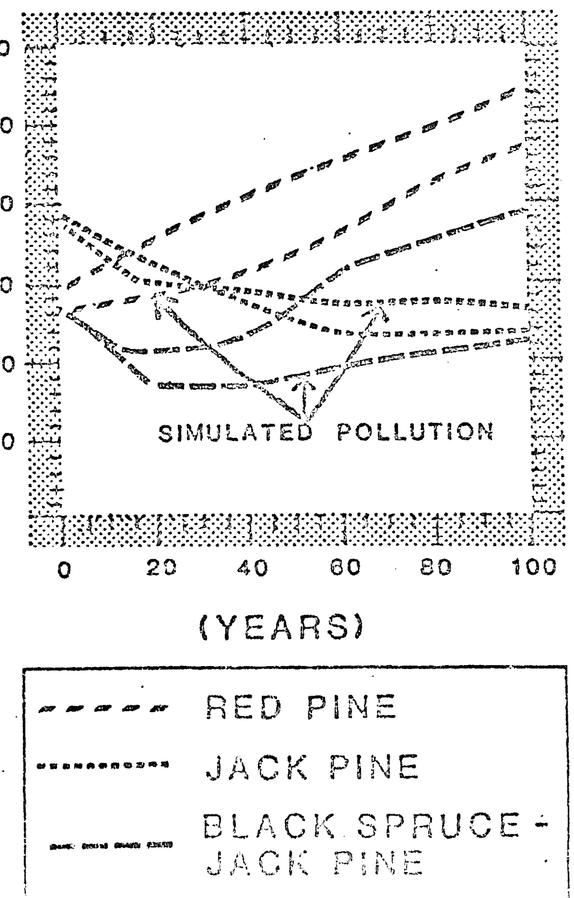
Actual change will be less than what is predicted by this modeling, however, because of limitations in current knowledge, it is not possible to predict the amount of change that would occur but it must be interpolated from known conditions.

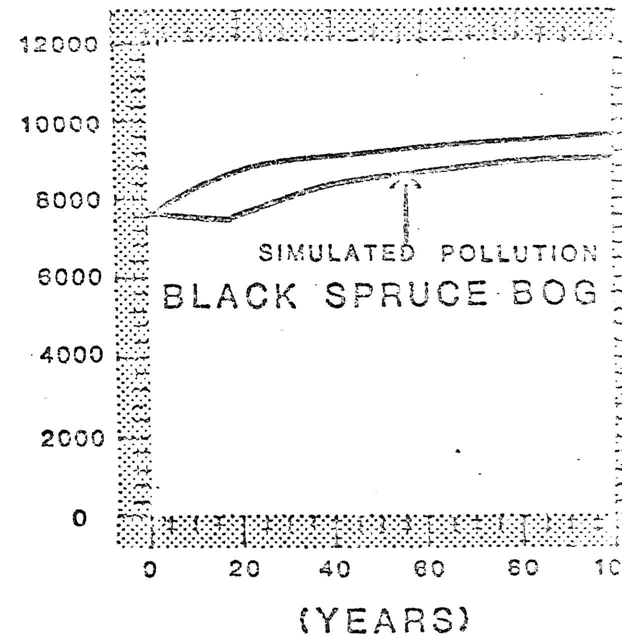
Reclamation includes all potential afteruses of minelands, including industrial, residential, or recreational uses as well as the re-establishment of natural communities. Reforestation may be accomplished on most types of minelands within reasonable periods of time after cessation of mining operations. For example, taconite tailings basins in northeastern Minnesota have been revegetated within 5 to 30 years. Among trees that have proved successful on tailings are paper birch, Russian olive, European larch, jack pine, red pine, mountain ash, white cedar, and a variety of poplars including the three species native to the Study Area.

FIGURE 46. SIMULATED CHANGES IN SUCCESSIONAL PATTERNS BASED ON FOREST MODEL AREA*









* THE MODEL ASSUMES WORST CASE POLLUTION (SEE TEXT)

SOURCE: SLOSS (1978)

In areas where mine wastes are especially high in sulfates or heavy metals, soil preparation is usually necessary to guarantee success of planted species. Usual techniques of soil amelioration include topsoiling, liming, and application of organic matter. Where these techniques have been used, all but the most inhospitable minelands (such as open pits themselves) have proved reclaimable.

Restoration, which reconstitutes the entire original ecosystem including its soils, groundwater, plant and animal species, and nutrient pathways, is a more difficult goal. The ease with which it can be approximated depends, in part, on the type of community to be restored.

Communities which recover easily from natural disturbances, such as fire and wind damage, do so because of several attributes. The constituent species may be resistant to the disturbance, or may possess organs that are protected from the disturbance and have a great capacity for vegetative reproduction, or they may be obliterated from the disturbed area but be particularly adapted to reinvade it. Aspen possesses both the ability to regenerate vegetatively and a tremendous capacity to invade (by seed) new areas. Under the conditions present in areas to be reclaimed, it is the ability to invade, rather than its regenerative capacity, that gives aspen the advantage over other species. Once it is established, its growth rate is rapid. It therefore appears that the aspen-birch community would probably be the easiest natural community to restore on reclaimed lands. On the basis of assumptions (see section 2.3.3.1) used for the Regional Study's forest succession model, restoration of aspen-birch to mature self-sustaining communities can reasonably be expected within 40 to 50 years after cessation of mining.

It is likely that restoration of forest floor species will lag behind that of the canopy because under natural conditions of disturbance the roots of these plants remain undisturbed, whereas they would be destroyed by a mining development. Many native forest floor plants flower and fruit most abundantly under the high light conditions that result from natural disturbance. Therefore, the invasion of these species may be expedited by canopy clearance without disturbance to the forest floor in areas immediately adjacent to reclamation areas. These areas would thereby serve as seed sources for sites being reclaimed, other special efforts to restore the forest floor species in addition to the canopy species may be necessary.

Restoration of communities dominated by shade-tolerant species (generally recognized as more "mature" stages of succession) can be expected to require the full length of time involved in the successional process. Thus, deciduous forests rich in maple or mixed upland conifer forests with their associated groundcover may be expected to require on the order of 80 to 100 years before restoration.

2.8 IMPACTS OF LAND APPROPRIATION

2.8.1 General Discussion of Stress

The stresses associated with mining development can be classified as either:

1) The direct, deliberate, and, to some extent, unavoidable destruction of habitats; or,

2) Indirect and, to a greater extent, avoidable damage caused by noise and toxic pollutants.

The first of these categories is treated in this section, whereas the second is discussed in Sections 2.9, 10, and 11. Of the various impacts that are of most concern, those resulting from direct land appropriation are the most obvious and straightforward with regard to effects. Although direct losses are largely unavoidable, impacts can be minimized by careful planning. Emphasis in this section is given to considerations that are important to terrestrial ecosystems.

Open pit mines permanently remove land from timber production, but proper planning can delay losses. If pit expansion is planned so that mature forests are affected, timber can be harvested prior to excavation activities. Poor planning may require the destruction of trees before they reach marketable size. Areas that will be reclaimed can be returned to productive forest land, and if harvests precede construction, losses will reflect only the duration of the mining operation and the period of time required to establish young stands on the area. Small waste rock piles may be available for reclamation in a few years, whereas mill site locations could not be reclaimed until mining operations cease. Young stands could become established most quickly on completed tailing basins and would take the most time on steep slopes. Economic factors related to land loss that involve reduced timber productivity are discussed in further detail in Volume 5-Chapter 6.

Lands appropriated for mining activity may be: 1) permanently lost; 2) reclaimable; or 3) undisturbed but removed from multiple use.

The most obvious example of land that is permanently lost with respect to its capacity for supporting terrestrial ecosystems is the site of an open pit mine. Once an excavation is begun, there is little likelihood that the landscape will be restored to its former contours. Although abandoned mines may serve as reservoirs or lakes (as has been done with some iron mines in Minnesota), they represent land lost from the terrestrial ecosystem. The filling of large open pits with waste rock or overburden is neither economically feasible nor practical from a land use standpoint.

Based on development models presented in Volume 2-Chapter 5 of this report, it is estimated that approximately 5 to 7 percent of the land (representing the open pit mine) will be permanently lost. Such losses for an underground operation would be minimal because little or no ground subsidence is expected. The remaining land required for a mining, milling, and smelting operation would be potentially reclaimable (see Volume 2-Chapter 2). Waste rock piles would cover about 20 percent of reclaimable lands and would probably be the least amenable to revegetation because of their adverse physical and chemical conditions.

Down and Stocks (1977) cite three factors that influence the impact of a mining operation. These are: 1) size of the operation; 2) geographic and locational factors; and 3) method of mining. The model 20 X 10^6 mtpy open pit mine (see Volume 2-Chapter 5) with a mill and smelter would require 4,146 ha of land, whereas an 12.35 X 10^6 mtpy underground mine would require 2,305 ha (Table 19). These models, developed by the Regional Study, are based on the assumption that ore, lean ore, and waste rock cannot be transported economically beyond three miles and that the length of a tailings pipeline between the mill and the basin would not exceed one mile. These assumptions limit direct land use to the six-mile wide copper-nickel development zones (Figure 37).

Table 19

The geographic location of a proposed mining operation within this belt could affect its impacts on the terrestrial ecosystem. As can be seen from Table 15, habitats are not evenly distributed throughout the seven zones. As is generally the case for conifers in the Study Area as a whole, nearly 60 percent of all jack pine in the development zones is concentrated in the north (zones 1 and 2). But counter to the trend for the Study Area as a whole (Table 14), red pine in the development zones is differentially concentrated in zone 5. An operation within this zone could thus have a significant impact on the total red pine resources of all the zones.

Method of operation significantly affects the amount of land required for mining (Table 19). The 20 X 10^6 mtpy open pit operation discussed above would produce 5 X 10^6 mtpy ore less than two 12.35 X 10^6 mtpy underground mines (each with a mill and smelter) but would require 220 ha more land because of the greater production of waste rock. Similarly, two 11.33 X 10^6 mtpy open pit operations with no mill would produce more ore than the 20 X 10^6 mtpy open pit operation but would require only 7.5 square miles (1,927 ha) because tailings are assumed to be produced elsewhere (although probably still in one of the development zones). Eventual proposals for mining in the Study Area may combine one or more of the above operations and the amount of land lost to mining operations should be a factor in choosing the mixture of mining methods.

2.8.2 Susceptibility of Development Zones to Direct Land Use

Major impacts of direct land use are likely to affect various parts of the Study Area differentially, depending on the properties of the soils, habitat types, and patterns of current land use. Regardless of where development occurs, certain impacts can be expected to affect certain ecosystem components more than others, as is illustrated in Tables 11, 12, and 13. The probability that impacts will occur within given zones (Table 20) depends on siting. Probabilities presented in Table 20 are based on models developed by the Regional Study and may change if development patterns differ from those projected by the models.

Table 20

Mining activities were assumed to be most likely in those areas where the mineral resource is greatest. Following this assumption, projected residential settlement patterns to accompany mining development in zones 1-5 were used to assess the probability of increased human populations (see Volume 5-Chapter 7 for projected settlement patterns). Populations are likely to concentrate in divisions 1, 7A, and 6B (see Figure 45) according to these assumptions. Smelter siting was assumed to follow the constraints discussed in section 2.9.2 and presented in detail in Volume 3-Chapter 3. It was therefore assumed that a smelter could be locted anywhere throughout or outside of the Study Area except in divisions 1 and 7A (because of Class I air standards). Because visible effects of air pollution on vegetation are only expected to occur during breakdown con-

TABLE 20

PROBABILITY OF IMPACTS OCCURRING IN EACH OF THE DEVELOPMENT ZONES*

IMPACT

ZONE	LOCALIZED						REGIONAL				
	DIRECT LAND USE	SEEPAGE	NOISE	HEAVY METAL LOADING	VISIBLE EFFECTS OF AIR POLLUTION ON VEGETATION	SUBTLE EFFECTS OF AIR POLLUTION ON VEGETATION	ACID PRECIPITATION	VISIBLE EFFECTS OF AIR POLLUTION ON VEGETATION	PRESENCE OF INCREASED HUMAN POPULATION	CONFLICT WITH INCREASED HUMAN POPULATION	INCREASED HUNTING PRESSURE
1											
2											
3											
4											
5											
6											
7											

* Probability assessments were made based on the factors discussed in the text on on a zone-by-zone basis, assuming development actually takes place in the zone.

ditions and near a smelter, there is a possibility that such damage could occur within any of the other divisions in the event that a smelter is located nearby.

2.8.2.1 Zone 1--Zone 1 (Figure 38) has the mineral potential for development of either underground or open pit mines (see Volume 3-Chapter 2) and such operations could reasonably be expected to be related to those in zone 2. Both zones lie on the east side of the Birch Lake-Kawishiwi River system and share common properties of the soil, vegetation, and animal communities.

Direct land use impacts of open pit and underground mines are complicated in zone 1 by the fact that 2,090 ha of the zone lie in the BWCA and an additional 2,372 ha drain directly into it. The remaining area includes 306 ha of water with a shoreline area of 590 ha protected by the Shipstead-Newton-Nolan Act. Land actually available for mining is thus reduced to a maximum of 3,980 ha, including lands that drain directly into the BWCA but are not part of it. This area would barely accommodate a 20 million metric ton open pit mine (2,963 ha of direct area). A 16.68 mtpy combination open pit/underground mine or 12.35 mtpy underground mine would reduce the operational area to 2,357 ha or 1,454 ha, respectively, with no allowance for undisturbed forest between various portions of the operation.

This zone is a mosaic of upland deciduous communities, conifer uplands, and lowlands. The deciduous communities contain a high proportion of conifers. Although the zone is dominated by aspen-birch communities (50%), it contains one-third of all the jack pine in the development zones (Table 15). Despite their limited extent, the most uncommon plant communities are the upland mixed black spruce-jack pine and floodplain black ash communities, both near their range limits. The steep slopes and rocky nature of the black spruce-jack pine community provide possible microhabitats for rare ferns and mosses. In general, the conifer uplands are important as habitat for animals of national and statewide interest including marten and fisher whose distributions are confined to the northeastern part of the state. Seven wolf packs with 32 to 63 individuals have territories overlapping zone 1 (Figure 32).

The mosaic nature of the vegetation in zone 1 makes it unlikely that any mining operation can avoid direct use of several habitat types. Because of the small area of wetlands (593 ha), their discontinuous nature, and their proximity to Filson Creek, and Omaday, Bogberry and Nickel Lakes they would probably be unsuitable for tailing disposal. Pine communities in the zone are mainly associated with bedrock ridges. It therefore appears that most direct land use associated with either an underground or open pit mine will impact most heavily on the 3527 ha of upland aspen-birch which is more continuous (Figure 38) and is developed on soils more amenable to earthmoving. Because of the Kawishiwi River on the west, the BWCA on the east, and the chain of lakes and Filson Creek in the heart of the zone, it appears likely that some direct land use from mining would extend south or southeastward of this zone.

Reclamation in zone 1 is likely to be more difficult than in the other zones, partly because of the predominent topographic influence of bedrock features but particularly because of the shallowness of the soils. Calculations based on the Study's 20 X 10^6 mtpy open pit mine model indicate that 1.69 X 10^6 cubic meters of overburden would be required to topsoil stockpiles to a depth of 20 cm and that 2.46 X 10^6 cubic meters would be required to topsoil the tailing basin to a depth of 15 cm (Volume 2-Chapter 2). Average depth of overburden removed during all (open pit) mining processes must be 40 cm in order to obtain sufficient overburden for reclamation without mining and transporting overburden from another area specifically for this purpose. Although average depth to bedrock is not known throughout the zone, depths of less than half a meter have been encountered in the Filson Creek area.

Addition of soil and fertilizer during reclamation would probably convert the area eventually from a scenic and rocky conifer area to aspen-birch uplands similar to those in zone 5.

2.8.2.2 Zone 2--Vegetation in zone 2 is mainly dominated by deciduous stands with a high proportion of conifers (Figure 39). Known mineral resources suggest underground mining as the most likely technology for removal of copper-nickel resources in this zone (Volume 3-Chapter 2). Shorelines of navigable streams from T61 northward in the Superior National Forest are protected from logging by the Shipstead-Newton-Nolan Act. If this protection is interpreted to include direct land use by mining, roughly one-tenth of the zone is protected from direct impacts. The effect of this protection on terrestrial ecosystems is the preservation of habitat for riverine furbearers such as otters and mink. Forest Service Administrative policy currently protects the Keeley Creek Research Natural Area (1 square mile, S14, T61N, R11W) and the South Kawishiwi Special Management Area (campground and research facilities) from commercial use, but these areas are not restricted by legislative mandate (see Volume 5-Chapter 10 for further details). Together with water, these areas remove an additional 1,726 ha from potential mining availability. The 25,482 ha of the zone remaining after all the above exclusions provide adequate area for siting of a 2,036 ha underground mine operation. Zone 2 contains the largest concentration of identified copper-nickel resources (53%), compared to all other zones. If the entire 1.6 X 10^9 metric tons of underground resources (Volume 3-Chapter 2) were eventually exploited, approximately 5,150 ha of land would be covered by mine and mill waste (21 m deep) using the models presented in Volume 2-Chapter 5. This would cover 42 percent of Zone 2.

Areas near the present INCO test site and west of the Keeley Creek Natural Area are dominated by decadent aspen-birch with fir understories which exhibit symptoms of budworm damage. Their only inherent wildlife value lies in their use as a wintering area by deer that are under especially high stress from wolf predation. Development of mines within the 3 km buffer between wolf packs could completely destroy this buffer zone. It is likely that the area would not be reoccupied by deer after cessation of mining because once deer establish traditional use patterns they continue to use them even when new habitat becomes available.

Like zone 1, zone 2 contains a high proportion of communities that are important on a national or statewide scale because of their associated populations of wolves, eagles, osprey, marten and fisher. The zone accounts for 28% of all jack pine and 34% of all spruce-fir within the development zones. Mixed black spruce-jack pine stands are not as well-developed south of zone 2 as they are within the zone. These communities are closely associated with topographic patterns and occur in narrow belts along east and west-facing slopes between pine uplands and conifer lowlands. The habitat has the potential of providing appropriate conditions for rare ferns and mosses because of its rocky, steep topography.

From an economic point of view the mature conifer uplands of the zone are an important asset. Natural stands are presently being harvested, but plantations along Highway 1 generally range from 20 to 40 years of age and may not have reached recommended rotation age if the onset of mining occurs within 30 to 50 years.

Acreage of aspen-birch (5858 ha) and mixed conifer-deciduous (858 ha) communities is sufficient in itself to accommodate all direct land uses associated with a 12.35 X 10^6 mtpy underground mine (Table 15 and 19). These communities are fairly continuous in distribution (Figure 39) and lie near known areas of mineralization.

Reclamation in zone 2 is likely to be affected by some of the problems encountered in zone 1. Shallow soils and bedrock outcrops are common in zone 2, but depth of overburden is unknown at this time. The distribution of natural communities at the time of the General Land Office Survey suggests that soils surrounding Birch Lake are somewhat deeper than those in the eastern part of the zone. Aside from the possible limitation of available overburden, major reclamation considerations in zone 2, as in zone 1, are likely to center around the prevention of seepage into natural waters that drain into the BWCA.

2.8.2.3 Zone 3--The area of zone 3 is small (8,084 ha) with approximately 1,043 ha in land uses directly associated with taconite mining. The belt of copper-nickel mineralization lies within or immediately adjacent to taconite operations. The amount of known copper-nickel mineralization is such that if mining does occur, development of satellite mines in zone 3 with mill and smelter sites elsewhere is the most likely situation, unless more resources are discovered in this area. In this instance, open pits could be expected to be located on lands dominated by aspen-birch forests, (Figure 40) but acreage of deciduous uplands (2942 ha) is not sufficient to accommodate all associated land uses if milling does occur within the zone (Tables 15 and 19). Because of the high hydrolic conductivity of the outwash soils and their low cation exchange capacity it is unlikely that the Dunka outwash plain will be used for either tailing or waste rock disposal, unless economic factors alone prevail. Although a tailings basin could be sealed by the use of fine slimes, water losses from a basin overlying outwash would still create a severe deficit in the water budget.

The 1,862 ha of Dunka outwash accounts for most of the area of black spruce, tamarack, and ash in the zone. Although the mixed conifer bog north of USFS road 424 in the Dunka Outwash Plain was the sole location at which the southern bog lemming was captured during both the 1976 and 1977 field seasons, factors contributing to the presence of this species have not been determined. If there is industrial development of the Dunka Outwash Wetlands it would be well to conduct a complete faunistic and floristic survey to determine whether any species restricted to former glacial lake beds are present. If so, the disjunct distribution of such populations may merit special concern because of their likelihood of being genetic variants.

Although cedar accounts for only 1 percent of the area in zone 3, this figure represents nearly a fourth of all cedar in the development zones. Cedar stands are distributed both in the Dunka wetland and along the drainage of Unnamed Creek which empties into Bob Bay. Although these cedar stands have proven to be a haven for rare or unusual lichens and ferns, they are likely to be increasingly disturbed or destroyed by road building or expansions of the taconite industry.

If a 1½ mile exclusion zone is placed around the taconite belt and the Dunka outwash plain is not considered for mineland uses, siting of waste rock and lean ore piles could reasonably be expected on the mature uplands between USFS road 424 and Birch Lake or on recently harvested uplands south and west of the Stony River. Although red pine in zone 3 accounts for nearly half of all red pine in the development zones much of this pine is at or near maturity and is presently being harvested. A more serious timber loss would be the 1,773 ha of clearcut and young plantation which represents one-fifth of all forests in the development zones expected to reach rotation age in the first half of the next century. Given the physiography of the zone it is likely that these lands will be directly used by the mining industry and that such use will extend eastward beyond the boundaries of the zone.

Aside from mitigation procedures that may be required in advance if the Dunka Outwash Plain is used for mining purposes, reclamation in zone 3 is influenced by factors similar to those in zones 1 and 2.

Average depth-to-bedrock in zone 3 is influenced by the great depth of the outwash body. However, these coarse outwash soils with low cation exchange capacity are unsuitable for topsoiling tailing basins and waste rock piles. Average depth of overburden on the uplands north of the outwash plain is similar to that in zone 2. Sufficient upland overburden should be available for topdressing of waste materials. If such overburden is not available it could possibly be obtained readily from the nearby taconite industry, unless future state reclamation regulations require the use of these materials for taconite minelands reclamation. If the outwash plain is used for tailing or waste rock disposal reclamation could never be expected to return the area to its weakly minerotrophic wetland communities because of changes in hydrology and nutrient status. The area occupied by wetlands might ultimately become revegetated with upland brush or aspen-birch communities.

2.8.2.4 Zone 4--Zone 4 is highly influenced by taconite mining. The nature of mineralization in the zone is such that both underground and open pit mines are possibilities. Portions of the available area are underlain by outwash associated with Glacial Lake Dunka. The coarse outwash materials are particularly permeable and present hydrologic difficulties in isolating potential leachates from the groundwater. For these reasons, areas underlain by outwash may also be excluded from direct land use associated with copper-nickel mining. If areas underlain by outwash are avoided, available acreage within zone 4 would be reduced to 3,256 ha in the eastern one-third of the zone (see Figure 41). Uplands in this area are dominated by aspen stands which are often of open and mixed composition resulting from incomplete harvest and reforestation in the 1930s and 1940s. The patchiness of these habitats encourages high densities of songbirds. Despite the abundance of upland shrubs, deer densities are generally low. Loss of upland habitat within the zone would probably not affect wildlife significantly because large areas of similar habitat are available throughout northern Minnesota, and no species of national or statewide interest are concentrated in the zone.

Wetlands in the zone lie mainly within the Dunka Outwash plain. Should mining proceed on this plain the loss of these wetlands would mean loss of roughly 15% of all habitat for the wetland conifer songbird association within the development zones. The high proportion of the development zone's mixed conifer-deciduous communities (30%) contained in zone 4, reflects the incomplete reforestation of uplands in this zone following logging in the 1940s. Many of the mixed stands are conifer plantations that were not released from deciduous competition. Although these patchy communities support a high diversity of bird species, these species are not without other (in some cases more suitable) preferred habitats.

Roughly one-fifth of zone 4 has been recently harvested or clearcut, accounting for 19% of all such lands in the development zones. Approximately half these lands are located in areas available for copper-nickel mining after all possible exclusions. Direct use of recently planted lands could not be avoided if a 20×10^6 mtpy mine were developed outside the exclusion areas because such a mine would require all remaining acreage in the zone. In the event that no exclusions are made, portions of recently planted areas could be avoided. The mature pine within the area are approaching harvest age and could be harvested before the construction phase.

Reclamation in zone 4 should be as easy as anywhere in the Study Area. The present upland mixed conifer-deciduous communities should probably not be used as a standard for reclamation activities, because they are an example of some of the most poorly managed cutover forests in the area. On the other hand, wetlands in the upper reaches of the Dunka and Partridge rivers are examples of some of the best restocking of harvested spruce bogs.

Depth of overburden in zone 4 should be sufficient for topsoiling of tailing basins and waste rock piles. Several soil associations are present in the zone and overburden could be stockpiled separately to take advantage of soils with higher cation exchange capacity for topsoiling materials rich in heavy metals.

2.8.2.5 Zone 5--Zone 5 is a large zone (11,227 ha) with mineralization that suggests the development of an underground mine. If a 1½ mile buffer zone is allowed outside the ultimate taconite pit limit, 6,674 ha would be available to a copper-nickel development within the zone. Nearly one-fourth of this remaining area is young plantation and clearcut, with almost another quarter in wetlands (Figure 42). A 932 ha tailing basin could not be accommodated entirely within a single wetland outside the taconite buffer area, some upland conifer, deciduous, or young plantation area would be involved. As is the case in zones

4 and 6, lowland conifer communities are those of highest biological value because they foster a unique avian fauna. The zone contains over twice as much area of wetland conifer bogs as any other zone, with several bogs exceeding 40 acres in area. It can be expected that the larger a contiguous wetland the more likely it is to harbor a unique bird community.

Roughly one-tenth of the zone is comprised of clearcut and young plantation. About one-half the 1,136 ha of this habitat are continuous and could probably be avoided if mining activities focus on the 3,774 ha of discontinuous aspen uplands which are probably the habitat of least biological or economic value.

Because of the probability that tailing disposal would affect several of the conifer wetlands in tributaries of the Partridge River, reclamation of these areas would probably result in the conversion of approximately 900 ha of wetlands to upland forest communities (either pine or aspen-birch). Soils of the area are varied and overburden depth is more than sufficient to provide for topdressing of both a tailing basin and waste rock piles.

2.8.2.6 Zone 6--A 20 X 10^6 mtpy open pit mining operation would impact nearly one-third of the area of zone 6. If all areas within $1^1/_2$ mile of the ultimate taconite pit limit are excluded from availablity for copper nickel mining 10,540 acres would be removed, including roughly one-sixth young conifer plantations and two-thirds uplands aspen-birch communities (Figure 43). If the area within the taconite buffer is excluded it would be almost impossible to avoid direct impact to all habitat types. In some cases, it is technically and economically most feasible for a mining operation to utilize lowland areas for tailing disposal because less dike construction is necessary than in uplands. No single lowland system in this zone is large enough to accomodate a 1,620 ha tailing basin without containing the Partridge River within the basin, a situation which a mining company would clearly seek to avoid. With the assumptions made here, it appears that inclusion of the Partridge River and its associated wetlands within the boundaries of an operation would be unavoidable (Figure 43). These wetlands include 17 percent of all spruce bogs in the development zones, and are the most inherently valuable habitat within the zone because of their size and their unique bird community. Almost two-thirds of the eastern 1½ mile band is comprised of recent clearcuts and young plantation that would not reach harvestable age until the end of the first quarter of the next century. Although some direct impact on plantations in the central part of the area could hardly be avoided, concentration of mining activities (other than the mine itself) northwest of the Partridge River would protect the continuous plantations in the eastern mile and one-half of the zone.

Reclamation activities within zone 6 could be affected by the proximity of the zone to Hoyt Lakes and Aurora. Development of recreational or industrial sites may be more likely in zone 6 than in any other zone. Reforestation efforts could be complicated by the higher probability of injury from air pollution in this zone but original establishment of vegetation should be easier than in zones 1-5 because of the predominance of soils with a higher cation exchange capacity in this and zone 7.

2.8.2.7 Zone 7--Open pit or underground mine direct land appropriation in zone 7 would entail approximately 22 percent of the area for a 20 X 10^6 mtpy open pit mine or approximately 10 percent of the area for a 12.35 X 10^6 mtpy underground mine.

Very limited information exists regarding mineral resources in this zone. Based on available information, no mining would occur within the zone. Future exploration activities or information unavailable to the state may identify significant deposits; it is likely that development will occur in other zones before development occurs in zone 7.

Although upland areas may be used for tailing disposal, such use requires the construction of dikes. Whereever possible, lowlands are preferred for tailing disposal. Although several small basins offer the advantage of progressive filling and availability for reclamation, a single large basin offers the advantage of requiring less pipeline. Within zone 7, total area of wetlands (1,165 ha) exceeds the acreage requirements for one tailing basin associated with either an open pit or underground mining operation, but as Figure 44 indicates, wetland areas are generally interrupted. The largest continuous wetlands are conifer bogs surrounding Hush Lake, north of the St. Louis River and in sections 15, 16, 20 and 21 (T58N, R14W) south of the same river. It appears that a 1,620 ha tailing basin associated with an open pit mine would necessarily impact both wetland and upland habitats and that it would be difficult to avoid both habitats if tailing material from an underground mine were contained in a single basin.

Mature conifer stands and recently harvested uplands are mainly concentrated in the eastern and western strips of the zone. Mature stands originated after the Palo-Markham-Aurora fire and range around 40 years of age. Over one-fourth of all mature red pine in the development zones is included in this zone. These pine stands are among the best-managed and most productive in the Study Area and their premature harvest would be a significant timber loss.

Uplands in the central 3 mile band of the zone are dominated by aspen-birch forests which provide preferred habitat for deer, moose, ruffed grouse, and woodcock. In general, populations of these species are higher in the Toimi Drumlin Field (of which zone 7 is a part) than elsewhere in the development zones. However, centers of deer and moose populations appear to lie outside the innermost 3 mile band of the zone where mining activities are likely to be concentrated.

The shrub carrs of zone 7 are generally dominated by alder and many represent an early stage in post-fire succession for this area. These wetlands generally lie in parallel lowlands between drumlins and because of their small size many are likely to be eliminated as part of mining operations. Some may also be used as tailing basins because of the desirability of using drumlins as part of the tailing impoundment dams system. Loss of these communities could have a detrimental effect on woodcock and grouse populations in zone 7. Reclamation in this zone is likely to change its topographic features more than its plant communities. Pioneer forests similar to those in the area should be easy to regenerate on soils with a high cation exchange capacity.

In general, zones in the northern part of the area are dominated by communities of more national importance that are more difficult to regenerate than those in the south. In addition, soils in the north are shallow, more easily eroded, and provide less overburden for topdressing during reclamation. Impacts of direct land use and difficulties in reclamation are therefore anticipated to be greatest in the north and least important in the south. This is summarized in Table 17.

A policy of wise use of resources would suggest that more susceptible and less common habitats should be avoided wherever feasible during the mine development planning process. On a purely "biological" basis, habitats and components are ranked according to their susceptibilities and commonness in Tables 4a and 12. Coniferous uplands and rare habitats, such as cedar, should be avoided whenever possible because of their ecological importance. Wetlands would be more difficult to reclaim than deciduous uplands because of their unique hydrological characteristics. Disturbance of "easily" regenerated deciduous upland communities would probably result in the least long-term ecological damage therefore whenever feasible these areas should be utilized in order to avoid the more sensitive and "important" habitats. These broad guidelines may be useful in initial planning stages but consideration of these factors must be made on a site specific basis. See sections 2.5.3, 2.5.4, and 2.6 of this volume of the report for further discussion of susceptibility and distribution of communities and their components.

2.9 IMPACTS OF AIR POLLUTION

2.9.1 General Discussion of Stress

Of the potential impacts associated with copper-nickel mining and smelting, air pollution effects may extend over a larger geographical area than those associated with land appropriation, noise, and seepage. Smith (1974) identifies three classes of air pollution effects on temperate forested ecosystems:

Class I - low dosage effects where vegetation and soils act as a sink for pollutants.

Class II - subtle detrimental effects caused by moderate dosages and resulting in such symptoms as nutrient deficiencies, reduced photosynthesis, lower growth and/or reproductive rates, and increased incidence of stress-related insect and disease damage.

Class III - severe damage causing acute morbidity and mortality of specific plants, increased erosion, reduced nutrient cycling, and structural simplification of the ecosystem.

Levels of pollutants projected for the Study Area in the presence of copper-nickel mining with a smelter (in addition to projected increases from other sources such as new electric-generating plants) are discussed in Volume 3-Chapter 3. The potential impact of air pollution damage on terrestrial ecosystems can be summarized by the statement that expected normal levels of pollution for the Study Area are all in the range that has been shown to cause class I and class II effects, whereas levels produced under breakdown conditions can be expected to cause class III effects in a narrow band extending between 10 and 20 km. Known stress effects caused by class III damage are summarized in Table 22.

Table 22

The paucity of knowledge about class I and class II effects arises from several sources including the variable responses of individual plant species, the influence of local environmental factors (such as climate and soil type) on pollution effects, the lack of available information on types of damage and threshold levels for many native species, the lack of information on interactions of more than one pollutant, the high levels of exposure used in experimental studies, and the dirth of field studies.

2.9.1.1 Nature and Effects of Particulate Pollutants--Down and Stocks (1977) identify five major air pollutants that are generally associated with mining and smelting: carbon monoxide, hydrocarbons, NO_x, SO_x, and particulates. Of these pollutants, particulates are the most important and widespread air pollutants associated with copper-nickel mining, whereas SO_2 is the major pollutant associated with smelting.

Particulates arise either from point sources (e.g. chimneys, vents, exhaust systems) or non-point sources (e.g. tailing basins, stockpiles, haul roads). Non-point sources may be particularly important to terrestrial ecosystems because they are scattered more broadly on the landscape exposing more area to direct impact. Actual transport distances of particulates vary with particle size and are generally classified into three groups (Down and Stocks 1977):

TABLE 22 KNOWN EFFECTS OF CLASS III DAMAGE TO VEGETATION*

EFFECT \ STRESS	ACID RAIN	ARSENIC	BORON	CADMIUM	CHLORIDE	COBALT	COPPER	FLOURIDES	LEAD	MANGANESE	MERCURY	NICKEL	SODIUM	SULFUR DIOXIDE	ZINC
CHLOROSIS															
LEAF NECROSIS															
DISCOLORATION OF LEAVES															
LEAF WILTING/ DEFOLIATION															
DAMAGE TO ROOTS															
REDUCED BRANCHING															
INHIBITION OF FLOWERING															
DAMAGE TO FRUITING BODIES															
DECREASED GROWTH/YIELD															
RETARDED GERMINATION															
OTHER SYMPTOMS															
TOXICITY RATING (TR)	3	3	1	3	3	1	2	2	3	2	3	3	1	3	2

TR-1-LOW TOXICITY

TR-2-MEDIUM TOXICITY,POTENTIAL PROBLEMS

TR-3-VERY TOXIC,SERIOUS PROBLEMS ASSOCIATED

* SOURCE: Krupa et al. 1977

less than 0.1 micron-diameter - (aerosols), never settle but may combine to form larger particles

0.1-1.0 micron-diameter - particles formed by condensation of vapors and settling over periods of months

greater than 1.0 micron-diameter - particles formed by the abrasion of solids and having definite settling velocities

Smith (1977) emphasizes the scavenging ability of foliage for even sub-micronsized particles, thus suggesting that forested areas have the potential for accumulating large amounts of particulate heavy metals if dust control is not an integral part of a mining operation. The fate of such particulates is more likely deposition on the forest floor than direct uptake by the plants. Deposition may occur by the processes of throughfall (rain washing substances off the leaves to the ground), by stem-flow (water washing substances along the trunk) or by leaf fall. The proportions of particulates reaching the ground by these mechanisms are not well known. Although iron concentrations in through-fall at study plot G21 (adjacent to Erie Mining Company's Dunka Pit) were not significantly higher than at five other study plots sampled for throughfall, they did exhibit elevated levels.

The toxic effects of heavy metals on soil micro-organisms have been recognized for a long time. Metal salts are used as fungicides and investigations into the relative toxicity of various fungicides date from the 19th century. Horsfall (1956) surveyed existing literature and found that fungitoxicity decreased in the following order: Ag-Hg-Cu-Cr-Ni-Pb-Co-Zn-Ca. The fungitoxicity of metals results in reduced decomposition of litter. Ruhling and Tyler (1973) found significant correlations between total heavy metal concentrations (Zn+Cu+Cd+Ni) and reduced CO_2 evolution rates for partially disintegrated spruce needles. Tyler (1975a,b) reports that as copper concentrations increase in excess of 20 ppm, nitrogen mineralization decreases rapidly, although initial levels of 15 to 30 ppm appear to increase nitrogen mineralization, especially in organic soils where copper is often unavailable.

In addition to retarding the cycling of nitrogen, heavy metals (Cu and Zn) decreased phosphatase activity at copper concentrations of 30 to 300 ppm (Tyler, 1975a, 1976a). Because phosphatases are enzymes involved in the breakdown of organic phosphates, reduction of their activity reduces the recycling of the phosphorus. Reduced recycling of nutrients has the eventual effect of slowing tree growth, because the processes of nitrogen mineralization and phosphate breakdown are important steps in the conversion of nutrients from unavailable organic forms (locked up in protein or bone) to forms available for uptake by plants. If nutrients are tied-up in organic compounds, they are as unavailable for direct uptake by plants as if they were not there. There is some evidence that nutrient deficiency may make plants more susceptible to gaseous air pollution (Guderian 1977). If this is the case, the slowed recycling caused by accumulation of particulate heavy metals could have an influence on the forests' ability to resist SO_2 pollution.

Effects of heavy metals on young plants may be direct or indirect. In studies of the direct effects of metals on germination and root elongation, Hutchinson and Whitby (1974) studied soil extracts sampled along transects away from smelters in the Sudbury area. Root elongation of radish, cabbage, lettuce, and tomato was increasingly inhibited by extracts from soils at decreasing distances from the smelters. The results of this work prompted the Copper-Nickel Study to conduct investigations (Olson 1978) into the germination and radical growth of seeds of several Minnesota forest species.

This study found that three heavy metals (Cu, Ni, Co) had no apparent effect, at the concentrations tested, on the germination of the species tested, but radical growth was inversely related to the concentrations of the metals. Experiments with radical growth on filter paper revealed a stimulatory effect from copper and cobalt (both micronutrients) at concentrations less than 5 ppm. Growth was increasingly inhibited at greater concentrations of all three metals. Higher concentrations were required to affect radical growth on mineral soil than on filter paper and on organic soil than mineral soil. Total concentrations of 50 to 500 ppm in mineral soil and 1,000 to 10,000 in organic soil had similar effects on seedling growth for all three metals.

In addition to direct effects on the development of seedlings, slowed decomposition resulting from heavy metal loading may produce deep litter layers that are poor seedbeds for species that require mineral soil for establishment, such as red and jack pine. Studies by Thomas (1965), Jordan (1975), and Whitby and Hutchinson (1974) suggest that near smelting operations heavy metals have a tendency to remain in the humus of the forest floor rather than leaching into the mineral horizons of the soil. In a study in Pennsylvania, Buchauer (1971) found that accumulations of zinc and cadmium caused greater damage to vegetation than did SO_2.

The Regional Study's air pollution modeling suggests that loading of soils by heavy metals is probably the most severe terrestrial impact of air pollution that can be expected from a smelter in northeastern Minnesota. By estimating the loading of metals on the soils of the area at present and projected rates at a distance of 20 km from a smelter, assuming base case emission control (see Volume 2-Chapter 5), operating for 25 years (see Volume 3-Chapter 3 for air modeling details), comparisons were made of the relative potential impact on soils and vegetation types in the mineral resource zone. This model does not account for the effects of additional litter disposition and decomposition, input of metals from weathering sources, and rate of leaching of metals from the litter layer during the 25-year period. This model is totally dependent on the accuracy of loading values and should be used to consider trends but not the magnitude of the problem.

Present loadings for copper, nickel, and iron (the elements with relatively large projected loadings from a smelter) were calculated using Copper-Nickel Study data for forest floor weight and metal concentrations for the litter layer of 4 upland soils and 4 vegetation types. The highest present loadings of copper (kg/ha) are in pine stands on soil association 8.

Reported pH values (SCS) for upland soils reach a maximum of 6.0. These values suggest that heavy metals are probably available for uptake by plants. Cation exchange capacities for soils 7, 8, and 5 (1976 Copper-Nickel Study data) are comparable with each other and range from 15 to 28 millequivalents/100g. No data are available for the cation exchange capacity of soil association 50, but this clay soil may be expected to have a higher cation exchange capacity than the three coarser soils, suggesting that metals should be less available for plant uptake.

For this model, predicted loading of copper is approximately .2 kg/ha/yr (5 kg/ha after 25 years), and of nickel is .03 kg/ha/yr (.7 kg/ha after 25 years) were used. These projected loadings were added to present levels in the soil (see Volume 3-Chapter 1 and first level soils characterization report) to generate projected concentrations after 25 years of smelter operation. There is a strong negative correlation between forest floor litter weight and projected concentration across most communities and soils for both nickel and copper (Figure 47 and 48). Mean projected concentrations of both metals are highest across all vegetation types on soil association 5 (Newfound-Newfound) which predominates in the Toimi Drumlin Field where litter weights are low. Because current loadings of copper are lower under jack pine than red pine on soil association 7 (Toivola-Cloquet) projected loadings would make a greater change in red pine stands. Projected average new concentrations of Cu on this soil are comparable for deciduous and coniferous stands. Projected concentrations of Cu on soil association 8 (Mesaba-Barto) are three times higher in deciduous than coniferous stands. For soil association 5 where projected Cu concentrations are highest, projected mean concentrations for deciduous and white spruce stands are comparable whereas those of pine are almost half as great. The effect of litter weight in the spruce stands is an important factor contributing to the projected similarity between white spruce and deciduous stands. Forest floor litter weight in stand G35 is low because of site preparation (rock raking) which removed all litter before the plantation was established.

Figures 47 & 48

Average projected concentrations for nickel are slightly higher in pine stands than deciduous stands for soil association 7, comparable on soil association 8, and higher in deciduous stands on soil association 5. Projected increases of nickel in the clayey soil type 50 are slightly lower than in comparable vegetation types on the neighboring soil association 5.

Freedman (unpublished research) is studying loadings of heavy metal and litter decomposition along a transect downwind of the Copper Cliff (Ontario) smelter. Copper concentrations predicted by the above model for soils in the Study Area

FIGURE 47

RELATIONSHIP BETWEEN FOREST FLOOR WEIGHT AND PROJECTED COPPER CONCENTRATIONS IN LITTER AT A DISTANCE OF 20 KM FROM A SMELTER AFTER 25 YEARS OF OPERATION

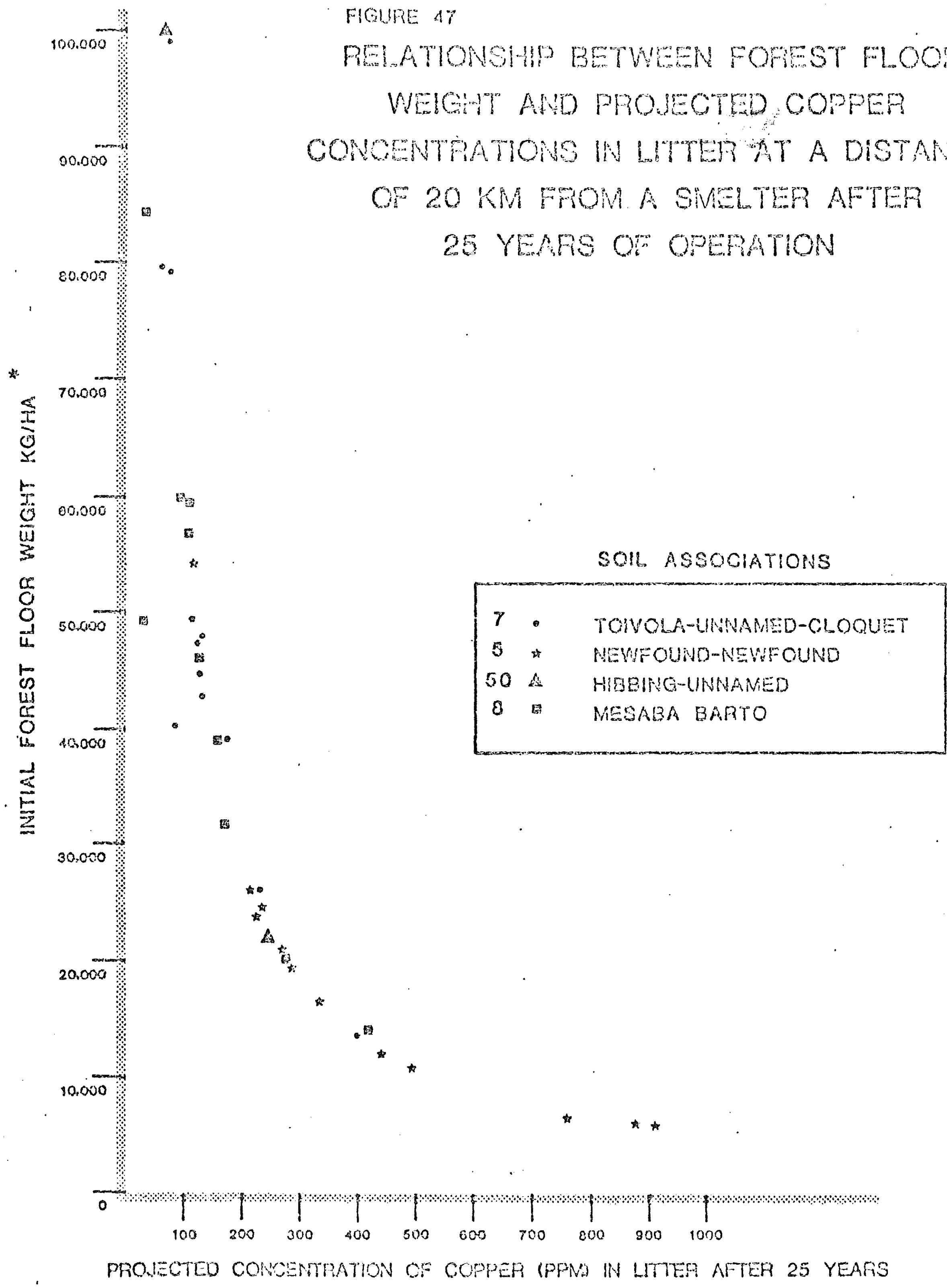
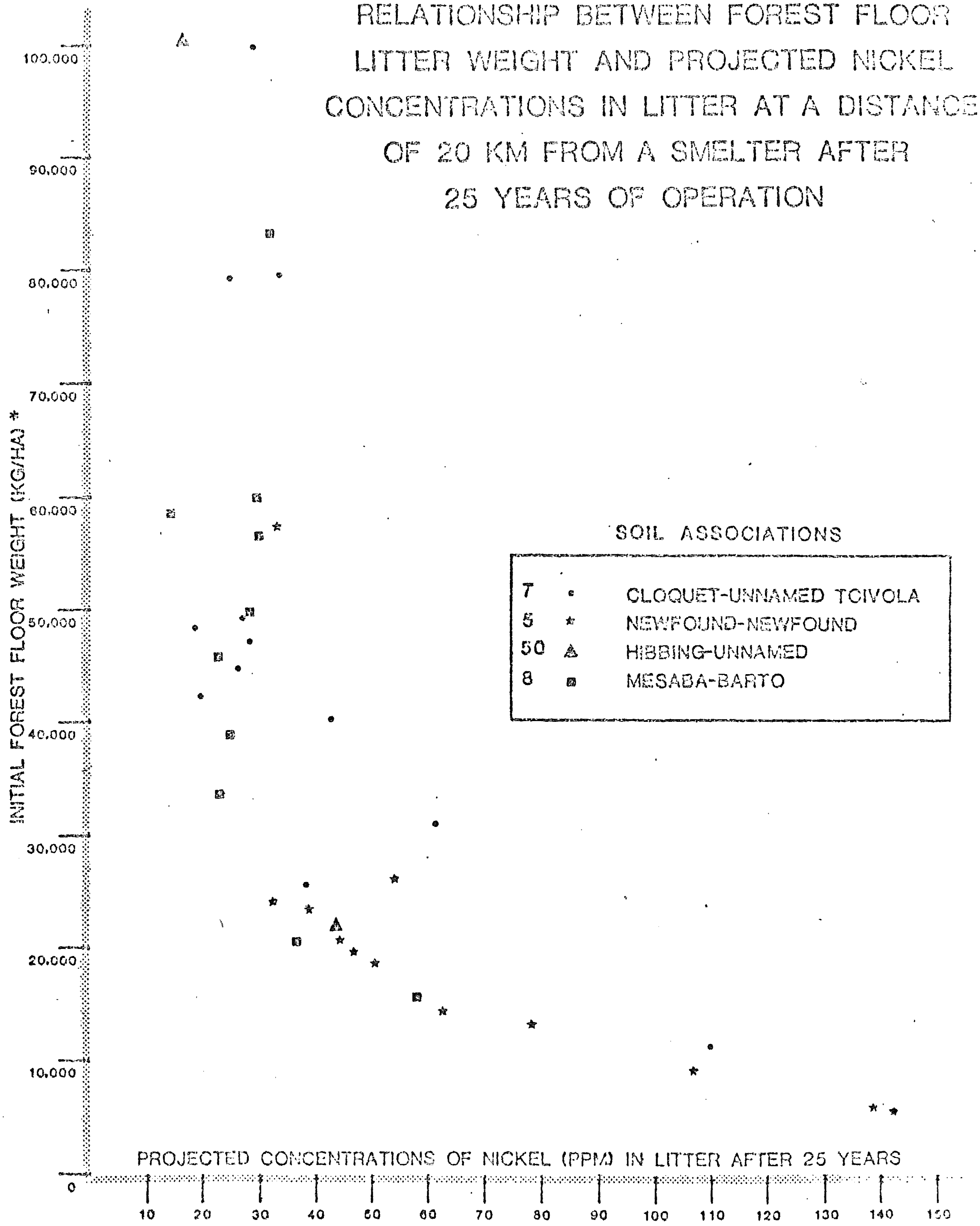


FIGURE 48

RELATIONSHIP BETWEEN FOREST FLOOR LITTER WEIGHT AND PROJECTED NICKEL CONCENTRATIONS IN LITTER AT A DISTANCE OF 20 KM FROM A SMELTER AFTER 25 YEARS OF OPERATION



after 25 years of smelter operation at 20 km generally fall within concentrations comparable to those observed by Freedman approximately 40 km downwind of the Copper Cliff smelter (200 $\pm$ 80 ppm). On soil association 5, which has a lower litter weight, predicted concentrations after 25 years of smelter operation are comparable to values observed by Freedman 30 km downwind of the Copper Cliff smelter (400 $\pm$ 400 ppm). Average predicted nickel values are generally half those observed by Freedman at approximately 40 km from the Copper Cliff smelter (this smelter has a high stack, smelts copper and was first blown in 1888).

Freedman's litter decomposition data have been used to calculate the half-life and 95 percent loss time for decomposition of birch, aspen, and white pine litter (see Soil Decomposition Studies report for further details). These rates can be compared with current rates of decomposition for aspen litter determined by the same litter-bag method in the Study Area. The time required for 95 percent decomposition of aspen litter at 40 km from Copper Cliff is 6.25 years, compared with 4.65 years in the Study Area, suggesting that after 25 years of smelter operation, projected metal loadings in most Study Area soils would reduce litter decomposition rates by roughly 25 percent. On soil type 5, where the concentration would be comparable to that at a distance of 30 km from Copper Cliff, 95 percent decomposition time could be expected to be 6.52 years. It should be noted that these calculations are based on projected levels of metal loading at a distance of 20 km from a smelter. In order to reduce the areal extent of slowed decomposition to within a distance of 2 km of the smelter, the amount of metal from stack sources would need to be reduced to 1/5 to 1/10 the levels predicted by the Regional Study's model. The model does not include fugitive emissions, which also would contribute to loadings. However, with reasonably good housekeeping procedures at the smelter, these contributions are expected to be small.

Because most plantations are managed for pioneer conifer species (such as red and jack pine) that require mineral soil for germination and good seedling survival, the litter layer is usually removed before planting. Those stands with the least initial litter weight can be expected to be most affected by heavy metal loading. The low initial litter weight of young plantations implies that these stands are likely to be the most susceptible to effects of higher heavy metal concentrations. Thus, recycling of nutrients may be reduced more in these most intensively managed stands than in older stands and unmanaged stands with greater initial litter weights.

Once metals reach the litter layer, they are effected by several processes including: leaching to deeper soil horizons, transport in runoff to the aquatic ecosystem, transmutation to other chemical species, binding to organic or other materials and being taken up by plants. The chemical availability of heavy metals for uptake by plants depends on several factors: the form in which the metals occur, the species of plants present, the cation exchange capacity of the soil, and the soil pH. Soils with higher cation exchange capacities, such as organic soil associations 58 (Moose Lake) and 59 (Washkish), can be expected to bind more metals in unavailable form than clay soils, and clay soils more than sandy soils.

Soil pH and buffering capacity vary naturally between soils and under different plant communities. For example, sandy soils under conifers are naturally more acidic than the same soils under some deciduous species. Micronutrient cations such as Fe, Mn, Zn, Cu, B, Mo, Cr, and the toxic Zn, Cd, and Ni are most soluble under acidic conditions. The pH at which metals are readily soluble in water varies with the metal. In Swedish mor (organic) soils, Tyler (1978) found sudden release of Cu at pH values below 3.4 and Pb below 3.5. Less than 10 percent of Cr was released at any pH between 2.8 and 4.2, whereas over 10 percent of Cd, Zn, and Ni was released at 4.2 and over 50 percent at 3.2. Although polluted soils contained more metal at the outset of leaching experiments, Tyler found that they had higher base saturation resulting in more efficient initial neutralization of acid rainfall. The total amount of metal released from polluted and unpolluted soils at the end of Tyler's leaching experiments varied with the metal. More Zn, Cd, Cu, Pb, and V were released from polluted soils whereas greater amounts of Mn, Ni, and Cr were released from unpolluted soils. Tyler estimated the residence time of heavy metals in the two soils. At pH values of 4.2 (most nearly like pH values projected for the Study Area in 1985) residence times of all metals except V were much longer in polluted than unpolluted soils (Table 23). It should be noted that these leaching experiments were conducted with organic soils most likely to bind heavy metals and that no estimates of loading were made for organic soils in the Study Area.

Table 23

2.9.1.2 Nature and Effects of Gaseous Pollutants--Unlike particulates, SO_2 is emitted primarily from stacks of smelters (or as fugitives) during the smelting of sulfide-bearing ores or from coal-burning power plants. Based on models presented in Volume 3-Chapter 3, projected annual ambient levels of SO_2, for the total Study Area in 1985 without a smelter are 2.3 ug/m^3 and 1.1 ug/m^3 above the current level. Addition of a single smelter, with base case emission controls (Volume 2-Chapter 5), would raise the annual concentration to 2.5 ug/m^3.

Table 23. Residence time of heavy metals in Swedish organic soils.

		RESIDENCE TIME IN YEARS	
Metal	pH	Unpolluted Soil	Polluted Soil
Mn	4.2	3	30-40
Zn	4.2	7	9
Cd	4.2	6	20
Ni	4.2	5	15
V	4.2	17	2
Cu	4.2	13	80-120
Co	4.2	20	100-150
Pb	4.2	70-90	200

SOURCE: Tyler (1978).

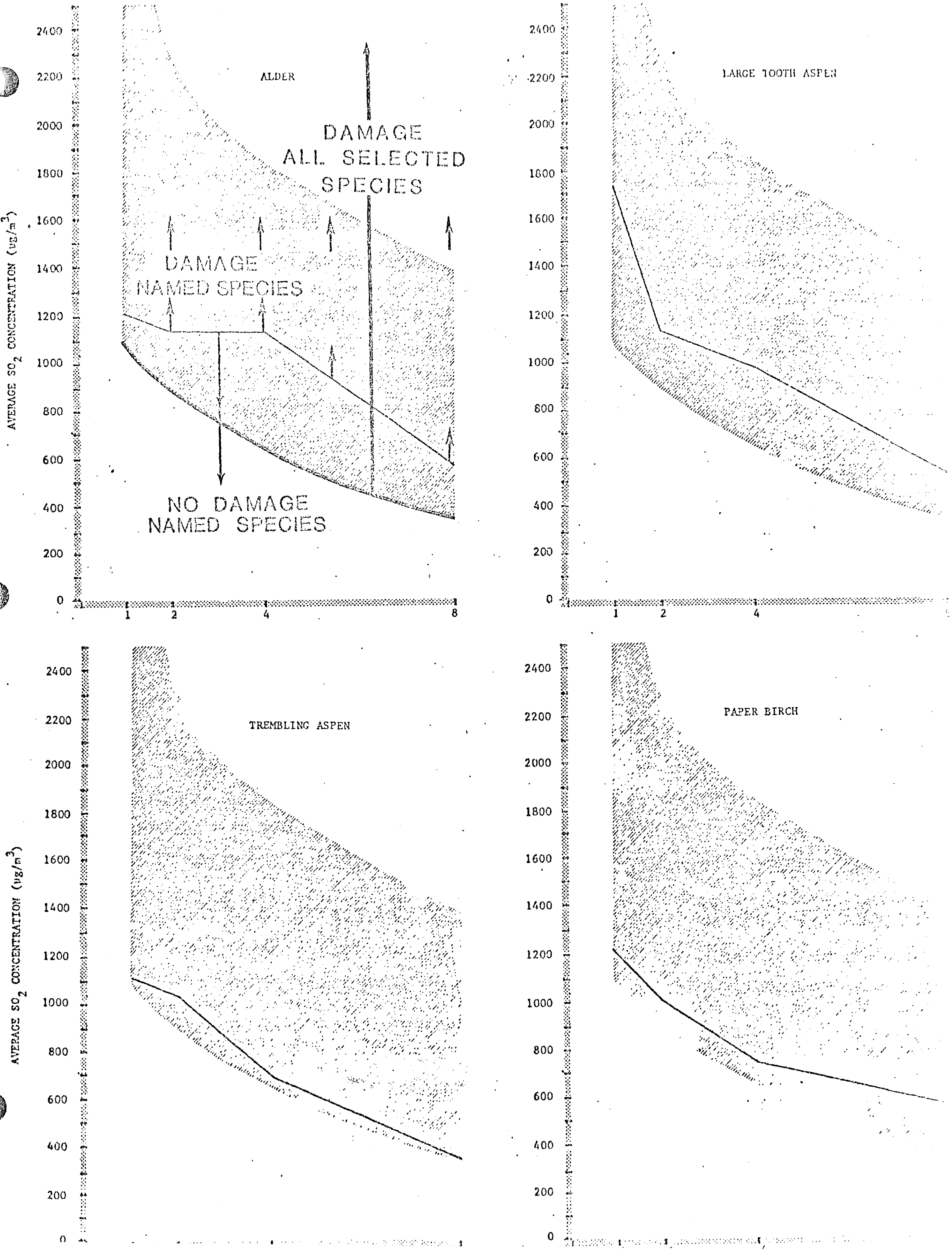
Gaseous pollutants such as SO_2, HF, and NO_x can enter plants directly through the stomata (openings in leaves), causing direct damage to the foliage. The phytotoxicity of SO_2 appears to be about one-half that of equivalent concentrations by volume of HCl and one-eighth that of HF (as measured by accumulation of S, Cl, and F in the plants)(Guderian 1977). In addition to the toxicity of SO_2 itself, the gas combines with oxygen to form the strongly hygroscopic SO_3. The combination of SO_3 with atmospheric moisture produces sulfuric acid, creating "acid rain", which is discussed in greater detail in the following section. The presence of an extensive taconite industry in northeastern Minnesota may especially enhance the probability of acid rainfall, because in the presence of iron or manganese-rich particulates the $SO_2 \longrightarrow SO_3$ reaction is catalyzed, magnifying the effects of the reaction 3 to 4 times (Down and Stocks 1977). Krause and Kaiser (1977) report magnification of direct SO_2 damage in the presence of heavy metals. The influences of concentration and duration have been combined empirically in many studies to show threshold levels of acute injury for many species of agricultural crops, commercial forest species, and ornamentals. Data from Driesinger and McGovern (1970) for the Sudbury region of Ontario were used to estimate the maximum allowable SO_2 concentrations before there is visible damage to several species present in northeastern Minnesota. The results are depicted graphically in Figures 49a-l. Zeyen (1978) has grouped species native to the Study Area as having high, medium, or low sensitivity to SO_2. These ratings, and pollution levels causing damage to each group, are presented in Table 24. As can be seen from this table, resistance to pollution varies a great deal between species. Variations in pollution resistance within species, as documented by Rohmeder et al. (1962, 1965) for European species of pine and spruce, Schonbach et al. (1964) for European larch, and Dochinger et al. (1965a,b) for white pine, provide the basis for breeding programs to produce resistant strains.

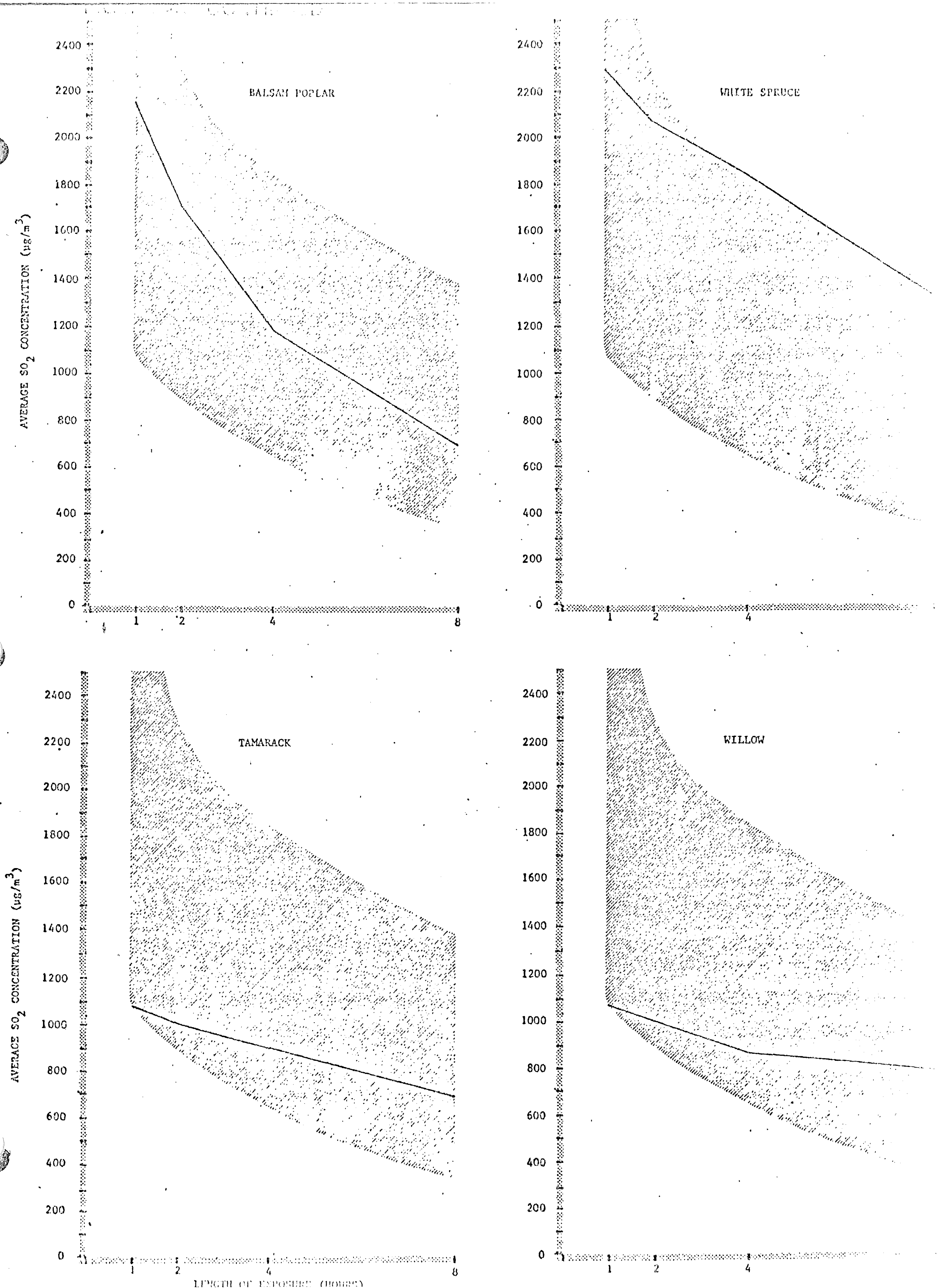
Figures 49a-1, Table 24

The degree of damage to vegetation from gaseous pollutants (especially SO_2) is dependent on several environmental factors. The effects of relative humidity, soil moisture, light, temperature, time of day, and season are all related to the size of stomatal pore opening. In general, the stomatal pores are open to allow evapotranspiration when the plant is actively photosynthesizing. Under dry conditions the pores close to conserve water, explaining the relationship found by several investigations between degree of wilting (Zimmerman and Crocker 1934), soil moisture (Katz 1937; Katz and Ledingham 1937) or water deprivation (Van Haut 1961; Zahn 1963b), and susceptibility to SO_2 damage. Damage was greater when the stomatal pores were open (e.g. under conditions of sufficient moisture or active photosynthesis) and gas exchange could take place. Although NO_2 is taken into the plant by the same gaseous exchange process as SO_2 when the stomatal pores are open, it appears to cause more injury under conditions of low light or darkness. Under full light conditions NO_2 is reduced to ammonia, which can be used by the plant; but under dark conditions toxic levels of nitrite accumulate (Taylor 1973).

Although HF is not expected to be a problem with a copper-nickel smelter, elevated levels are associated with power plants and could be a problem with future power plant development in the area. The degree of uptake of HF does not appear to be related to rate of gas exchange of the plant (Guderian 1977). The stage of development and leaf age have a strong influence on the susceptibility of plants to pollution. Short-lived plants exhibit a strong degree of resistance during early stages of development. Younger leaves are generally more resistant

FIGURE 49 SENSITIVITIES OF SELECTED SPECIES TO SULFUR DIOXIDE BASED ON DRIESINGER AND MCGOVERN 1970




BALSAM POPLAR
WHITE SPRUCE
TAMARACK
WILLOW
AVERAGE SO_2 CONCENTRATION ($\mu g/m^3$)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
1
2
4
8
LENGTH OF EXPOSURE (HOURS)

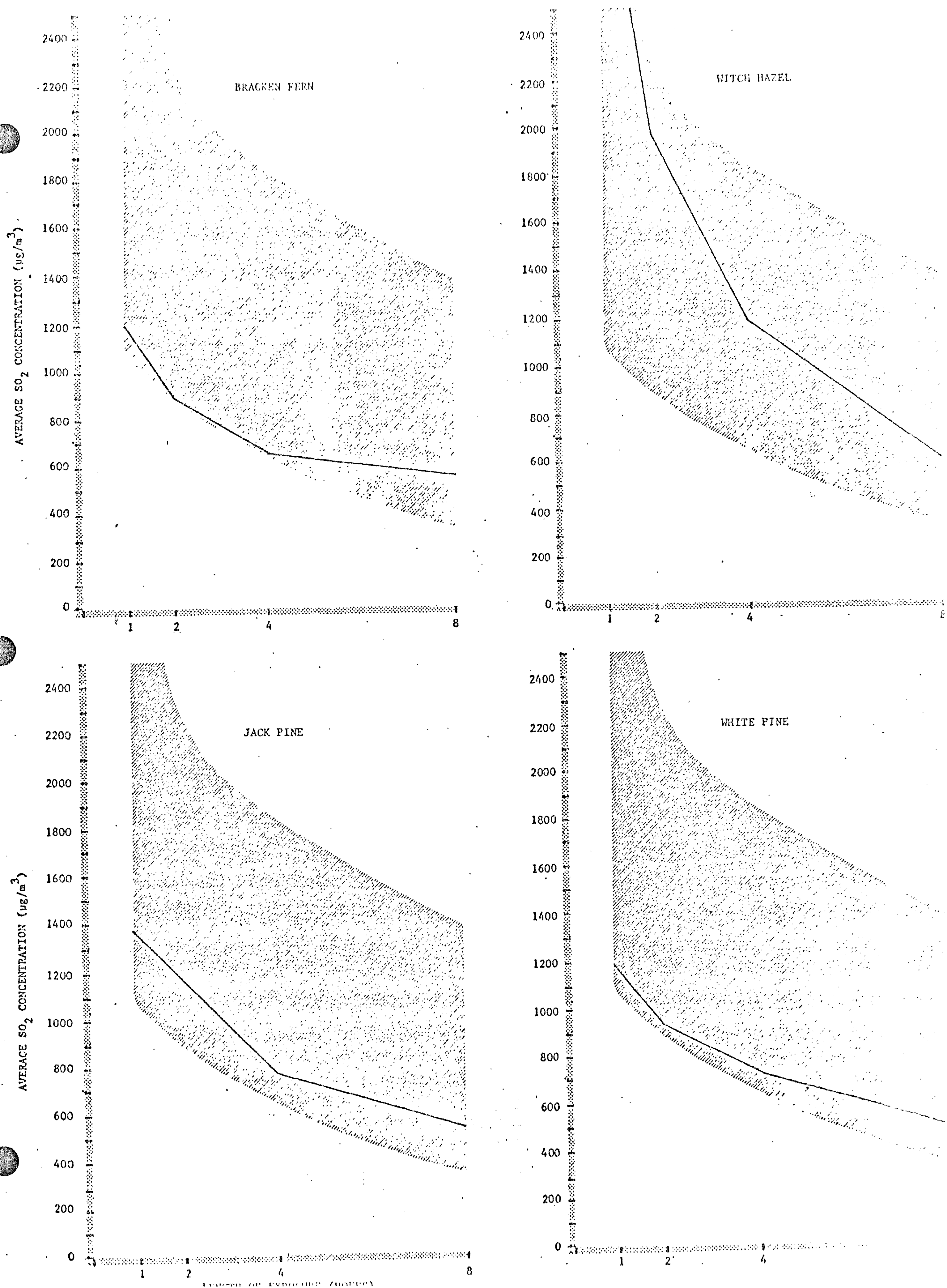

BRACKEN FERN
WITCH HAZEL
JACK PINE
WHITE PINE
AVERAGE SO2 CONCENTRATION (μg/m3)
AVERAGE SO2 CONCENTRATION (μg/m3)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
1
2
4
8

Table 24. Sulfur dioxide concentrations causing threshold Class III injury to various sensitivity groupings of vegetation and sensitivities of Minnesota species.[a,b,c] *

Sensitivities of Minnesota Species

Sensitive	Intermediate	Resistant
Jack pine	Balsam fir	White spruce
Red pine	Balsam poplar	Black spruce
White pine	Basswood	White cedar
Paper birch		Red maple
Black ash		Red oak
Quaking aspen		Bur oak
Bigtooth aspen		

MAXIMUM AVERAGE CONCENTRATION	SENSITIVITY GROUPING Sensitive ug/m^3	Intermediate ug/m^3	Resistant
Peak	2,620 to 3,930 (1.0 to 1.5 ppm)	3,930 to 5,240 (1.5 to 2.0 ppm)	5,240 (2.0 ppm)
1 hr	1,310 to 2,620 (0.5 to 1.0 ppm)	2,620 to 5,240 (1.0 to 2.0 ppm)	5,240 (2.0 ppm)
3 hr	786 to 1,572 (0.3 to 0.6 ppm)	1,572 to 2,096 (0.6 to 0.8 ppm)	2,096 (0.8 ppm)
8 hr	262 to 1,310 (0.1 to 0.5 ppm)	524 to 6,550 (0.20 to 2.5 ppm)	unknown

[a]Peak, 1-hour, and 3-hour concentrations based on observations of visible injury occurring on over 120 species growing in the vicinities of SO_2 sources in the southeastern United States and on other field observations. Adapted from Jones et al. 1974.

[b]Eight-hour concentrations based on Heagle 1973.

[c]Parts per million converted to micrograms per cubic meter (ug/m^3) by the multiplication of ppm X 2,620. Adapted from Stern et al. 1973.

*Source: Zeyen 1978

than leaves in stages of full growth and active photosynthesis (Van Haut 1961; Van Haut and Stratmann 1970). Similarly, sensitivity of conifers is highest, beginning at the late sapling stage and continuing throughout the period of cumulative growth (Guderian 1977).

The relationship between phenological condition (leaf size and age) and pollutant sensitivity to SO_2 has a direct implication for control of pollution injury. Data from Sudbury, Ontario, (Driesinger and McGovern 1970) show that the greatest injury to vegetation resulted from pollution events during midsummer, whereas the same levels of pollution at the beginning and end of the season had little influence on the vegetation.

Models developed by the Regional Study (Volume 3-Chapter 3) indicate SO_2 concentrations of approximately 1,000 to 2,000 ug/m^3 within a distance of 5 km of a smelter if pollution controls failed for a period of 3 hours in midsummer, and concentrations of 500 to 1,000 ug/m^3 at distances up to 8 km. Such levels would be potentially injurious to all major forest species except white spruce (Figures 49a-1). In the months of June and July, around 55 percent of potentially dangerous fumigations in the Sudbury area resulted in injury to vegetation, suggesting that half the accidents occurring during these months could be expected to cause acute injury to vegetation within 10 km of a smelter in the Study Area. Because of changing wind conditions, the probability is low for damage to occur repeatedly in the same area.

No Class III impacts on vegetation are expected to occur during normal operation of a smelting facility. Class I and II impacts on vegetation may occur, but knowledge of these impacts is so limited at the present time that it is not feasible to either predict the extent of potential change or to measure this damage if or when it does occur. Current state air pollution standards are, therefore, expected to provide adequate protection for the terrestrial ecosystems of northeastern Minnesota. At the present time there are no quantitative criteria to be used during breakdown periods to determine compliance with state air quality standards. The standards, therefore, cannot be referenced with respect to ambient concentrations which might be expected to cause damage to vegetation during such upset conditions, and thus cannot be rigorously used to safeguard against vegetation damage (Minnesota State Air Quality Standards and Regulations 1976, Chapter 21).

Topographic setting and structure of the vegetation also influence susceptibility to pollution damage. Damage is more likely on sides of hills facing the smelter and recovery may occur more slowly on xeric southwest-facing slopes which are more susceptible to fire. The combination of fire and air pollution causes severe erosion, as is evidenced in the Sudbury region in Canada and the Copper Hill region in Tennessee, where open roasting of ores at the turn of the century was responsible for the severity and persistence of the degradation. In a study of fluoride uptake, Knabe (1968) points out that different structural layers of the vegetation (canopy, shrubs, and herbs) are subject to different rates of air exchange, resulting in different pollutant accumulation rates for the different forest strata at the same pollutant concentration.

Foliar injury is not always a good measure of the sensitivity of plants to SO_2 damage. Although plants exhibit an ability to recover from low level intermittant fumigations (Guderian 1977), subtle effects at the cellular level, such as changes in the structure of the chloroplasts, result in the reduction of CO_2 assimilation and thence of growth.

Studies by Westman (1974) on Swedish conifer forests, Linzon (1966) on white pine in Ontario, Lathe and McCallum (1939) on British Columbia pine forests, and Kotar (1974) on balsam fir, white spruce, and aspen in Michigan, suggest reduction in growth of conifer species under conditions of chronic exposure to SO_2. In addition to direct injury by SO_2, Jonsson and Sundberg (1972) in Sweden and Cogbill (1976) in New Hampshire and Tennessee have attempted to relate decreased forest growth to acidification. Both studies suggested a decrease in growth but were inconclusive because of uncontrolled variables.

Linzon (1971) related pollution damage to economic loss from depressed growth of white pine near Sudbury. He found growth losses of .1 cu ft/yr per tree in the 7 to 12 inch diameter class. These are higher than can be expected in the Study Area, because white pine is the most susceptible pine species and concentrations in the inner fume zone near Sudbury are higher than those projected for northeastern Minnesota. Tamm and Aronson (1972) report studies near Kvarntorp, Sweden, in which decreases in growth rates of spruce and pine were estimated near an oil-shale plant. Estimated growth reduction of 3 percent at ambient monthly SO_2 concentrations between 39 (.015 ppm) and 52 (.020 ppm) ug/m^3 and 20 percent at concentrations around 79 ug/m^3 (.030 ppm) have been used to estimate losses that might be expected under comparable levels of pollution in northeastern Minnesota (Coffin 1977). In reality, estimated losses of approximately 1.3 cu ft/yr per acre are much higher than can be expected with normal smelter operation, because projected monthly concentrations of SO_2 for the Study Area range around 1 ug/m^3.

Reproductive capacities of red and white pine in New York have been reported to be reduced by monthly sulfation rates as low as 5.73 mg/m^2 (Houston and Dochinger 1977). These sulfation rates are roughly five times as high as projected rates from a single base case model smelter in the Study Area (1.2 mg/m^2 per month). Even at pollution rates sufficient to influence pollination, it is doubtful that reduced reproduction of pines would seriously affect the economic productivity of forests in the Study Area because nearly all plantations are established by aerial seeding or by planting of nursery stock raised outside the area. On the other hand, if reduction of the capacity of sexual reproduction is a widespread effect of SO_2 exposure, it is to be expected that in unmanaged areas the species composition of Study Area forests would shift in favor of those species best able to perpetuate themselves vegetatively (e.g. aspen).

2.9.1.3 Nature and Effects of Acidic Precipitation--Inputs of SO_2 and NO_2 from anthropogenic sources appear to be decreasing the pH of rainfall (below 5.7) in several regions of the world (Likens and Bormann 1974). The acidification of rainfall appears to be a potential problem in the Study Area (Volume 3-Chapters 3 and 4). Acid precipitation may present more of a problem in forested than nonforested ecosystems. Studies in Alberta (Baker, Hocking and Nyborg 1976) and Norway (Abrahamsen, Horntvedt and Tveite 1976) report higher acidity of rainfall intercepted by vegetation than of rainfall in the open. In both cases, acidity of stemflow was even greater than that of throughfall, suggesting that acids from the bark of trees are leached by the acid precipitation. Most areas subjected to acidic precipitation lie downwind (in some cases long distances downwind) of a complex of sources, making it difficult to estimate the possible area of influence of single sources. Nyborg, Crepin, Hocking, and Baker (1976) report as much as 50 kg/ha/yr deposited as far as 20 to 30 km downwind of single emission sources in Alberta.

Tamm and Cowling (1976) review the potential effects of acidic precipitation on vegetation itself (Table 25, from Tamm and Cowling). Their review includes effects on the cellular, organ, and whole plant level. In addition to these effects there are those that operate at the ecosystem level, either through changes to the soils or changes in community composition and function.

Table 25

Knowledge of the acidity of precipitation itself is not sufficient to predict acidity of the soil. Acid precipitation may be neutralized by basic substances present in dust, plant exudates, litter, or soil colloids. The higher the cation exchange capacity of the soil the greater its ability to neutralize acid rainfall. High exchange capacities are characteristic of soils with high proportions of clay minerals or organic substances. Alteration of the chemical properties of soil organic acids by acid precipitation may permanently affect the ability of the soil to recover from acidification (Hutchinson and Whitby 1976).

The release of heavy metals into runoff water discussed in Volume 3-Chapter 4 has been reported not only from experimental studies but from field studies. In addition to the release of toxic metals produced by Sudbury smelters, Hutchinson and Whitby (1976) found increasing concentrations of aluminum in leachate and vegetation along a transect approaching the Coniston smelter in Canada. The aluminum occurs naturally in soil clays and is leached at low pH values, as has been reported near gas works in Alberta (Baker, Hocking and Nyborg 1976) and in soils affected by acid strip-mine runoff in southeastern Ohio (Cribben and Sanachetti 1976). Because available aluminum is toxic to vegetation, there is a danger of heavy metal toxicity even in areas where there is no metal pollution if soil acidities reach pH values around 3.0.

Table 25. Potential effects of acidic precipitation on vegetation (from Tamm and Cowling 1976).

Direct Effects

1) Damage to protective surface structures such as cuticle

Damage to surface structures may occur due to accelerated erosion of the cuticular layer that protects most foliar organs. It also could result from direct injury to surface cells by high concentrations of sulfuric acid and other harmful substances that are concentrated by evaporation or adherence of soot particles on plant surfaces.

2) Interference with normal functioning of guard cells

Malfunction of guard cells will lead to loss of control of stomata and thus altered rates of transpiration and gas-exchange processes and possibly increased susceptibility to penetration by epiphytic plant pathogens.

3) Poisoning of plant cells after diffusion of acidic substances through stomata or cuticle

This could lead to development of deep necrotic or senescent spots on foliar organs including leaves, flowers, twigs, and branches.

4) Disturbance of normal metabolism or growth processes without necrosis of plant cells

Such disturbances may lead to decreased photosynthetic efficiency, altered intermediary metabolism, as well as abnormal development or premature senescence of leaves or other organs.

5) Alteration of leaf- and root-exudation processes

Such alterations may lead to changes in populations of phyllosphere and rhizosphere microflora and microfauna, including nitrogen-fixing organisms.

6) Interference with reproduction processes

Such interference may be achieved by decreasing the viability of pollen, interference with fertilization, decreased fruit or seed production, decreased germinability of seeds, etc.

7) Synergistic interaction with other environmental stress factors

Such reinforcing interactions may occur with gaseous sulfur dioxide, ozone, fluoride, soot particles, and other air pollutants as well as drought, flooding, etc.

Table 25 continued.

Indirect Effects

1) Accelerated leaching of substances from foliar organs

Damage to cuticle and surface cells may lead to accelerated leaching of mineral elements and organic substances from leaves, twigs, branches, and stems.

2) Increased susceptibility to drought and other environmental stress factors

Erosion of cuticle, interference with normal functioning of guard cells, and direct injury to surface cells may lead to increased evapotranspiration from foliar organs and vulnerability to drought, air pollutants, and other environmental stress factors.

3) Alteration of symbiotic associations

Changes in leaf- and root-exudation processes and accelerated leaching of organic and inorganic substances from plants may affect the formation, development, balance, and function of symbiotic associations such as mycorrhizae, nitrogen-fixing organisms, lichens, etc.

4) Alteration of host-parasite interactions

Resistance and/or susceptibility to biotic pathogens and parasites may be altered by predisposing plants to increased susceptibility, altering host capacity to tolerate disease, altering pathogen virulence, etc. The effects of acidic precipitation may vary with: the nature of the pathogen involved (whether a fungus, bacterium, mycoplasma, virus, nematode, parasitic seed plant, or multiple-pathogen complex); the species, age, and physiological status of the host; and the stage in the disease cycle in which the acidic stress is applied--for example, acidic rain might decrease the infective capacity of bacteria before infection and increase the susceptibility of the host to disease development after infection.

The process of nitrification may be depressed by acid precipitation (Abrahamsen, Horntvedt and Tveite 1976). The importance of reduced nitrification in forest ecosystems is de-emphasized by Tamm (1976) who notes that retention of N in ammonia form may help retain it within the ecosystem instead of losing soluble nitrates in runoff and surface groundwater. Within the Study Area, it is likely that decreased nitrification would be most important in ombrotrophic bogs, the community in which nitrogen is probably most limiting. The distribution of the pitcher plant and sundew may perhaps serve as an indicator of susceptible communities. In addition to decreased nitrification, acid precipitation may result in a loss of nutrients such as Ca and Mg through increased leaching. Although a portion of the leachate is likely to leave the system as runoff, another portion is likely to be leached to deeper soil horizons where nutrients would be less available for herb roots but more available to tree roots.

Few studies have attempted to relate acid precipitation to community characteristics. Changes in species composition near centers of pollution such as Sudbury are the result of the differing susceptibilities of species to a complex of pollutants. In an effort to detect community properties related to soil acidity, Cribben and Sanachetti (1976) studied riverbottom communities in southeastern Ohio where acid runoff from strip mines has affected soil acidity. They report lower species diversity, equibility and "productivity" (measured by basal area) in black birch communities on more acid soils with higher available aluminum. The direct causal relationship between acid precipitation and reduced productivity measured by growth remains to be demonstrated conclusively. Jonsson and Sundburg (1972) report lower forest productivities in areas of Sweden more susceptible to acid precipitation and "have found no reason for attributing the reduction in growth to any cause other than acidification." On the other hand, Norwegian and American investigators have failed to detect differences in diameter growth that can be related to acid rainfall (Abrahamsen, Horntvedt and Tveite 1976; Cogbill 1976).

2.9.2 Susceptibility of Zones to Air Pollution Impacts

Direct impacts caused by air pollution are not expected to range far from the smelter. For this reason, only the development zones are considered in this discussion of susceptibility. In as much as air pollution impacts on vegetation and soils are expected to be related more to the presence of a smelter than to the mining operation itself, these impacts are likely to be restricted to the zones within which a smelter is located. The siting of a smelter is very flexible in contrast to a mine. Strictly considering operating requirements, a smelter could be located anywhere in the Study Area, Minnesota, or where it is economically feasible to transport the concentrate. The following analysis of impacts is limited to the development zones, but could be applied to much larger regions (e.g. Study Area, Arrowhead Region) using the source approach. The Regional Study's model suggests that no smelter using the control technology presently utilized on new domestic smelters could be located in zone 1 without violating Class I, no significant deterioration air quality standards. Within zones 2 and 3 a model smelter based on the best state-of-the-art control technology would likely not violate the class I standards of the BWCA, assuming normal operation. On the other hand, a smelter that simply meets New Source Performance Standards (NSPS) could probably not be located nearer than zones 5, 6, and 7 without violating the BWCA's class I standards. (This analysis as it relates to violations of PSD Class I standards for the BWCA, assumes no contribution from other sources in the PSD increment analysis presented in Volume 3-Chapter 3, indicates that existing and expected future regional SO_2 emissions will result in two-fold exceedance of the Class I increment in the BWCA without a smelter in the region. This situation could foreclose the option of siting a smelter in the Study Area.)

Although the influence of a smelter on air quality standards may extend through several zones, projected levels of emission from all sources do not suggest that potentially injurious fumigations will extent beyond a radius of about 5-10 km from the smelter. Under normal operating conditions, no visible injury is expected even within this zone. However, under midsummer conditions of a worst case breakdown, a single incident may damage several hundred hectares. It is likely that vegetatively reproducing species such as aspen have a greater overall capacity for recovery from such infrequent fumigations, so that long-term injury to vegetation is likely to be less in zones dominated by aspen (zones 1, 2, 6, and 7).

As discussed earlier, a modification of the Regional Study's forest succession model presents an exaggerated vision of possible successional trends under the influence of injurious levels of pollution similar to those at Sudbury, Ontario. Figure 46 illustrates expected changes in community type over 100 years, with the smelter operating for the first 20 years. The change in area of a community type does not imply the death of every individual of the dominant species, but that a sufficient thinning of canopy occurs to result in reclassification of the area on aerial photographs.

During smelting, damage to sensitive species, such as pines and aspen, is likely to result in a reduction of the area classified as these community-types and an increase in area classified as upland brush. After cessation of smelting, normal successional processes and management practices will again become the controlling factors in determining forest types in the region. Normal successional processes are likely to result in increasing acreages of mature communities (such as mixed conifer-deciduous). Management would result in conversion of such mixed communities and upland brush into commercially valuable species (pines and aspen) near the end of the 100-year period. Because the model assumes pollution levels equivalent to those at Sudbury, it should not be taken as a true projection of succession but rather as a suggestion of the possible direction of successional trends (see sections 2.3.3.1 and 2.7.

In addition to potential restrictions on the siting of a smelter in the Study Area and differential susceptibilities of the dominant vegetation, the susceptibility of undisturbed areas in any given zone depends on soil attributes. Deeper soils with higher cation exchange capacities, such as those found in the southern part of the direct impact belt, should prove less susceptible than shallow soils with low exchange capacities. Soils with a thicker forest floor layer should suffer less impact from heavy metal loading than those with thin humus layers such as the Newfound soil type. Table 26 illustrates the relative susceptibility of the seven development zones to air pollution impacts, based on the important attributes in each zone and secondly the susceptibility of the zone to certain types of impacts.

Table 26

2.9.2.1 Zone 1--Although both the vegetation and soils of zone 1 suggest that the zone is highly susceptible to air pollution damage, siting of a smelter within the zone would likely violate class I air quality standards in the BWCA. Therefore, the zone is probably protected from potential direct air pollution damage.

TABLE 26 SUSCEPTIBILITY OF DEVELOPMENT ZONES TO AIR POLLUTION IMPACTS

ZONES			1	2	3	4	5	6	7
ZONE ATTRIBUTES	SOILS	THIN LITTER							
		LOW CATION EXCHANGE CAPACITY							
		COARSE TEXTURE							
	PLANTS	SENSITIVE SPECIES							
IMPACTS		HEAVY METAL LOADING							
		CLASS III SO_2 DAMAGE							
		CLASS I AND II SO_2 DAMAGE							
		ACID RAIN							

MORE SUSCEPTIBLE   LESS SUSCEPTIBLE

SUSCEPTIBILITY TO IMPACTS IS BASED ON ZONE ATTRIBUTES. THE TABLE ASSUMES THAT SO2 DAMAGE ARISES FROM A SMELTER LOCATED WITHIN THE ZONE IN QUESTION AND THAT ACID RAINFALL IS REGIONAL IN DISTRIBUTION.

2.9.2.2 Zone 2--Zone 2 shares the natural susceptibility of zone 1. Again, the proximity to the BWCA, and the extreme emission control requirements this would likely place on a smelter all suggest that siting decisions will make it unlikely that air pollution will have a major impact on the vegetation and soils of this zone.

2.9.2.3 Zone 3--Should a smelter be developed within zone 3, the potential of soil acidification on sandy outwash soils is high. Acidification is most likely to affect soils of low buffering capacity such as those found on conifer stands with outwash soils. Overrein (1972) reports leaching of nutrients, and Likens and Bormann (1974) reports reduced forest growth in Sweden as a result of acidification. Slowed decomposition, whether from acidification or heavy metal loading, has the effect of reducing forest growth. Such a reduction has an especially high impact in areas like zone 3, which contains roughly 20 percent of the young plantation and clearcut within the development zones.

Catalysis of the $SO_2 \dashrightarrow SO_3$ reaction by ferrous particulates could be expected to occur in this zone because of the highly developed taconite industry on its western edge. Combined with the ecosystem properties discussed above, the increased rate of acidification may make this zone the most susceptible to air pollution impacts.

2.9.2.4 Zone 4--Potential impacts of air pollution in zone 4 are similar to those in zone 3. The proportion of the development zones in plantations and in taconite operations is comparable for the two zones. Portions of the zone on outwash soils could be especially susceptible to both acidification and heavy metal loading. The open, discontinuous canopy of much of the upland aspen area within this zone lends itself to a higher natural incidence of the shoestring root-rot fungus (Armillarea mellea) which rises in incidence when host trees (aspen and pine) are under any condition of stress, including pollution.

2.9.2.5 Zone 5--About 20 percent of the soils in zone 5 are likely to be relatively susceptible to acidification and heavy metal loading. The proximity and extent of taconite operations within the zone is less than in zones 3 and 4, but the probability of catalysis of the $SO_2 \rightarrow SO_3$ reaction by ferrous particulates is still high.

2.9.2.6 Zone 6--Although soils in zone 6 have a high buffering capacity, their thin forest floor layer may make them especially susceptible to heavy-metal loading. At present, this zone is the only part of the development zones exhibiting elevated levels of HF, probably associated with the presence of a power plant (Krupa 1977). These elevated levels suggest the possibility of multiple effects of pollution from HF and SO_2. Although the effects of this combination of pollutants on forests similar to those of the Study Area are unknown, their effect on vash soils could be especially susceptible to both acidification and heavy metal loading. The open, discontinuous canopy of much of the upland aspen area within this zone lends itself to a higher natural incidence of the shoestring root-rot fungus (Armillarea mellea) which rises in incidence when host trees (aspen and pine) are under any condition of stress, including pollution.

2.9.2.7 Zone 7--Zone 7 is underlain predominantly by Newfound soils, whose thin forest floor layer makes them especially susceptible to heavy metal loading. In addition to the effect of the soil itself, large portions of the zone were burned in the Palo-Markham-Aurora fire, which reduced the litter layer. Although the acreage of susceptible young conifer plantations is less than in zone 6, large areas of aspen and birch are now being harvested. If these areas are converted to pine, the total acreage of susceptible species in the zone will be increased.

2.9.3 Mitigation and Reclamation

Little can be done to reclaim areas that have been affected by widespread chronic air pollution. Damage may not even be visible but may take the form of depressed growth. Liming is only effective in mitigating soil acidification if it can be mixed into the upper soil horizons. It, therefore, appears that the best corrective measure with regard to air pollution is prevention. Siting of smelters away from young, sensitive conifer plantations and in areas having soils with a high cation exchange capacity can reduce potential impacts. On the basis of the Study's models and literature review, it appears that heavy metal loading of soils poses the greatest potential threat because of its effect on forest growth. Reduction of the modeled levels of metal particulates emitted from all sources to 1/5 to 1/10 of the modeled rates could restrict the areal extent of damage from heavy metal loading to the smelter site and its immediate environs. Management of areas immediately adjacent to a smelter for resistant (white spruce) or rapidly regenerative species (aspen) could reduce the impact of accidental fumigations.

In summary, communities in the northern two zones are most susceptible to air pollution because of properties of their soils and vegetation, but the class I air quality standards in the BWCA afford some protection from smelter development in zones 1 and 2. Zone 3 is the most likely to suffer from air pollution because of the combination of susceptible soils and vegetation with the presence of ferrous particulates, which increase the possibility of acidification. Zones 4 through 6 are most likely to see smelter development, if such development occurs in the Study Area. Zone 6 is most likely to be affected by serious pollution problems because of elevated HF levels from power plants and proximity to urban centers. Of these zones, zone 4 is the most susceptible to acidification and undisturbed areas of zone 6 to heavy metal loading. Zone 7 is probably least susceptible. Although soils are susceptible to heavy metal loading, they have a high cation exchange capacity, communities are easily regenerated, and and in zone 7 ferrous particulates are not expected to be present in significant quantities.

2.10 IMPACTS OF SEEPAGE FROM MINING WASTES

2.10.1 General Discussion of Stress

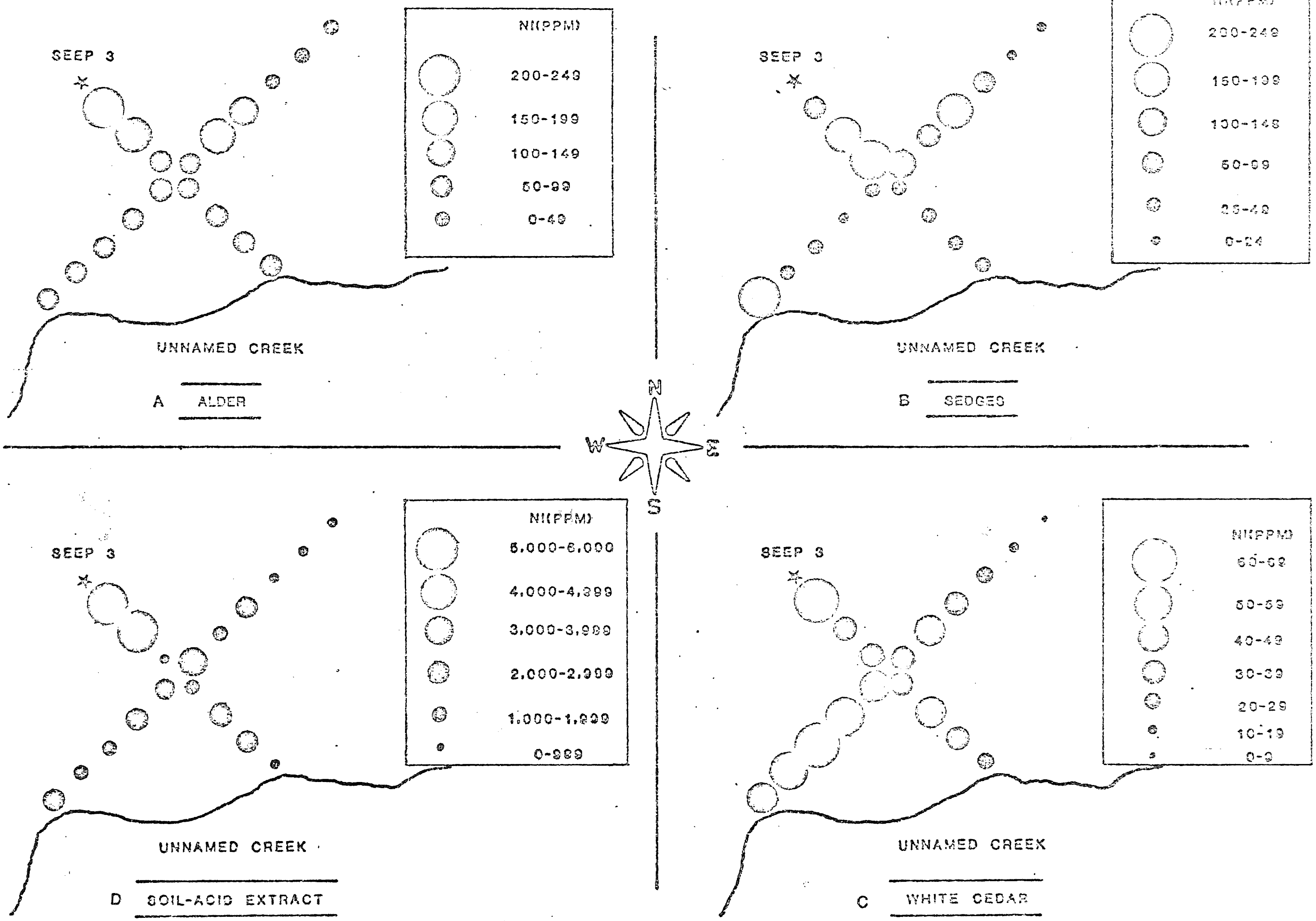
This section considers the problems associated with the release of toxic materials from the by-products of mining and smelting operations (i.e. tailings, wasterock, lean ore, and slag). Although the area affected by pollutants from these materials is not as large as, for example, that affected by air pollutants, seepage problems are important to terrestrial ecosystems. Impacts may be either internal (i.e. within the waste materials themselves) or external (e.g. as might result from the leakage of heavy-metals-containing groundwater into lowland ecosystems). Problems generated by internal factors may initially be the most obvious, because they often affect efforts to establish vegetation on materials that lack an existing plant cover. In these situations, chemical factors interact with harsh physical environments to make revegetation difficult. Leakage problems are perhaps more insidious, however, both because they affect already established ecosystems and because they have the potential for contaminating much larger areas (as when leachates enter aquatic ecosystems).

External seepage problems arise when waste materials are located in such a way that leachates from them contaminate the surface waters of lowland ecosystems. Because of the large number of bogs in the Study Area, it is unlikely that large areas free of lowlands can be located and utilized for waste disposal. For example, one storage site is currently located near a white cedar stand adjacent to the Erie Mining Company's Dunka Pit. An examination of leaching problems associated with this large stockpile provides an excellent preview of possible situations that might arise elsewhere (see Volume 3-Chapter 4 for further details).

Heavy-metal-containing leachates were first observed here at a groundwater seep (Seep 3) in 1975. During the summer of 1976, Study personnel who were investigating the leaching problem observed that plant life in a bog near Seep 3 was undergoing stress. The foliage of several plant species appeared chlorotic and in ill health. During 1977, samples of vegetation were taken for chemical analysis. Elevated levels of nickel were observed in the foliage of white cedar, speckled alder, and sedge. Transects that bisected the area in N-S and E-W directions show that tissue levels are highest near the origin of the groundwater seep (Figures 50a-c). The results of soils analyses in this area also show high nickel values at stations close to the seep (Figure 50d). It appears that uptake by soils is restricted to the surface layers of the peat, which are exposed to flow. Uptake is a progressive phenomenon extending concentrically downstream from the locus of contamination as exchange sites in nearer soils are filled. Because most bog plants are shallowly rooted, it is probable that they will be affected mainly by the chemistry of the top 30 cm of peat. Foliar nickel concentrations were typically 30 to 60 ppm and reached a maximum value of 239 ppm for alder at the sampling station closest to the stockpile. Nickel concentrations in leaf samples collected at a control site 500 m away averaged 11 ppm. Foliar analysis for elements other than nickel (Cu, Zn, Ca, Mg, and Fe) showed that only iron occurred at levels that were consistently higher at Seep 3. In addition to the tree, shrub, and herb samples, lichens from selected stations were analyzed for Pb, Fe, Cu, S, and Ni content. As with the higher plants, only iron and nickel values were higher than background levels (as reported for lichens by Nieboer et al. 1978, Laurentian University, personal communication).

Figures 50a-d

FIGURE 50 NICKEL CONTENT ALONG TRANSECTS AT SEEP 3



The high concentrations observed in tissues of plants at Seep 3 suggest that nickel is the most labile of the elements studied. Copper, for example, is high in water draining from the stockpile but not in the foliage. This suggests that copper may be bound by the organic soils of the bog and is unavailable to plants. Alternatively, copper may be absorbed by roots but not translocated to the foliage. In either instance, copper remains inaccessible to herbivores and thus does not enter the food chain (although some copper may be taken-up by animals that take water from the bog). Nickel, by contrast, is translocated to the foliage where concentrations exceed the 50 ppm level that is often considered to be phytotoxic (Krupa 1977). The high nickel content of lichens, which receive few minerals from their substrate, suggests that this element is cycled in throughfall, and studies detailed in Volume 4-Chapter 1 indicate that nickel is transported beyond Seep 3 and is being concentrated in the sediments and macrophytes of Bob Bay in Birch Lake.

The studies at Seep 3 do not conclusively prove that nickel is causing the disease symptoms observed in the bog, but foliar concentrations are much higher than those observed elsewhere in the Study Area, and the results certainly suggest that nickel is a potentially serious phytotoxic pollutant associated with copper-nickel mining wastes. More research into this possibility is clearly warranted and should receive high priority in the event that an actual mining development is proposed.

Although other metals do not appear to be causing problems at Seep 3, they might in situations where soils are more acid. The soils of white cedar bogs are generally nutrient-rich and well buffered. Water flowing through the bog has a pH of 5.5 to 6.9 and values in areas where heavy metals concentrations are highest are 6.0 or higher. Thus, the acid-metal interaction discussed earlier does not appear to present problems for plants. Many bogs in the Study Area are much more acid, however, with soils of the Greenwood soil series having values of 4.0 to 5.0. If acid bogs received heavy-metal-contaminated runoff, additional problems might arise. Most metals are more labile under acid conditions, and the greater availability of heavy metals could combine with higher acidity to produce a more toxic chemical environment. Seep 3 may represent an example of the least susceptible type of wetland, and the results presented above should be applied with caution to other areas, since these might be affected more drastically by seepage from stockpiles.

Waste pile seepage will be primarily a post-operational problem because during operation seepage can be collected and recycled. Once the mill is shut down, there is no longer a use for this contaminated water and it would either become a non-point source of water pollution, be treated, or some method found to eliminate the discharge altogether (no methods to eliminate such waste are presently known).

2.10.2 Susceptibility of Development Zones

As is the case with direct land use, vegetation damage caused by seepage is expected to be restricted to the development zones. Because of the proximity of the BWCA, seepage of toxic materials is of greatest concern in zone 1, but is generally of concern in all areas north of the Laurentian Divide (zones 1, 2, 3, and part of 4). Soils of these zones generally have lower cation exchange capacities and less ability to bind any metals being transported in surface runoff from uplands to wetlands.

Flow is generally confined to the top half-meter of peat, but actual depths were not measured for wetlands of various types in different geographic areas. Until the depth of surface water flow and pH of bog waters is known for wetlands throughout the area, it is impossible to assess any differential impacts that may occur from zone to zone. It is likely that visible vegetation damage will cover larger areas in wetlands with shallower flow because soils will become saturated more rapidly at greater distances from the source. Site-specific studies of individual wetlands should be undertaken before potentially toxic materials are stockpiled or disposed of in their vicinity.

2.11 IMPACTS OF NOISE

2.11.1 General Discussion of Stress

The impacts of noise pollution on wildlife are largely uninvestigated. Casual observations by field biologists suggest that individual animals and different species vary in their susceptibility to noise. Possible impacts of noise include physical damage to hearing organs, behavioral changes ranging from changed land-use patterns to desertion of long-term nesting sites, physiological stresses, and reduced reproductive capacities. Until more data are available for wildlife, inferences must be based on studies of laboratory and farm animals.

Animals differ in their abilities to perceive sound as pitch, volume, and tone. The frequency ranges of most animals are largely unknown. Caution must be exercised in extrapolating the results of studies from one species to another.

Effects of noise have been monitored by structural changes in ear anatomy, physiological changes, and behavioral changes. Most studies on laboratory animals have exposed them to stimuli at sound pressure levels (in decibels) and for durations greater than would normally be encountered by animals in nature even in industrial areas.

Both guinea pigs and chinchillas have exhibited damage to the auditory system in experiments involving exposure to sound pressure levels of 100 decibels or greater. Because intense noise is regarded as a stressful stimulus, several studies have been directed toward the adrenal system. Exposure to very severe noise stress can result in decreased adrenal activity and pathology in other organs influenced by adrenal activity. Because the reproductive organs are directly influenced by secretions from the adrenal gland, an important concern is the detrimental impact noise pollution may have on an animal's reproductive biology. At present, the results of numerous studies suggest that sexual behavior of laboratory and farm animals is not adversely affected by noise; but mice, rabbits, and rats have exhibited abnormalities of the reproductive organs or decreased success of pregnancy related to noise stress (Zordic 1959; Zondik and Isachar 1964; Singh and Rao 1970; Ishii and Yokobori 1960; Ward, Barletta, and Kay 1970). The noises to which these test animals were exposed were more continuous than any that small mammals could be expected to experience even at the site of a mining operation (e.g. continuous ringing of a bell for 8 hours a day for 1 to 21 days). However, the lower threshold at which such damage might occur has not been investigated and the possibility of such stresses to animals with small home ranges very near industrial operations cannot be precluded.

Most experiments with agricultural animals and wildlife have suggested that animals soon adapt to persistent noises in their environment. However, there are circumstances in which interruptive noises may interfere with key circumstances in the animal's life cycle. For example, nesting terns and condors have been shown to desert their nests temporarily when disturbed by sonic booms, blasting, or traffic (Graham 1970; Shaw 1970). Behavior of individual species cannot be predicted, for in another study on noise pollution and avian reproduction, Teer and Truett (1973) were unable to demonstrate that any phase of the reproductive cycle of wild birds was adversely affected by noise.

Nest sites of bald eagles and ospreys in the Study Area lie near the zone of mineralization (Figure 35) and the possibility of disturbance of these nests by noise should be considered. A secondary impact of increased mining in the Study Area is associated with projected increases in human population. Recent research has documented the effects of snowmobiles on white-tailed deer and suggests that even though the overt behavior of the animals may not change (Bollinger, Rongstad, Soom, and Ecstein 1973), their heart rate may increase from the normal 30 to 40 beats to 300 beats per minute (Karns 1977, MDNR, personal communication). Studies in St. Croix State Park (Huff and Savage 1972) have shown that deer leave the conifer cover type where heat loss is less and move to the more exposed hardwood type when snowmobile activity is high.

Activities related to mining are likely to create continuous noises (hauling trucks, ventilating fans), interrupted noise at infrequent intervals (train whistles, sirens, blasting) and persistent interrupted noises (back-up warning whistles). No studies are available that consider the potential impact of these noises on wildlife. Within the Study Area, wolves observed within 10 km of open pits responded to sirens by howling back. Logging operations have occurred within 1 km of an active eagle nest, and deer, moose, and wolves have been observed within 1 km of the pellet plant at the Erie Mining Company (Dickenson 1978, Barr Engineering, personal communication).

Because the impacts of noise on animals are unknown, the best way to assure that no impact is perceived by target species (such as eagles and ospreys) is to leave a buffer zone between mining operations and target animal-use areas.

A sound propagation model developed for the Regional Study (Volume 3-Chapter 5) can be used to anticipate the distances required before mining noises will be completely imperceptible to the human ear. These distances vary with the kind of noise being generated and the vegetation type in the vicinity of the receiver. Wind levels and noise propagation within vegetation types vary seasonally.

For example, preoperational noises are expected to resemble logging noises and are modeled to be perceptible at a distance of 7 km in red pine but 3.8 km in birch. The distances at which an underground mining operation can be heard are less than for an open pit. It is anticipated that if ventilating fans are provided with noise barriers, noises from underground mines will be heard to a distance of 5 km. Similar distances are projected for interrupted noises such as railroad whistles (4 km) and back-up warning signals (5 km). Wildlife in the area is already exposed to these noises from the taconite industry. The unknown impacts on nesting eagles and osprey are most likely to affect development in zones 1 and 2, which are the furthest from existing mining operations. Blasting, the noise most likely to affect birds, was not considered in the Regional Study's model.

2.11.2 Susceptibility of Zones to Noise

Of the four anticipated impacts on terrestrial ecosystems, only noise is likely to produce impacts that extend throughout much of the Study Area. In addition to increased noise levels related directly to mining, which will affect mainly the development zones, it is likely that the general noise level outside these zones will increase. Elevated noise levels may be expected wherever increased densities of residences, traffic, or recreation are projected. Such noise levels may affect the distribution of animal populations, particularly of those animals more shy of humans such as wolves and boreal animals.

Because of the higher proportion of conifer stands and the presence of eagle and osprey nests in zones 1 and 2, as well as the relative isolation of these areas at present, the impacts of mining-related noises can be expected to be somewhat greater in these zones. Noise impacts directly related to mining can be expected to decrease southward as deciduous forests become more dominant and sensitive animals decrease in abundance.

2.12 REGIONAL IMPACTS

2.12.1 General Discussion of Impacts

Seven terrestrial biology divisions (Figure 45a-g) were generated by cluster analysis of watersheds based on similarities in dominant vegetation and soils. Insofar as any given impact affects factors directly related to vegetation and soils, its effect can be expected to be similar throughout a division. Direct fumigation, acid precipitation, and direct removal of vegetation types used by habitat-specific animals are examples of impacts that should influence divisions as units. Because each division consists of a mosaic of vegetation and soils, just as detailed as those illustrated in Figures 34 through 44 for the development zones, differences in susceptibility can be expected within divisions. Comparisons between divisions are made on the basis of broad scale vegetation and soil characteristics. Three sets of factors are involved in the assessment of potential impacts within these areas: habitat components (e.g. species of animals, rare plants), potential impacts, and the probability of impacts occuring where the components are susceptible.

"Susceptibility" can be interpreted either as the effect on a component within a division or as the overall effect that impact within a division would have on a component in the Study Area as a whole. The difference between these two interpretations is exemplified by consideration of deer susceptibility of Division 1. Within the division there are few deer, they are highly concentrated geographically, and they are under heavy predation pressure. Active mining within their wintering area could eliminate them from the division, but the effect on the deer population within the Study Area as a whole would be slight. For the purposes of this report, susceptibility is interpreted in the latter sense. A population is susceptible in a division if an impact in that division may significantly affect the number of individuals or presence of the species within the Study Area as a whole.

Although some animals are habitat-specific (e.g. marten, fisher, otter), others may range over several habitat types or may prefer a single habitat but are located within that habitat on the basis of behavioral and social traditions. For example, deer summer-use areas are closely linked to their wintering areas. Some available summer habitat may remain unused because it has not been used previously. Wolves provide an even better example of the influence of social patterns on habitat use. Territories are defended and used year after year. Individual wolves do not generally change packs or use the territories of other packs for hunting. Dispossessed wolves are generally more vulnerable because they may be forced into areas of low prey density or become involved in inter-pack rivalries. Known territories of wolves in the Study Area do not necessarily coincide with the boundaries of the seven terrestrial impact divisions. Distributions of several other animals vary geographically in ways that do not coincide with boundaries of divisions. For this reason several of the divisions have been subdivided along watershed boundaries to facilitate analysis of impacts on animal populations.

Within any division, impacts will only affect components such as animal species, rare plants and rare habitats where the impacts and components co-occur. Thus, although otters may be susceptible in division 2, they will only be affected by direct mining activities that take place within their preferred riverine habitat (preferred habitats of animal species were presented in Tables 2, 3, and 4 and are discussed in section 2.4). All components will be affected by direct mining within their preferred habitat. Rare plants and habitats will probably only be influenced by acute air pollution damage and seepage very near a smelter or rock piles. Those at a distance would probably remain unaffected. Effects of acid precipitation on components such as rare habitats are difficult to assess. Cedar bogs should be no more susceptible to the effects of acid precipitation than other terrestrial communities. Those components that are directly dependent on aquatic food sources such as fish and macrophytes may be affected by acid precipitation. Decreases in otter populations could be expected to parallel decreases in total numbers of fish (regardless of species). Preferred moose foods (bur-reed, wild rice, and water lily) are most common in waters with pH value of 7-8.8 (Moyle 1945) and can be expected to become less available as waters decrease in alkalinity. Species such as wolf and lynx tend to avoid centers of human population and their distribution within the area could be altered by changing settlement patterns. Others, such as bear and deer are attracted to settlements (because of dumps, gardens, and openings). For bear this attraction creates a greater risk of being shot. For deer it establishes use patterns near roads, where they may be more susceptible to hunting. Table 13 is a synopsis of the impacts that could affect each component.

The probability that an impact will occur within a given division depends on the location of new mining operations and settlement patterns. The matrix presented in Table 27 is based on models developed by the Regional Study. Assumptions were the same as those used in the preparation of Table 20. Mining activities were assumed to be most likely in those areas where the mineral resource is greatest. Following this assumption, projected residential settlement patterns to accompany mining development in zones 1-5 were used to assess the probability of increased human populations (see Volume 5-Chapter 7 for projected settlement patterns). Populations are likely to concentrate in divisions 1, 7A, and 6B (see Figure 45) according to these assumptions. Smelter siting was assumed to follow the constraints discussed in section 2.9.2 and presented in detail in Volume 3-Chapter 3. It was, therefore, assumed that a smelter could be located anywhere throughout or outside of the Study Area except in divisions 1 and 7A (because of Class I air standards). Because visible effects of air pollution on vegetation are only expected to occur during breakdown conditions and near a smelter, there is a possibility that such damage could occur within any of the other divisions in the event that a smelter is located nearby. If developments occur in areas other than those used in the models, such as a smelter located outside of the development zones, different divisions may be influenced. Regardless of where development occurs, susceptibilities of components and habitats to given impacts should be similar to those presented in Table 13.

Table 27

2.12.2 Susceptibility of Divisions (see Table 18 and Figure 45)

Division 1 contains a large number of susceptible components related to the boreal forest ecosystem which are present in the conifer-dominated, thin-soiled portions of division 1. The black spruce-jack pine upland community is present in this division and division 2 but rare elsewhere within the Study Area. This division is especially important for the eastern timber wolf and contains several known eagle and osprey nests. The division contains area used in several long term research projects including a fire ecology study and territories of several wolf packs being studied by radio telemetry. The Keeley Creek Research Natural Area, a USFS administrative unit, provides undisturbed stands of aspen-birch and black spruce-jack pine of value to students of natural succession.

TABLE 27 PROBABILITIES OF IMPACTS WITHIN TERRESTRIAL BIOLOGY DIVISIONS

	IMPACT										
	LOCALIZED						REGIONAL				
DIVISION	DIRECT LAND USE	SEEPAGE	NOISE	HEAVY METAL LOADING	VISIBLE EFFECTS OF AIR POLLUTION ON VEGETATION	SUBTLE EFFECTS OF AIR POLLUTION ON VEGETATION	ACID PRECIPITATION	VISIBLE EFFECTS OF AIR POLLUTION ON VEGETATION	PRESENCE OF INCREASED HUMAN POPULATION	CONFLICT WITH INCREASED HUMAN POPULATION	INCREASED HUNTING PRESSURE
1											
2											
3A											
3B											
4A											
4B											
5											
6A											
6B											
6C											
7A											
7B											

PROBABILITIES ARE BASED ON THE ASSUMPTIONS THAT DIRECT IMPACTS OF MINING WILL OCCUR NEAR MINERALIZED AREAS BUT THAT A SMELTER MAY BE LOCATED ANYWHERE.

Impacts within the division are most likely to be those directly associated with mining operations. The single most important factor would probably be direct habitat loss. Seepage from wasterock and lean ore piles may be complicated by the fact that most wetlands in the division drain directly or indirectly into the BWCA, which is a unique wilderness area of considerable national importance.

Division 2 lies mainly in the Complex Moraine province and Toimi Drumlin Fields. Uplands in division 2 are dominated by aspen-birch and by conifer stands. Along the moraines nearly pure aspen-birch communities dominate, whereas to the east and between moraines, mixed communities and 30 to 40-year-old conifer plantations are common. Large portions of the western part of division 2 have been recently cut as part of the Baird Sale. Animals of the division are similar to those of division 1, with wolf populations decreasing southward. If mining is confined to the development zones, division 2 would not be subject to direct habitat loss. In the event that the Dunka outwash area was judged hydrologically unfit to contain stockpiles or tailings basins, these direct uses might easily be placed in division 2, resulting in loss of plantation and deciduous habitat. Chronic effects of air pollution could be expected to be enhanced in areas immediately surrounding the Stony River because of the open and less vigorous nature of the aspen stands. Division 2 contains a high proportion of shoreline of small streams suitable for otter and beaver. Such streams might be especially subject to acidification from regional sources and a smelter in development zone 3.

Divisions 3A and 4A lie almost entirely in areas very likely to receive direct impacts from mines, stockpiles, and tailings basins. In addition to a great deal of habitat loss, impacts from a smelter could be expected to include both chronic and acute injuries. Division 3A lies within development zones 3 and 4

(Figures 40 and 41) and contains a higher proportion of both upland and lowland conifers than Division 4A. Upland conifers consist of jack and red pine stands near maturity and plantations between the age of 1 and 30 years. Young plantations can be expected to reach their most susceptible growth period during the lifetime of a smelter (30-40 years). Wetlands vary from ash and cedar to mixed, tamarack and spruce bogs, all within the bed of Glacial Lake Dunka. The underlying outwash makes these communities especially susceptible to seepage from stockpiles. Division 4A includes a higher proportion of Newfound-Newfound soils than 3A, suggesting that upland soils in 4A may be more susceptible to long-term heavy metal loading than uplands in Division 3A. Vegetation of 4A consists in large part of mixed deciduous and aspen uplands and very young plantations that will reach their most susceptible rapidly growing stage during the expected lifetime of a copper-nickel industry. Wildlife values of division 4A are probably lower than anywhere else in the Study Area. The division contains a higher proportion of known cedar communities than most, including an area of upland cedar east of Colvin Creek.

Division 3B is dominated by deciduous forests and agricultural lands. The division could be expected to receive indirect impacts from the mining industry, such as long-term chronic injury to vegetation if a smelter is located in development zone 5 or 6. Secondary effects of increased human population would probably result in greater conflicts between bears and humans and increased visibility of deer.

Division 5, lying along the upper reaches of the St. Louis River and extending north of Seven Beaver Lake into the watershed of the North River, is not a homogeneous unit. From south of Hoyt Lakes to just west of Seven Beaver Lake the division is characterized by aspen-birch uplands on soils with thin litter layers but high cation exchange capacities. Mining in development zones 6 and 7 could easily result in habitat loss, seepage, and noise impacts in the western half of division 5. A smelter located in the same development zones could produce acute vegetation damage near the smelter, chronic damage throughout the western half of the division, and heavy metal loading on the upland soils. Waterways of the division are prime waterfowl habitat, the best such area surveyed by the Copper-Nickel Study. The value of the slow-moving streams and the Sand Lake-Seven Beaver area for waterfowl could be reduced by acid rainfall. The eastern part of the division is characterized by a complex of conifer and open wetlands. Organic soils of these wetlands should have a greater capacity to bind heavy metals. Changes in rainfall chemistry might be expected to change the appearance of the bog landscape where vegetation patterns reflect patterns of nutrient distribution in the waterflow of the bog. Wetlands in the northeast part of the division are the most extensive ombrotrophic bogs in the Study Area. The chemistry of such bog waters is more dependent on rainfall than on runoff from nearby uplands. Such wetlands could be expected to respond differently to altered atmospheric chemistry than other smaller more minerotrophic wetlands.

Division 6A lies in the southwest portion of the Study Area and is generally dominated by deciduous forests, with scatterings of agricultural lands and conifer plantations. The assemblage of animals in the division is generally that of northern Minnesota conifer-deciduous forests including deer, woodcock, bobcat, beaver, and waterfowl. Influences from copper-nickel mining in the division would probably be restricted to secondary developments along transportation corridors and increased hunting pressures. Division 6B lies south and west of the zone of potential copper-nickel mines. Flora and fauna are similar to those of division 6A, but the area includes most of the agricultural land of the Study Area, as well as several centers of population. Species favored by openings, such as woodcock and deer, can be expected to persist in division 6B even with the further growth of human populations that may result from mining. Direct impacts of copper-nickel mining would not affect this division. Clay soils of division 6B should be less affected by heavy metal loading than other soils within the area.

Divisions 4B and 6C are dominated by deciduous forest communities in the Toimi Drumlin Field. Animals are more similar to those in divisions 6A and 6B than division 2. Moose populations within the Study Area increase from west to east, resulting in higher populations in division 6C than in 6A or 6B. Soils of these divisions include high proportions of Newfound soil, which has a low litter weight and is susceptible to heavy metal loading. In addition to this soil factor, the topography of the area could result in a pattern of differential pollution damage to vegetation with the west sides of drumlins developing damage symptoms. Division 4 might experience direct habitat loss, whereas impacts in division 6C can be expected to be minimal.

Division 7A, in the northwest part of the Study Area, is similar to division 1 in its flora and fauna but includes more miles of shoreline, providing more habitat for otter, beaver, and waterfowl. Aside from the region-wide influence of acid precipitation, potential impacts of copper-nickel development within the division can be expected to arise mainly from secondary development. Increased populations could affect the two known wolf territories in the division as well as attracting bear and deer into areas where they are likely to come into conflict with people. Although the plant communities of division 7B are similar to those in 7A and 1, densities of deer are higher and those of bear are lower than in the other northern divisions. The division is considered "susceptible" for rare plants because a large number of herbarium records for rare plants, collected within the Study Area, are centered around Vermillion Lake. Except for the regional effect of acid precipitation, impacts from copper-nickel mining in division 7 would probably be minimal.

2.13 POST SCRIPT

There are many uncounted costs to the terrestrial ecosystem that are not usually part of the cost-benefit analysis used to make development decisions. Some of these uncounted costs are expressed in the following discussion by Aldo Leopold (1949) from The Sand County Almanac:

> One basic weakness in a conservation system based wholly on economic motives is that most members of the land community have no economic value. Wildflowers and songbirds are examples. Of the 22,000 higher plants and animals native to Wisconsin, it is doubtful whether more than 5 percent can be sold, fed, eaten, or otherwise put to economic use.. Yet these creatures are members of the biotic community, and if (as I believe) its stability depends on its integrity, they are entitled to continuance.
>
> When one of these non-economic categories is threatened, and if we happen to love it, we invent subterfuges to give it economic importance. At the beginning of the century songbirds were supposed to be disappearing. Ornithologists jumped to the rescue with some distinctly shaky evidence to the effect that insects would eat us up if birds failed to control them. The evidence had to be economic in order to be valid.

It is painful to read these circumlocutions today. We have no land ethic yet, but we have at least drawn nearer the point of admitting that birds should continue as a matter of biotic right, regardless of the presence or absence of economic advantage to us...

Some species of trees have been 'read out of the party' by economics-minded foresters because they grow too slowly, or have too low a sale value to pay as timber crops: white cedar, tamarack, cypress, beech, and hemlock are examples. In Europe, where forestry is ecologicaly more advanced, the non-commercial tree species are recognized as members of the native forest community, to be preserved as such, within reason. Moreover, some (like beech) have been found to have a valuable function in building up soil fertility. The interdependence of the forest and its constituent tree species, ground flora, and fauna is taken for granted.

Lack of economic value is sometimes a character not only of species or groups, but of entire biotic communities: marshes, bogs, dunes, and "deserts" are examples. Our formula in such cases is to relegate their conservation to government as refuges, monuments, or parks. The difficulty is that these communities are usually interspersed with more valuable private lands; the government cannot possibly own or control such scattered parcels. The net effect is that we have relegated some of them to ultimate extinction over large areas. If the private owner were ecologically minded, he would be proud to be the custodian of a reasonable proportion of such areas, which add diversity and beauty to his farm and to his community.

In some instances, the assumed lack of profit in these "waste" areas has proved to be wrong, but only after most of them had been done away with...

The ecosystem characterization provided by this report should help identify some of the elements of non-economic value in the Study Area and potential impacts discussed in this chapter of the report should aid in making decisions before some of these areas are lost for generations.

2.14 REFERENCES

Aaseng, N.E. 1978. A reassessment of Kotar's data analysis. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

-------. 1978. Problems and approaches in the revegetation of mine wastes. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

Abrahamson, G., R. Horntvedt and B. Tveite. 1976. Impacts of acid precipitation on coniferous forest ecosystems pp. 991-1010 in Proceedings of the 1st International Symposium on Acid Precipitation and the Forest Ecosystem. USDA For. Ser. Gen. Tech. Report NE-23.

Agricola, G. 1556. De Re Metallica p. 7 in C.G. Down and J. Stocks, 1977, Environmental Impact of Mining. New York, Toronto. John Wiley and Son.

Ahlgren, C.E. 1957. Phenological observations of nineteen native tree species in northeastern Minnesota. Ecology 38:622-638.

Aldrich, J.W. 1963. Geographical orientation in American Tetraonidae. J. Wildl. Manage. 27(4):529-545.

Anderson, L.J. 1973. Habitat use, behavior, territoriality, and movements of the male Canada spruce grouse of northern Minnesota. MS thesis, Univ. of Minnesota.

Baker, J., D. Hocking and M. Nyborg. 1976. Acidity of open and intercepted precipitation in forests and effects on forest soils in Alberta, Canada pp. 779-790 in Proceedings of the 1st International Symposium on Acid Precipitation and the Forest Ecosystem. USDA For. Ser. Gen. Tech. Report NE-23.

Bakuzis, E.V. and H.L. Hansen. 1959. A provisional assessment of species synecological requirements in Minnesota forests. Univ. of Minn. Sch. For. Minn. For. Notes 84.

Banfield, A.W. 1974. The mammals of Canada. Univ. of Toronto Press.

Batten, E.M. 1978. Small mammal distribution in the Study Area. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

Berg, W. 1976. Ruffed grouse drumming count. Minnesota Department of Natural Resources, Job. No. Forest Wildlife C/S 14.

Bishop, J.A. and T.S. Harper. 1970. Melanism in moth Gonodontis bidentata, a cline with Mercyside Conurbation. Heredity 25:449.

Blauel, R.A. and D. Hocking. 1974. Air pollution and forest decline near a nickel smelter. Environment Canada, Information Report NOR-X-115.

Bollinger, J.E., O.J. Rongstad, A. Soom and R.G. Ecstein. 1973. Snowmobile noise effects on wildlife. Rpt. 1972-1973. Univ. of Wisconsin, Madison.

REFERENCES continued

Bookhout, T.A. 1965. Feeding coactions between snowshoe hares and white-tailed deer in northern Michigan. Tran. N. A. Wildl. Conf. 30:321-335.

Braun, E.E. 1950. Deciduous forests of eastern North America. New York, London. Hafner Publ. Co.

Buchauer, M.J. 1973. Effects of zinc smelter emissions on forest soil microflora. Bul. Ecol. Soc. Am. 54:33.

Clements, F.E. 1916. Plant succession: analysis of the development of vegetation. Carnegie Instit. of Washington. Publ. 242.

Coffin, B.A. 1977a. The effect of smelter emissions on Forest tree productivity. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

-------. 1977b. Forest productivity in the Superior National Forest outside the BWCA. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

-------. 1977c. Lichens as pollution indicators. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

Cogbill, C.V. 1976. The effect of acid precipitation on tree growth in eastern North America pp. 1027-1031 in Proceedings of the 1st International Symposium on Acid Precipitation and the Forest Ecosystem. USDA For. Ser. Gen. Tech. Report NE-23.

Cooper, W.S. 1913. The climax forest of Isle Royale, Lake Superior, and its development. Bot. Gaz. 15:1-44, 115-140, 189-235.

Cribben, L.D. and D.D. Sanachetti. 1976. Diversity in tree species in southeastern Ohio Betula nigra L. communities pp. 979-990 in Proceedings of the 1st International Symposium on Acid Precipitation and the Forest Ecosystem. USDA For. Ser. Gen. Tech. Report NE-23.

Daubenmire, R.F. 1936. The big woods of Minnesota, its structure and relation to climate, fire, and soils. Ecol. Monographs 6:233-268.

Dochinger, L.S. and C.E. Seliscar. 1965a. Results from grafting chlorotic dwarf and healthy eastern white pine. Phytopathology 55:404-407.

Dochinger, L.S., C.E. Seliscar and F.W. Bender. 1965b. Etiology of chlorotic dwarf of eastern white pine. Phytopathology 55:1055 (abstract).

Dodds, D.G. 1960. Food competition and range relationships of moose and snowshoe hare in Newfoundland. J. Wildl. Manage. 24(1):52-60.

Down, C.G. and J. Stocks. 1977. Environmental impact of mining. New York, Toronto. John Wiley and Sons.

REFERENCES continued

Driesinger, B.R. and P.C. McGovern. 1970. Sulfur dioxide levels and resultant injury to vegetation in the Sudbury area during the 1969 season. Dept. of Energy and Resources Management, Sudbury, Ontario.

Erskine, A. 1977. Birds in boreal Canada. Canadian Wildlife Service, Report Series No. 41.

Flaccus, E. and L.F. Ohmann. 1964. Old-growth northern hardwoods forests in northeastern Minnesota. Ecology 45:448-459.

Floyd, T.J. 1978. Winter densities of deer and moose in northeastern Minnesota. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

Goodman, G.T., C.E.R. Pitcairn, and R.P. Gemmell. 1973. Ecological factors affecting growth on sites contaminated with heavy metals pp. 149-174 in Hutnick, R. and G. Davis (eds.), Ecology and reclamation of devastated land, Vol. 2.

Graham, F. 1969. Ear pollution. Audubon 71:34-39.

Grant, M.L. 1934. The climax forest community in Itasca County, Minnesota, and its bearing upon the successional status of the pine community. Ecology 15:243-257.

Green, J.C. 1971. Summer birds of the Superior National Forest, Minnesota. Loon 43:103-107.

Green, J.C. and R.B. Janssen. 1975. Minnesota birds. Univ. of Minnesota Press.

Grigal, D.F. and L.F. Ohmann. 1975. Classification, description, and dynamics of upland plant communities within a Minnesota wilderness area. Ecol. Mono. 45:389-407.

Guderian, R. 1977. Air pollution, phytotoxicity of acid gases and its significance in air pollution control. Springer-Verlag. Berlin, Heidelberg, New York.

Gullion, G.W. 1970. The ruffed grouse in northern Minnesota. Rev. Ver. Univ. of Minn. For. Wildl. Relations Project.

Haas, G.H. 1974. Habitat selection, reproduction, and movements in female spruce grouse. Ph.D. thesis, Univ. of Minnesota.

Handley, C.J. 1954. Phenacomys in Minnesota. Jour. Mammalogy 35:260.

Heagle, A.S. 1973. Interactions between air pollutants and plant parasites. Ann. Rev. Phytopathology 11:365-388.

Heinselman, M.L. 1973. Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. Quat. Res. 3:329-382.

Henderson, C. 1977. Bobcat status report. Minnesota Department of Natural Resources.

Hoskinson, R.L. and L.D. Mech. 1976. White-tailed deer migration and its role in wolf predation. J. Wildl. Manage. 40(3):429-441.

Houston, D.B. and L.S. Dochinger. 1977. Effects of air pollution on cone, seed, and pollen characteristics in eastern white and red pines. Environ. Pollut. 12:1-5.

Huempfner, R.A. 1978a. Bald eagle (Heliaeetus leucocephalus). Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

-------. 1978b. Black bear (Ursus americanus). Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

-------. 1978c. Fur-bearers. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

-------. 1978d. Moose (Alces alces). Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

-------. 1978e. Osprey (Pandion heliaetus). Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

-------. 1978f. Ruffed grouse (Bonasa umbellus). Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

-------. 1978g. Snowshow hare (Lepus americanus). Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

-------. 1978h. Spruce grouse (Canachites canadensis). Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

-------. 1978i. White-tailed deer (Odocoileus virginianus). Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

-------. 1978j. Wolf (Canis lupus). Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

Huempfner, R.A. and L.A. Pfannmuller. 1978a. Raptors. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

-------. 1978b. Waterfowl. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

Huff, D.E. and P.J. Savage. 1972. A correlation of deer movements with snowmobile activity in Minnesota during winter, 1972. Paper presented to the 34th Midwest Fish and Wildlife Conference at Des Moines, Iowa, December 12, 1972.

Hutchinson, T.C. and L.M. Whitby. 1976. The effects of acid rainfall and heavy metal particulates on a boreal ecosystem near the Sudbury smelting region of Canada pp. 745-765 in Northeast Forest Exp. Station. USDA For. Ser. Gen. Tech. Report NE-23.

Hutchinson, T.C. and M. Havas. 1977. The effect of long-term acidification of tundra ponds in the Canadian Arctic at Smoking Hills, N.W.T.S.I.C. Abstracts 20:124.

Ishii, H. and K. Yokobori. 1960. Experimental studies on teratogenic activity of noise stimulation. Gumma Journal of Medical Sciences 9:153-167.

Jessen, R.L. and J. Parker. In press. Waterfowl breeding ground survey segment 1--Statewide aerial census 1975, 1976, and 1977. Minnesota Department of Natural Resources, Wildlife research job completion report.

Jones, H.C., D. Weber and D. Baisillie. 1974. Acceptable levels of air pollution dosages and vegetation effects: sulfur dioxide. Report No. 74-225, 67th Annual meeting of the Air Pollution Control Association, Denver, Colorado.

Jonsson, B. and R. Sundberg. 1972. Has the acidification caused by atmospheric pollution caused a growth reduction in Swedish forests. Institutionen fur Skogsproduktion. Nov. 20. Skogshogskolan, Stockholm.

Jordan, M.J. 1975. Effects of zinc smelter emissions and fire on a chestnut-oak woodland. Ecol. 56(1):78-91.

Jordan, P.A., D.B. Botkin, A.S. Dominski, H.S. Lowendorf and G.E. Belovsky. 1973. Sodium as a critical nutrient for the moose of Isle Royale. 13-42. 9th N. Amer. Moose Conf. and Workshop. Ontario Min. of Nat. Res. Fish and Wildl. Res. Branch and Wildl. Branch.

Katz, M. 1937. Report on the effect of dilute sulphur dioxide on alfalfa in trail smelter question. Ottawa. Nat. Res. Council of Canada. Doc. Ser. D.D., Append. D.D.3.

Katz, M. and G.A. Ledingham. 1937. Report on the effect of dilute sulphur dioxide on alfalfa in trail smelter question. Ottawa. Nat. Res. Council of Canada. Doc. Ser. D.D., Append. D.D.3.

Kettlewell, H.B.D. 1956. Further selection experiments on industrial melanism in the Lepidoptera. Heredity 10:287-301.

Kittredge, J. 1934. Evidence of the rate of forest succession on Star Island, Minnesota. Ecol. 15:24-35.

Knabe, W. 1968. Experimentelle Prufung der Fluoranreicherung in Nadeln und Blattern von Pflanzen in Abhangigkeit von deren Expositionshohe uber Grund. Zaklad. Baden. Naukowych Gornoslaskiego Okregu Przemyslowego Polskieg Akademii Nauk, Katowice IX:9-14.

REFERENCES continued

Kotar, J. 1974. The effect of sulfur dioxide on the diameter increment of trees in the vicinity of White Pine Smelter (prelim. report).

Krause, G.H.M. and H. Kaiser. 1977. Plant response to heavy metals and sulfur dioxide. Environ. Poll. 12:63-71.

Krefting, L.W. 1975. Effect of white-tailed deer and snowshoe hare browsing on trees and shrubs in northern Minnesota. Univ. of Minnesota, Agr. Exp. Station Tech. Bull. 302, Forestry Series 18:1-44.

Krupa, S. 1977. Impact of copper-nickel development in northern Minnesota on terrestrial vegetation, final report. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

Krupa, S., B.I. Chevone, S. Fagerlie and D.S. Lang. 1976. Impact of air pollutants on terrestrial vegetation, a literature survey. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

Lakela, O. 1965. A flora of northeastern Minnesota. Univ. of Minnesota Press, Minneapolis, Minn.

Lathe, F.E. and A.W. McCallum. 1939. The effect of sulfur dioxide on the diameter of conifers pp. 147-206 in Effect of SO_2 on vegetation. Nat. Res. Council of Canada. Publ. 815.

Leopold, A.S. 1949. A Sand County almanac. Oxford University Press. New York.

Likens, G.E. and F.H. Bormann. 1974. Acid rain, a serious regional environmental problem. Science 184:1176-1179.

Linzon, S. 1958. The influence of smelter fumes on the growth of white pine in the Sudbury region. Ontario Dept. of Lands and Forests and Ontario Dept. of Mines.

------. 1966. Damage to eastern white pine by sulfur dioxide, semi-mature needle blight and ozone. Jour. Air. Poll. Cont. Ass. 16:140-144.

------. 1971. Economic effects of SO_2 on forest growth. Jour. Air. Poll. Cont. Ass. 21(2):81-86.

Marschner, F.J. 1930. The original vegetation of Minnesota (a map). Published 1964 by Soil Conserv. Ser., USDA, St. Paul, Minn.

Matsushima, J. and R.F. Brewer. 1972. Influence of sulfur dioxide and hydrogen fluoride as a mix or reciprocal exposure on citrus growth and development. Jour. Air. Poll. Cont. Ass. 22:710-713.

Mech, L.D. 1971. Wolves, coyotes, and dogs pp. 19-22 in The white-tailed deer in Minnesota, Symposium Proc., M.M. Nelson (ed.). Minnesota Department of Natural Resources, St. Paul, Minn.

Mech, L.D. 1977b. Population trend and winter deer consumption in a Minnesota wolf pack pp. 55-83 in Proceedings of the 1975 predator symposium (eds.) Phillips, R.L. and C. Jonkel. Montana For. and Conserv. Exp. Station, Univ. of Montana, Missoula.

-------. 1977c. Wolf-pack buffer zones as prey reservoirs. Science Vol. 198:320-321.

Mech, L.D. and P.D. Karns. 1977. Role of the wolf in a deer decline in the Superior National Forest. USDA For. Ser. Res. Paper NC-148.

Mech, L.D. and L.L. Rogers. 1977. Status, distribution, and movement of martens in northeastern Minnesota. USDA For. Res. Paper NC-143.

Minnesota Department of Natural Resources. 1976. Minesite data manual. Vegetation Inventory and Map (V16). St. Paul, Minn.

Minnesota Department of Natural Resources. 1975. The uncommon ones: animals and plants which merit special consideration and management. St. Paul, Minn.

Minnesota State Planning Agency, Minnesota Land Management Information Service (MLMIS). Land use map V45. St. Paul, Minn.

Minnesota Statute 17.23.

Morley, T. 1972. Rare or endangered plants of Minnesota with the counties in which they have been found. Mimeo by author. Dept. of Botany, Univ. of Minnesota, St. Paul, Minn.

Moyle, J.B. 1945. Some chemical factors influencing the distribution of aquatic plants in Minnesota. Am. Midl. Nat. 34:402-420.

Nichols, G.E. 1935. The hemlock-white pine-northern hardwood region of eastern North America. Ecol. 16:403-421.

Nyborg, M., J. Crepin, D. Hocking and J. Baker. 1976. Effect of sulfur dioxide on precipitation and on the sulfur content and acidity of soils in Alberta, Canada pp. 767-778 in Proceedings of the 1st International Symposium on Acid Precipitation and the forest ecosystem. USDA For. Ser. Gen. Tech. Report NE-23.

Olcott, P.G. and D.I. Siegel. 1978. Physiography and surficial geology of the Copper-Nickel Study region, northeastern Minnesota. Water-Resources Investigations 78-51, Open-file report.

Olson, J. 1978. The effects of heavy metals on the germination and radicle growth of some forest plants in northern Minnesota. Plan B Paper. College of Forestry, Univ. of Minnesota.

Orloci, L. 1967. An agglomerative method for classification of plant communities. J. Ecol. 55:193-205.

Overrein, L.N. 1972. Sulfur pollution patterns observed: leaching of calcium in forest soil determined. Ambio 1:145-147.

Patterson, W.A. III. 1978. Soil decomposition studies. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

Patterson, W.A. III and N.E. Aaseng. 1968. Soils of the Study Area. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

Peek, J.M. 1971. Moose habitat selection and relationships to forest management in northeastern Minnesota. Ph.D. thesis, Univ. of Minnesota.

Pfannmuller, L.A. 1978. Song birds of the Study Area. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

-------. 1977. The effects of noise on wildlife. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

Rogers, L.L. Social relationships, movements, and population dynamics of black bears in northeastern Minnesota. Ph.D. thesis, Univ. of Minnesota.

Rohmeder, E., W. Merz, and A. Von Schonborn. 1962. Zuchtung von gegen Industrieabgase relativ resistenten Fichten und Kiefernsorten. Forstw. Cbl. 81:321-332.

Rohmeder, E. and A. Von Schonborn. 1965. The influence of environment and heredity on the resistance of forest trees to the atmospheric impurities originating from industrial waste gases. A contribution for the breeding of a relatively flue gas resistant species of spruce trees. Forstwiss. ZentrBl. 84:1-3.

Rollings, C.T. 1945. Habits, food, and parasite of the bobcat in Minnesota. J. Wildl. Manage. 9(2):131-145.

Rowe, J.S. 1959. Forest regions of Canada. Canada Dept. North. Aff. and Nat. Res. For. Branch Bull. 123.

Ruhling, A. and G. Tyler. 1973. Heavy metal pollution and decomposition of spruce needle litter. Oikos 24:402-416.

Sargent, C.S. 1884. Report on the forests of North America, exclusive of Mexico. U.S. Dept. of Interior, Census Office Report 10th census.

-------. 1933. Manual of the trees of North America (exclusive of Mexico). Ed. 2. Boston and New York. Houghton Mifflin.

Sather, N.P. 1978. Rare plants. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

REFERENCES continued

Sather, N.P. 1979a. Flora of the study plots. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

--------. 1979b. Seasonal variations in vegetation. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

--------. 1979c. Vegetation of the Study Area. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

Schlesinger, W.P. and G.L. Potter. 1974. Lead, copper, and cadmium in small mammals in the Hubbard Brook Experimental Forest. Oikos 25(2):148.

Schonbach, H. H.G. Dassler, H. Enderlein, E. Bellman and W. Kastner. 1964. Uber den unterschiedlichen Einflus von Schwefeldioxid auf den Nadeln verschiedener 2jahriger Larchenkruezungen. Zuchter 34(8):312-316.

Schroeder, H.A. and M. Mitchener. 1971. Toxic effects of trace elements on the reproduction of mice and rats. Arch. Environ. Health 23:102-106.

Shaw, E.W. 1970. California condor. Library of Congress Legislative Reference Service, SK351:70-127.

Singh, K.B. and F. Rao. 1970. Studies on the polycystic ovaries of rats under continuous auditory stress. Amer. J. Obstetics and Gynecology 108:557-564.

Sloss, R. 1977. Predicting forest cover type changes for a region of northeastern Minnesota. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

Smith, W.H. 1974. Air pollution-effects on the structure and function of the temperate forest ecosystem. Environ. Poll. 6:111-129.

--------. 1977. Removal of atmospheric particulates by urban vegetation: implications for human and vegetative health. Yale J. Biol. Med. 50:185-197.

--------. 1978. Impacts of air pollutants on terrestrial vegetation, a critique. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

Smithsonian Institution. 1975. Report on endangered and threatened plant species of the United States submitted to the 94th Congress, 1st Session. House document No. 94-51, Washington, D.C., U.S. Govt. Printing Office.

Society of American Foresters. 1954. Forest cover types of North America (exclusive of Mexico). Washington. Soc. Am. For.

Stallard, H. 1929. Secondary succession in the climax forest formation of northern Minnesota. Ecol. 10:476-547.

REFERENCES continued

Stern, A.C., H.C. Wohlers, R.W. Bouble and W.T. Lowry. 1973. Fundamentals of air pollution. Academic Press. New York.

Swanson, G. 1945. A systematic catalog of the mammals of Minnesota in The mammals of Minnesota (eds.) G. Swanson, T. Surber and T.S. Roberts. Minnesota Dept. Conserv. Tech. Bull 2:52-105.

Tamm, C.O. 1976a. Acid precipitation, biological effects on soil and on forest vegetation. Ambio. 5:235-238.

------. 1976b. Acid precipitation and its effect on forest soils pp. 681-684 in Proceedings of the 1st International Symposium on acid precipitation and the forest ecosystem. USDA For. Ser. Gen. Tech. Report NE-23.

Tamm, C.O. and A. Aronsson. 1972. Plant growth as affected by sulfur compounds in polluted atmosphere, a literature survey. Nr. 12 Skogshogskolan, Stockholm.

Tamm, C.O. and E.B. Cowling. 1976. Acidic precipitation and forest vegetation pp 845-856 in Proceedings of the 1st International Symposium on acid precipitation and the forest ecosystem. USDA For. Ser. Gen. Tech. Report NE-23.

Tansley, A.G. 1935. The use and abuse of vegetational concepts and terms. Ecol. 16:284-307.

Taylor, O.C. 1973. Acute responses of plants to aerial pollutants in Air pollution damage to vegetation, J.A. Naegele (ed.) Advances in Chemistry series, Amer. Chem. Soc., Washington, D.C.

Teer, J.G. and J.C. Truett. 1973. Studies of the effects of sonic booms on birds. Bureau of Sport Fisheries and Wildlife, U.S. Fish and Wildl. Ser.

Thomas, M.D. 1965. The effects of air pollution on plants and animals pp. 11-33 in Ecology and the industrial society, G.T. Goodman, R.W. Edwards and J.M. Lambert (eds.). Blackwell, Oxford, England.

Tyler, G. 1975a. Effects of heavy metal pollution on decomposition in forest soil. Nat. Sw. Environ. Prot. Bd.

------. 1975b. Heavy metal pollution and mineralization of nitrogen in forest soils. Nature 255:701-702.

------. 1976. Heavy metal pollution, phosphatase activity, and mineralization of organic phosphorus in forest soils. Soil Biol. Biochem. 8:327-332.

------. 1978. Leaching rates of heavy metal ions in forest soil. Water, Air, and Soil Pollution 9:137-148.

U.S. Department of Agriculture, Soil Conservation Service. 1973. Arrowhead soils map. Minnesota Land Management Information Service (MLMIS) V.15. St. Paul, Minn.

REFERENCES continued

Van Ballenberghe, V. 1972. Ecology, movements, and population characteristics of timber wolves in northeastern Minnesota. Ph.D. thesis, Univ. of Minn.

Van Ballenberghe, V. and L.D. Mech. 1975. Weights, growth, and survival of timber wolf pups in Minnesota. J. Mammal. 56(1):44-63.

Van Haut, H. 1961. Die Analyse von Schwefeldioxidwirkungen auf Pflanzen in Laboratoriums versuch. Staub 21:52-56.

Van Haut, H. and H. Stratmann. 1970. Farbtafelatlas uber Schwefetdioxidwirkungen an Pflanzen. Essen. W. Girardet-Verlag.

Ward, C.O. M.A. Barletta, T. Kaye. 1970. Teratogenic effects of audiogenic stress in albino mice. J. of Pharmaceutical Sciences 59:1661-1662.

Waring, R.H. 1959. Some characteristics of the upland forest types in the rock outcrop area in northeastern Minnesota. M.S. thesis, Univ. of Minnesota, St. Paul, Minn.

Weaver, J.E. and F.E. Clements. 1929. Plant ecology. New York, McGraw.

Westman, L. 1974. Air pollution indications and growth of spruce and pine near a sulfite plant. Ambio 3(5):189-193.

Whitby, L.M. and T.C. Hutchinson. 1974. Heavy metal pollution in the Sudbury mining and smelting region of Canada. II. Soil and toxicity tests. Environmental Conservation 1(2):191-200.

Winter, T.C., R.D. Cotter and H.L. Young. 1973. Petrography and stratigraphy of glacial drift, Mesabi-Vermilion Iron Range Area, northeastern Minnesota. U.S. Government Printing Office. Geological Survey Bulletin 1331-C. Washington, D.C.

Wood, T.J. and S.A. Munroe. 1977. Dynamics of snowshoe hare populations in the maritime provinces of Canada. Can. Wildl. Ser. Occasional Paper No. 30.

Zahn, R. 1936. Uber den Einflus verschiedener Umweltfaktoren auf die Pflanzenempfindlichkeit gegenuber Schwefeldioxid.z. Pflanzenkrankh. Pflanzenschutz 70:81-95.

Zeyen, R.J. 1978. Interactions between air pollutants and plant diseases caused by biotic agents. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

Zeyen, R.J. and J.V. Groth. 1978. Plant diseases affecting forest trees in northeastern Minnesota. Regional Copper-Nickel Study, Minnesota Environmental Quality Board.

Zondik, B. and T. Isachar. 1964. Effect of audiogenic stimulation on genetal function and reproduction. Acta Endocrinologica 45:227-234.

Zordic, V. 1959. Effects of sound on mouse testes. Acta Anatomica 38:176.