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REGIONAL COPPER-NICKEL STUDY

MOOSE (*Alces alces*)

Minnesota Environmental Qualtiy Board
By: Dick Huempfner
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PRELIMINARY DRAFT REPORT, SUBJECT TO REVIEW

ABSTRACT

Moose populations have fluctuated considerably in the Superior National Forest (SNF) since 1915 and are currently at an all-time high. The moose herd in northeastern Minnesota has remained relatively stable since the early 1970's at about 2500 animals (uncorrected aerial estimate), and actual numbers may be twice this figure.

The density of moose in the eastern two-thirds of the Study Area (Minnesota Department of Natural Resources (MDNR) aerial census) gradually increases from north to south and from west to east. The highest density is in the tier of townships along the southern and eastern boarder of the area.

A winter census conducted by the Copper-Nickel Study located only one small "high density" wintering area in the southern portion of the Zone of Mineralization (1400km^2). The largest area of use was adjacent to Highway 1 and 2 in the northern portion of the area and east of Birch Lake and the Kawishwi River. Overall moose numbers within the 1400km^2 zone were estimated at 434.4 animals, or 0.28 moose/km^2 (estimated corrected for bias of aerial census)

The larger Study Area (5200km^2) contains 17.2 percent of the entire state moose range. A total of 13.5 percent of the area open to hunting in the northeast occur within the boundaries of the Study Area, or 3.6 of the land open for moose hunting in the state.

High density moose populations can only be maintained if large cutover areas containing large quantities of favorite shrub and tree browse are available.

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Forty to fifty percent of township - sized blocks should contain cutovers less then 20 years old, with five to fifteen percent spruce-fir, and thirty-five to fifty-five percent aspen-birch over 20 years old, and water. Logging within aspen-birch stands is considered the most beneficial to moose.

An estimated 90 percent of the moose diet on an annual bases in north-eastern Minnesota is provided by browse species. The leading food is willow, with aspen, paper birch, beaked hazel, fire cherry, and balsam fir also ranking high. The principle non-browse foods in this region are aquatic plants, including yellow pond lilly, wild rice and bur reed.

Sources of mortality for moose include wolves, man and "moose sickness", a nematode disease carried by, but not affecting white-tailed deer. This disease may be the single most important form of mortality on the Study Area.

Future moose numbers depend largely on the forest harvest practices in the region. If aspen-birch types are utilized more extensively then they are presently, large quantities of high quality browse will result. This could more than offset expected land withdrawls due to mining. If aspen-birch remain economically low or unavailable to the wood fiber industry, the regional moose population will decline from the current levels as the forest matures.

INTRODUCTION TO THE REGIONAL COPPER-NICKEL STUDY

The Regional Copper-Nickel Environmental Impact Study is a comprehensive examination of the potential cumulative environmental, social, and economic impacts of copper-nickel mineral development in northeastern Minnesota. This study is being conducted for the Minnesota Legislature and state Executive Branch agencies, under the direction of the Minnesota Environmental Quality Board (MEQB) and with the funding, review, and concurrence of the Legislative Commission on Minnesota Resources.

A region along the surface contact of the Duluth Complex in St. Louis and Lake counties in northeastern Minnesota contains a major domestic resource of copper-nickel sulfide mineralization. This region has been explored by several mineral resource development companies for more than twenty years, and recently two firms, AMAX and International Nickel Company, have considered commercial operations. These exploration and mine planning activities indicate the potential establishment of a new mining and processing industry in Minnesota. In addition, these activities indicate the need for a comprehensive environmental, social, and economic analysis by the state in order to consider the cumulative regional implications of this new industry and to provide adequate information for future state policy review and development. In January, 1976, the MEQB organized and initiated the Regional Copper-Nickel Study.

The major objectives of the Regional Copper-Nickel Study are: 1) to characterize the region in its pre-copper-nickel development state; 2) to identify and describe the probable technologies which may be used to exploit the mineral resource and to convert it into salable commodities; 3) to identify and assess the impacts of primary copper-nickel development and secondary regional growth; 4) to conceptualize alternative degrees of regional copper-nickel development; and 5) to assess the cumulative environmental, social, and economic impacts of such hypothetical developments. The Regional Study is a scientific information gathering and analysis effort and will not present subjective social judgements on whether, where, when, or how copper-nickel development should or should not proceed. In addition, the Study will not make or propose state policy pertaining to copper-nickel development.

The Minnesota Environmental Quality Board is a state agency responsible for the implementation of the Minnesota Environmental Policy Act and promotes cooperation between state agencies on environmental matters. The Regional Copper-Nickel Study is an ad hoc effort of the MEQB and future regulatory and site specific environmental impact studies will most likely be the responsibility of the Minnesota Department of Natural Resources and the Minnesota Pollution Control Agency.

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INTRODUCTION

Minnesota's moose population has been steadily increasing in recent years from the extremely low number that were present around the turn of the century. Peek (1971, p15-16) compiled a history of moose in northeastern Minnesota from various sources and concluded that this species was common in this region and in adjacent Quebec, Canada in the 1700's and early 1800's. By the 1870's and 80's, moose were scarce in both Cook and Lake Counties, and by 1885 only a few animals were thought to remain in the entire northern part of the state. Moose apparently shifted their range towards the northeast from further south and were considered common in northern Lake County again by 1912-1915.

Moose populations have fluctuated considerably in the Superior National Forest (SNF) over a 55 year period from 1915 to 1970 (Fig. 1). Peek (1971, p203) interpreted these highs and lows as being indicative of the importance of logging to moose densities in this region:

> "It is redundant to state that increases in this moose population appear to be correlated with logging activities, since this has so frequently been the case across North America and Eurasia. The increase in 1925-34 coincided with sawtimber harvests in the Cloquet Lake area (10 miles S, SE of Isabella, Minn.) . . . where moose populations have persisted since. The increase in the 1950's coincided with pulpwood harvests, primarily within the Boundary Waters Canoe Area (BWCA)."

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More recent aerial census figures from the Minnesota Department of Natural Resources (MDNR) (data presented and discussed later) indicate the moose population in northeastern Minnesota has remained relatively stable in the 1970's at about 2500 animals. Moose are currently distributed throughout the Study Area, but are more numerous in the eastern half of this area.

METHODS

MDNR aerial moose census data on the eastern two-thirds of the Study Area were compiled from the winter of 1959-60 to 1976-77 to reflect long-term density and distribution trends. A more detailed aerial census within the zone of mineralization was conducted by the Copper-Nickel Study during the winter of 1977-78. These data, other records from the MDNR and a literature review form the basis for this characterization report.

Aerial census techniques used to estimate moose populations in northeastern Minnesota by Peek et. al. (1976), the MDNR and the Copper-Nickel Study are modifications of the technique described in detail by Siniff et. al. (1964) and later modified for moose by Evans et. al. (1966). Briefly the procedure is to divide the census area into two or more strata based on animal density. Random plots are then intensively searched in each strata. Specifics are presented in Appendix A.

A correction factor is used to adjust aerial census data for animals concealed by vegetation. For example, only 34.2 percent of the white-tailed deer (Odocoileus virginianus) present on the Study Area were seen, requiring the use of a 2.92 correction factor (Appendix A).

Floyd suggests, based on work done by Le Resche and Raushe (1974) that a correction factor of 2 be applied to aerial moose census data for the area. When census data are presented in the text, we will indicate whether the density are corrected or uncorrected.

Additional information on moose was provided by observations made by field personnel of the Copper-Nickel staff. The location and number of animals seen are included in this report.

Forest types considered important to moose in the region, either presently or when harvested in the future, follow recommendations of Peek (1971) and Peek et. al. (1976). These types and assumptions we made in the habitat preference discussions that follow are listed below:

1. Recent cutover areas (20 years or less) in aspen, aspen-birch, and mixed (aspen-birch-fir-pine-etc.) are the key for producing and maintaining high moose densities.
2. Stand conversion in the future will be minimal. After harvest, stands will grow back to the same or a mixture dominated by the same species that are currently present.
3. Habitats dominated by brush, whether upland or lowland in nature, are preferred moose habitat types.
4. The long-term affect of upland conifer plantations on moose densities is considered neutral, neither causing an increase or decrease in animal numbers.

5. Lowland conifer stands are and will be more than adequate to meet late winter habitat requirements. Since these types do not provide the quality or quantity of browse required by high density moose populations on an annual basis, they are not considered critical to moose in the area.

RESULTS

DISTRIBUTION AND IMPORTANCE OF SPECIES

MDNR aerial moose census data for the eastern two-thirds of the Study Area are summarized in Fig. 2 for the period from 1959-60 to 1976-77. The reader is cautioned that these density estimates are means for an 18 year period with highly variable sampling intensities per township. In addition, local estimates may be seriously altered by hunting harvest and severe winters between any given year, while maturing vegetation has affected habitat use in some portions of the region more than others.

Considering the limitations of the data presented in Fig. 2, the estimates do show a gradual increase in moose densities from west to east and from north to south across the Study Area. The highest densities generally occur in the most southern and eastern tier of townships.

Floyd's (Appendix A) aerial census over the entire Study Area in 1977-78 found only one small "high density" wintering area in the southern portion of the region in contrast to the long-term trend represented in Fig. 2. The largest area of use was in the northeast region adjacent to Hwy. 1 and 2, and mainly east of Birch

Lake and the Kawishiwi River. Overall moose numbers within the entire zone of mineralization were estimated at 434.4 animals, or 0.28 moose/km^2. The areas of high moose density noted by the MDNR census (Fig. 2) and this study (Appendix A) should both be considered important to the local moose herd.

On a state basis the MDNR recognizes two distinct moose populations, one in the northwest and the other in the northeast. The northwestern population has more than doubled since 1962-63, while that in the northeast (the Study Area included) has remained relatively stable (Table 1). Currently each broad region contains approximately one-half of the state's total population of some 5879 animals (Table 1, uncorrected estimate). The 217.2 moose on the eastern one-third of the Study Area (uncorrected) represent 3.7 percent (217.2/5879 of the total herd (Appendix A). A population estimate for the entire Study Area is not available, but probably does not exceed five percent of the Minnesota herd.

Although it is difficult to estimate the exact size of the entire moose range, there are two approaches that can be used to determine the importance of the Copper-Nickel Study Area relative to the "principle" range within the state. One is to compare the proportion of Minnesota's 1976-77 aerial moose census area that is included within the Study Area. Table 2 indicates that 32.6 percent of the northeastern range and 17.2 percent of the entire state range is within the boundaries of the Study Area.

Another comparison was made using the zones open to moose hunters during the alternate-year moose season of 1977. These hunting zones generally reflect portions of the moose range where local populations are productive and self-sustaining. However, boundaries are established wherever possible along road, river or lake systems to facilitate zone identification by hunters and low-enforcement officers, alike. As a result, seldom do entire zones represent strictly biological goals for moose harvest. In addition, zones in the northwest in some farming areas may be purposefully extended to include low density moose range to cull animals causing damage in these agricultural regions.

A total of 13.5 percent of the total area of 14 northeastern zones in 1977 (Table 3) were within the boundaries of the Study Area (Fig. 3). In the state as a whole, 3.6 percent of the entire area open to moose hunting occurs within the Study Area (Table 3). These data indicate that only a relatively small proportion of the hunting area within the state is potentially affected. However, a large proportion of that available in northeastern Minnesota may be impacted.

Moose observations by Copper-Nickel personnel were restricted to the zone of mineralization (Fig. 4). The 22 records were scattered throughout this area, with the exception of four clumped on the St. Louis River near Norway Point. This area had a rich growth of water lily (Nuphar variegatum) and was apparently a favorite summer feeding site.

HABITAT REQUIREMENTS

Habitat preferred by moose varies from region to region in North American and depends on such variables as availability of cover type, snow depth and degree of crusting, temperature, nutritional requirements, seasonal behavior (especially associated with the rut), and others. High moose densities can deplete present and future coverage of browse species and even reduce the tree canopy in certain forest types (Hanson et. al. 1973).

The habitat discussion that follows relies heavily on the extensive findings of Peek (1971 and Peek et. al. 1976). The proximity of his research area at Isabella to ours allows us to apply his findings directly to the Study Area.

Peeks (1976) work stresses the importance of early successional stages to moose: "Area 1, a cutover comprised of large brush fields interspersed with balsam fir (Abies balsamea), black spruce (Picea mariana) and jack pine (Pinus banksiana) stands, was considered the best moose habitat on the Study Area. Areas 2 and 3 also were in extensively cutover areas and were considered above average moose habitats, but the former was more reforested to red pine (Pinus resinosa), jack pine and black spruce, while the latter contained more balsam fir and a taller shrub understory. The remaining areas were considered lower-than-average moose habitats and were comprised of lowland balsam fir - white cedar (Tsuja occidentalis) swamps (Area 4), 90-100 year-white pine (Pinus strobus) - red pine stands, aspen (Populus tremuloines and P. grandadentata), and white birch (Betula papvrifera) stands (Areas 6 and 8), an extensively logged and replanted area (Area 7), and an uncut 100-year-old jack pine and black spruce stand (Area 5)."

The relative importance of the large cutover, brushy Area 1 for sustaining a high moose population was attributed to the Tomahawk timber sale in this portion of the BWCA Portal Zone between the years of 1949-65 (Peek 1976, p8). Although average density on all eight census areas was 0.77 moose/km^2 (uncorrected), the density on this recently logged area was 1.93 moose/km^2, two and one-half times the average (Peek 1976, p60).

Tables 4 and 5 (from Peek et.al. 1976) indicate the relative use of specific forest types within the three broad habitat types of lowlands, uplands and plantations. The authors summarized the habitat requirements of moose by stating that:

> "On a yearlong basis, 60 percent of the track locations were in uplands, 30 percent in lowlands, and 10 percent in plantations. Use of uplands was proportional to occurrence except in midwinter, while lowlands were used more frequently than expected from July through mid-October. Plantations were used less frequently than expected during July through early September and the rut. Upland communities dominated by aspen, white birch, black spruce, and balsam fir received about 90 percent of the observed use" (p56). These upland sites were often sparsely stocked and included cutover areas (p54). "Stands dominated by jack pine, red pine and white pine received only limited use, although no selection for or against pines was especially evident. Upland sites dominated by deciduous species were selected over spruce-fir in late summer and early winter, while the opposite was apparent in midwinter; at other times, no preference for one type over another was apparent.

Lowland communities dominated by black spruce and balsam fir received more use than white birch and aspen stands. Preference for deciduous stands was evident in June and early winter, while preference for lowland conifers occurred in midwinter" (p56).

Peek found that mostly mature upland conifer-deciduous stands dominated by fir-spruce were used most often during the most severe winters, with lowland use also increasing during this period. This same usage trend of uplands over lowlands in winter was noted in Nova Scotia by Telfer (1967). Conifers are an important part of this winter upland cover. Most moose beds were found under spruce or fir trees in the bowl-shaped, shallow snow areas under these dense canopier (Peek, 1971, p137). Mature stands of aspen and aspen-willow (Salix) may also serve as winter cover if conifer-deciduous stands are limited (Phillips and Berg 1973). By mid-April moose left these old-aged stands in northwestern Minnesota for low, open willow types.

Pine plantations, especially during the first 10-15 years after establishment, can produce high quality and diverse browse species for moose. The values of plantations to moose is inversely related to the silvicultural success of the plantation (increased stocking density, decreased use by moose; Peek 1971, p202). If stocking rate is low, the affect of plantations can be considered neutral, neither increasing or decreasing moose density in an area. However, high stocking rates and stand releasing (hand or herbicide) have a negative affect on moose densities. Peek (1976, p59) suggested that on prime moose range, one habitat management objective should be to utilize only the most suitable sites for pine planations, managing aspen where possible, and not converting types to pine after harvest.

The authors (Peek et. a. 1971, p59) suggest that "prime" moose habitat will be produced if the following types and proportions of age classes are present:

> "Moose movements, food habits, habitat selection, and census data all indicate that the primary or key moose habitat appears to be the open cutover used in early summer and late fall. Also, spruce-fir and more mature aspen-birch communities, plus the aquatic areas, were preferred habitats at other times of the year. Based on this field study, it appears that areas of highest potential for moose habitat management are township sized blocks within the current high-density range, with the following composition:
>
> 1. Cutover less than 20 years old--
>
>   --40-50 percent
>
> 2. Spruce-fir--
>
>   --5-15 percent
>
> 3. Aspen-white birch over 20 years old--
>
>   -- 32-55 percent & water
>
> Cutting should be done where white birch and aspen may be expected to regenerate naturally. Current economic conditions indicate that aspen may become valuable enough to facilitate such management. If cutting units are restricted in size, they should be placed as close

to each other as possible to create blocks of approximately 80 HA-l.c., a size which appears characteristic of the present prime moose range."

The potential of plant communities in various watersheds to provide prime moose habitat is evaluated by two ranking systems in Table 6. Only watersheds in the eastern portion of the Study Area are considered, but the technique could be applied to the entire region. The habitats selected for the comparisons are those suggested by Peek et. al. (1976, discussed above), and all age classes are included. Spruce and spruce-fir conifer lowlands used heavily during severe winters by moose are the principal types omitted from this discussion because they are generally wide-spread and available to moose.

Field data already presented indicated where the highest moose densities may be found. Table 6 predicts where they may be found if the proper proportion of cutover and mixed age classes (primarily of aspen and aspen-birch) are present in the respective watersheds. The future harvest and management of aspen-birch forest on the Study Area will largely determine the future density and distribution of moose in this region.

Some of the most extensive aspen-birch forest are located in the St. Louis and White Face watersheds. Fifty-one and 57 percent of each watershed, respectively, is aspen-birch, and they are ranked No. 1 and 3 in Table 6. They also contain some of the highest long-term moose densities (Fig. 2) for this eastern portion of the Study Area. Other watersheds that have high potential or currently contain high wintering moose densities are South Kawishiwi River, Partridge, Embarass and Nip Creek (Table 6, Fig. 2, Appendix A).

FOOD REQUIREMENTS

An estimated 90 percent of the moose diet on an annual basis in northeastern Minnesota is provided by browse species (Peek 1971; Abstract). Predominant species include willows, aspen, paper birch, beaked hazel (Corylus cornuta) and fire cherry (Prunus pensylvanica) (Table 7). Peek (1971) reviewed a number of papers from other moose ranges in North America and presented the five most important browse species from these studies (Table 8). The reader should be aware of the obvious problems of directly comparing food surveys from different areas.

Peek (1971, p96) concluded that "with the exception of areas where fir and white birch do not occur or are sparse, these two species were probably the major species for moose on eastern range " (See Table 8). Bergerud et al. (1968, Newfoundland) concluded that "the diet of balsam fir and white birch was considered adequate to maintain a healthy moose population." An earlier study in Newfoundland (Pimlott 1953) showed that within burned and logged areas white birch was used most intensively, with balsam fir use exceeding birch use in areas with higher relative moose densities. Balsam fir was also used extensively in winter in Quebec, Canada (Crete et. al. 1975; p371), and was found to contain higher levls of asorbic acid and carotene than deciduous species in late winter (Cowan et. al. 1950, Canada).

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Paper birch was ranked in the top three food items in various regions (Table 8), and was fifth (based on aggregate percent) and third (Importance Value (I.V.)) in northeastern Minnesota (Table 7). Birch was used on a year-long basis. The future abundance of young age classes of birch is directly tied to the management of trembling aspen, another important food species and ranking second (Table 7) on the Study Area. All three of these species (balsam fir, paper birch and trembling aspen) can sustain heavy browsing pressure and still persist.

The most important food on a year-round basis for moose in northeastern Minnesota are willows, providing 26 percent of all browse consumed (Table 7). Peek (1971 p85) noted that "the upland willows, pussy willows (Salix discolor), Bebb's willow (S. bebbiana), the tall prairie willow (S. humilus), received more use than sand bar willow (S. interior) or bog willow (S.pedicellaris), which are characteristic of poorly drained sites..." Peek goes on to say that pussy and Bebb are preferred, and cites Lakela (1965) as stating that both are abundant in northeastern Minnesota.

Peek (1971, p83) summarized the important moose browse species in northeastern Minnesota and the season(s) of peak use:

> Willows were the most important browse year-long, but received greatest use in September through December... Quaking aspen was the most important browse species in June, then declined through late summer, fall and early winter, then increased in mid-winter. White birch ranked third in importance year-long remaining relatively constant in the diet throughout the year. Beaked hazel, fourth in importance, was most intensively used in mid-winter.

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> Fire cherry was important primarily in summer and early fall. Red-oiser dogwood (Cornus stolonifera) was important in fall. June berries (Amelanchier spp.) and mountain ash (Sorbus americana), seventh and eighth in importance, occurred at low but constant levels in the diet year-long. Balsam fir was ninth in importance and was almost entirely a winter forage. Mountain maple (Acer spicatum) was used most commonly in late summer and again during the winter."

The principal non-browse food utilized by moose in northeastern Minnesota are aquatic plants (Peek)(1971) found yellow pond lily (Nuphar variegatum) wild rice (Zizania aquatica) and bur reed (Sparganium angustifolium) were the most heavily utilized, in that order. These aquatic macrophytes are most intensively used in June, and recent studies on Isle Royale (Jordan et al. 1973) suggest that aquatics supply 88 percent of the annual sodium requirement for moose and may be a factor in population regulation.

SOURCES OF MORTALITY

The two principle predators of moose in northeastern Minnesota are timber wolves (Canis lupus) and man. Neither are particularly effective. Studies by Mech (Mech 1977) have shown that very few moose are taken by wolves, their diet consisting mainly of white-tailed deer. A small number moose were taken when deer were extremely scarce during the winter period.

Harvest by man is also very limited and well within reproductive capabilities of this big game species. Four alternate-year lottery based hunting seasons since 1971 have taken about 10 percent of the herd each season (Berg, MDNR, Res. Biologist, Grand Rapids; per. comm.). State populations have remained stable (northeast) or actually increased (northwest) during these four hunting seasons (Table 1). It is unlikely that man or wolves will become a larger threat in the future.

Likewise, moose are much better equipped than deer to survive the normally severe winters of northeastern Minnesota. Deer movements are severely restricted when snow depths reach 45cm or more, while moose are restricted only after accumulations have reached twice that amount. Limited access to browse caused by deep snow, combined with the traditional winter yarding tendency of deer (this behavior is not characteristic of moose), has caused elevated winter mortality and reduced productive success in deer populations (Mooty 1971). The winter of 1968-69, one of the most severe in several decades, caused extensive deer losses throughout the state, but especially in northern Minnesota. By contrast, Peek (1971, p47) found no evidence that this same winter had any major affect on moose in northeastern Minnesota. Weather during this winter "...apparently did not appreciably affect fertility on fecundity of most adults because percent calves and twins did not change over the three years."

Biologists have expressed concern over the possibility of an increase in "moose sickness" disease as the population in the state builds. This disease is caused by the nematods Pneumostrongylus tenuis. White-tailed deer are the host and are apparently unaffected, but the infection is lethal to moose (Loken et. al. 1965, Karns 1967, Anderson 1964). Karns suggested that the increase in deer numbers in northeastern Minnesota in the early 1900's caused the incidence of <u>P. tenuis</u> to increase and moose populations to decline in the 1920's and 1930's. Both Karns and Telfer (1967, p424) have suggested that ecological separation of moose and deer on winter range (especially late winter) will reduce the incidence of this disease. Although the winter range of these two species appears to be largely separated on the eastern portion of the Study Area (App. A), Peek's (1976, p24) data from nearby Isabella suggest that <u>P. tenuis</u> was a major source of mortality among animals under 5 years old. The future abundance and distribution of moose in northeastern Minnesota may well depend upon fluctuations in this source of natural mortality.

IMPACTS

The major impact to the moose population residing in the Study Area will be from habitat lost to direct land development. It is clear from data presented in this paper that major land-use changes, especially in the eartern one-third of the Study Area, will eliminate a substantial portion of Minnesota's principal moose range.

An increase in the local human population may also increase the incidence of road-kills, poaching and harashment of moose by dogs. The placement of private residences and mining operations (e.g., open pit mines, tailings ponds, housing developments, fenced highways, and etc.) may disrupt seasonal movement patterns in the Study Area. A specific reference concerning this latter point is provided from research conducted by Phillips and Berg (1973) in northwestern

PRELIMINARY DRAFT REPORT, SUBJECT TO REVIEW of the fall-winter-spring movements by moose could be considered migrations. The affect of large physical barriers on seasonal movements of moose in northeastern Minnesota has not been studied.

The benefit to moose from human activities clearly centers on the extent and type of forest harvest practices that prevail in the region in the future. More complete utilization of mature and over-mature aspen, aspen-birch and mixed forest types for pulp, residential and commercial firewood, building material and etc. would have a beneficial affect and produce high-quality, high-density moose range. This may compensate, at least in part, for lands withdrawn for mining. If these forest types continue to mature due to low market demand and/or price, favorably moose habitat will decline. Hectarage lost to succession will be additive to hectarage lost to mining.

If pollutants are added to the terrestrial or aquatic ecosystems that seriously reduce the density, vigor or distribution of major food sources such as species of willow, birch, aspen, hazel, cherries, dogwoods, maples, and aquatic macropaytes, regional moose populations will suffer. Paramount would be affects to the aspen and aspen-birch ecosystem.

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TABLE 1

Aerial moose census for northwestern and northeastern Minnesota, 1962-63 to 1976-77[A]

Census Period	Calculated Moose Population: Northwest	Calculated Moose Population: Northeast
1962-63[1]	1,450±350	2,760±640
1963-64	1,450±350	2,880±520
1964-65	- - - - -	3,000±770
1965-66	1,840±290	- - - - -
1966-67	1,900±400	2,830± ?
1967-68	1,835±260	NO CENSUS
1968-69	1,620±220	- - - - -
1969-70	N O	C E N S U S
1970-71	2,040±430	2,560±430
1971-72*	2,350±?	2,800±350
1972-73[2]	3,140±230	- - - - -
1973-74*	2,760±210	2,210±270
1974-75	3,540±360	2,190±240
1975-76*[3]	2,415±245	2,400±370
1976-77	3,039±451	2,840±510

A From MDNR data provided by B. Berg. Numbers are actual observations and are not corrected for visibility factor.

* Post hunt census

1 First year with 2 strata, 80 percent confidence limits (CL)

2 First year with 5 strata, 95 percent confidence limits

3 Area restratified, 95 percent confidence limits

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TABLE 2

The proportion of Minnesota's 1976-77 aerial moose census area included within the Copper-Nickel Study Area

	Northwest	Northeast	Total
Area available for census in the state[A]	14320km^2	15959km^2	30279km^2
Proportion within 5200km^2 Study Area	---------	5200km^2/15959km^2= 32.6 %	5200km^2/ 30279km^2= 17.2 %

A Data provided by B. Berg, MDNR

TABLE 3

The amount and proportion of Minnesota's 1977 moose hunting zones included within Study Area

Northeast Zones

Zone Number	Area (km²) A	Amount of Zone within Study Area (km²)
20	395	25
21	542	0
22	320	320
23	322	98
24	350	0
25	460	0
26	428	0
27	420	0
28	500	0
29	385	205
30	415	0
31	530	92
32	362	0
33	278	32
SUBTOTALS	5707km²	772km²
PERCENT	-----	13.5% (772 km²/ 5707km²)

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TABLE 3 (Cont.)

Northwest Zones

Zone Number	Area (km^2)	Area of Zone within Study Area
1	3520	0
2	338	0
3	2902	0
4	755	0
5	2335	0
6	975	0
7	718	0
8	1378	0
9	1322	0
10	1702	0
SUBTOTALS	15945km^2	0km^2

TOTALS (Both Northeast and Northwest Zones)	21652km^2	772km^2
PERCENT	-----	3.6% (772km^2/ 21652km^2)

A DOT grid placed over MDNR hunting zone map with boundaries of Study Area indicated to compute area.

TABLE 4

Percentage of moose tracks recorded in upland, plantation, and lowland habitats dominated by various tree species/percentage occurrence of tree species as dominants along observation routes during seasonal periods from early summer through early winter. Total numbers of tracks recorded for each season are shown in parentheses.[A]

Dominant Species	Early Summer	Mid-Summer	Late Summer	Prerut	Rut	Postrut	Early Winter
	(302)	(806)	(278)	(319)	(456)	(180)	(184)
Uplands	63	60	71	62	59	65	61
Balsam fir	41/43	38/42	18/40	35/42	43/40	38/48	44/40
White birch	19/20	20/19	26/19	25/19	22/22	21/15	30/19
Black spruce	3/3	7/3	18/4	11/4	7/3	16/3	4/3
Jackpine	3/3	4/3	4/5	4/5	3/5	6/2	0/5
Red pine/white pine	0/3	1/3	0/3	0/2	1/3	1/2	0/3
Quaking aspen	24/21	25/20	34/22	18/21	22/21	15/15	23/22
Other species	10/8	6/9	1/7	8/8	3/6	3/16	0/8
Plantations	12	10	6	10	8	12	11
Balsam fir	14/4	15/3	13/2	19/3	5/3	23/3	11/2
White birch	14/12	5/12	0/13	3/14	5/14	10/18	0/13
Black spruce	14/13	9/11	13/7	13/10	14/12	14/9	0/9
Jackpine	43/34	34/33	25/30	42/30	46/33	24/28	47/32
Red pine/white pine	5/24	16/26	0/29	3/24	5/26	24/24	0/27
Quaking aspen	11/13	17/13	25/29	13/18	19/12	5/16	42/16
Other species	0/1	5/1	25/1	6/1	5/1	0/1	0/1
Lowlands	25	29	23	28	32	23	28
Balsam fir	25/31	19/29	11/30	23/32	24/27	31/40	14/29
White birch	18/8	29/9	5/8	19/8	18/9	15/6	24/7
Black spruce	47/48	35/47	63/50	48/46	45/51	39/39	41/49
Jackpine	0/0	5/1	5/3	3/3	3/0	0/0	4/0
Red pine/white pine	0/3	0/4	0/0	0/0	1/3	0/2	0/4
Quaking aspen	1/2	9/2	13/2	4/2	5/2	10/1	16/2
Other species	8/8	3/0	3/7	2/10	3/8	5/12	2/8

[A](from Peek 1976; his table no. 17).

TABLE 5

Percentages of moose tracks within uplands, plantations, and lowlands according to dominant overstory species during the deep snow and milder periods of the 1969 and 1970 winters. Numbers of tracks observed are in parentheses[A]

Major Overstory Species	14 Jan–26 Feb 1969			25 Feb–27 Mar 1970			Both Winters		
	Lowland	Plantation	Upland	Lowland	Plantation	Upland	Lowland	Plantation	Upland
				Severe Winter Periods					
	(81)	(38)	(258)	(36)	(44)	(136)	(117)	(82)	(394)
Balsam fir	23	0	39	33	0	56	26	0	45
White birch	12	18	9	14	2	0	13	10	6
Black spruce	46	18	26	39	7	13	44	12	21
Jackpine	6	24	7	0	59	0	4	43	5
Red pine/white pine	2	29	4	0	25	0	2	27	3
Quaking aspen	2	5	14	11	7	21	5	6	16
Other species	7	5	2	3	0	10	6	2	4

Major Overstory Species	31 Mar–4 Apr 1969			9 Jan–17 Feb 1970			Both Winters		
	Lowland	Plantation	Upland	Lowland	Plantation	Upland	Lowland	Plantation	Upland
				Mild Winter Periods					
	(15)	(8)	(69)	(19)	(65)	(156)	(34)	(73)	(22)
Balsam fir	27	0	10	47	8	38	38	7	30
White birch	13	0	26	0	6	10	6	5	15
Black spruce	53	0	16	37	6	12	44	5	13
Jackpine	0	13	4	5	22	7	3	21	6
Red pine/white pine	0	63	0	0	15	4	0	21	3
Quaking aspen	7	25	43	11	42	27	9	40	32
Other species	0	0	0	0	2	3	0	1	2

[A] (from Peek 1976; his table no. 21).

TABLE 5

Percentages of moose tracks within uplands, plantations, and lowlands according to dominant overstory species during the deep snow and milder periods of the 1969 and 1970 winters. Numbers of tracks observed are in parentheses[A]

Major Overstory Species	14 Jan–26 Feb 1969			25 Feb–27 Mar 1970			Both Winters		
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PRELIMINARY DRAFT REPORT, SUBJECT TO REVIEW

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	Lowland	Plantation	Upland	Lowland	Plantation	Upland	Lowland	Plantation	Upland
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[A](from Peek 1976; his table no. 21).

TABLE 5

Percentages of moose tracks within uplands, plantations, and low-lands according to dominant overstory species during the deep snow and milder periods of the 1969 and 1970 winters. Numbers of tracks observed are in parentheses[A]

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[A](from Peek 1976; his table no. 21).

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Percentages of moose tracks within uplands, plantations, and lowlands according to dominant overstory species during the deep snow and milder periods of the 1969 and 1970 winters. Numbers of tracks observed are in parentheses[A]

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	Lowland	Plantation	Upland	Lowland	Plantation	Upland	Lowland	Plantation	Upland
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Major Overstory Species	31 Mar–4 Apr 1969			9 Jan–17 Feb 1970			Both Winters		
	Lowland	Plantation	Upland	Lowland	Plantation	Upland	Lowland	Plantation	Upland
Mild Winter Periods									
	(15)	(8)	(69)	(19)	(65)	(156)	(34)	(73)	(22)
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Other species	0	0	0	0	2	3	0	1	2

[A](from Peek 1976; his table no. 21).

Table 6. Relative Importance of Present and Future Moose Habitat by Watersheds.*

Key: Amount of area in each cover-type from Minesite data base (MDNR) (calculated from 1 hectare cells).

A - Rank no. 1 assigned to watershed with highest percentage of vegetation in present or potential moose habitat. Relative area of watershed not included in this ranking scheme.

B - Rank no. 1 assigned to watershed with largest area of vegetation of all watersheds in present or potential moose habitat.

*Derived from MDNR Data Base.

Table 6-cont.

Vegetation Type	South Kawishiwi	St. Louis
	Ha	Ha
Aspen-Birch	11478	12336
Mixed Aspen-Birch-Fir-Pine-etc	1310	89
Northern Hardwoods	0	0
Grass	3	51
Hazel, Pine Cherry, etc	76	39
Marsh	276	190
Lowland Shrubs	777	1830
Total potential moose habitat (Ha)	13920	14535
Percent ot total watershed area containing potential moose habitat	59.4	59.8
Watershed $Rank_A$	5	4
Watershed $Rank_B$	2	1
Total watershed area, open water area included (Ha)	23426	24269

Table 6-cont.

Vegetation Type	Isabella	Stony River
Aspen-Birch	3079	3115
Mixed Aspen-Birch-Fir-Pine etc.	224	609
Northern Hardwoods	0	0
Grass	0	0
Hazel, Din Cherry, etc	22	56
Marsh	45	111
Lowland Shrubs	145	193
Total potential moose habitat(Ha)	3515	4084
Percent of total watershed area containing potential moose habitat	45.2	56.8
Watershed rank A	10	6
Watershed Rank B	8	6
Total watershed area, open water area included (Ha)	7770	7188

Table 6-cont.

Vegetation Type	Partridge	Whiteface
Aspen-Birch	5695	7077
Mixed Aspen-Birch-Fir-Pine etc.	119	130
Northern Hardwoods	0	0
Grass	59	1
Hazel, Din Cherry, etc.	58	0
Marsh	54	4
Lowland Shrubs	982	954
Total potential moose habitat (Ha)	6967	8166
Percent of total watershed area containing potential moose habitat	42.4	65.5
Watershed rank A	12	3
Watershed Rank B	4	3
Total watershed area, open water area included (Ha)	16424	12472

Table 6 - cont.

Vegetation Type	Embarrass	Dunka River
Aspen-Birch	1375	3525
Mixed Aspen-Birch-Fir-Pine etc.	8	1122
Northern Hardwoods	0	0
Grass	3	82
Hazel, Din Cherry, etc	23	157
Marsh	3	73
Lowland Shrubs	21	389
Total potential moose habitat (Ha)	1433	5348
Percent of total watershed area containing potential moose habitat	75.5	36.9
Watershed rank A	2	14
Watershed rank B	14	5
Total watershed area, open water area included (Ha)	1899	14489

Table 6 - cont.

Vegetation Type	North River	Colvin Creek
Aspen-Birch	641	2264
Mixed-aspen birch-fir-pine-etc	27	92
Northern Hardwoods	0	0
Grass	20	3
Hazel, Din Cherry, etc.	0	9
Marsh	5	25
Lowland shrubs	838	229
Total potential moose habitat (Ha)	1531	2622
Percent of total watershed area containing potential moose habitat	22.7	47.9
Watershed rank$_A$	15	7
Watershed rank$_B$	12	10
Total watershed area, open water area included (Ha)	6755	5476

Table 6-cont.

Vegetation Type	Argo Creek	Sand River
Aspen-Birch	2835	169
Mixed aspen-birch-fir-pine-etc.	249	0
Northern Hardwoods	0	0
Grass	89	0
Hazel, Din Cherry, etc.	6	0
Marsh	26	1
Lowland Shrubs	321	64
Total potential moose habitat (Ha)	3526	234
Percent of total watershed area containing potential moose habitat	45.3	15.2
Watershed Rank A	9	16
Watershed Rank B	7	16
Total watershed area, open water area included (Ha)	7778	1539

Table 6-cont.

Vegetation Type	Nip Creek	Denley Creek
Aspen-Birch	2460	1711
Mixed apsen-birch-fir-pine-etc.	15	75
Northern Hardwoods	0	0
Grass	0	0
Hazel, Din Cherry, etc.	0	6
Marsh	85	61
Lowland Shrubs	269	130
Total potential moose habitat (Ha)	2829	1983
Percent of total watershed area containing potential moose habitat	39.8	43.0
Watershed Rank A	13	11
Watershed Rank B	9	11
Total watershed area, open water area included (Ha)	7101	4607

Table 6-cont.

Vegetation Type	Kawishiwi River	Bear Island River
Aspen-Birch	1280	307
Mixed aspen-birch-fir-pine-etc.	112	88
Northern Hardwoods	0	0
Grass	0	0
Hazel, Din Cherry, etc.	0	0
Marsh	17	0
Lowland Shrubs	48	44
Total potential moose habitat(Ha)	1457	439
Percent of total watershed area containing potential moose habitat	81.1	45.6
Watershed $Rank_A$	1	8
Watershed $Rank_B$	13	15
Total watershed area, open water area included (Ha)	1795	963

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TABLE 7 Summary of browse species utilization and importance values with rankings for top ten species throughout the year, northeastern Minnesota, obtained by examination of moose feeding sites.[A]

	JUNE-SEPTEMBER				OCTOBER-DECEMBER				JANUARY-APRIL				YEAR-LONG				
	AGG. % USE	RANK	IMP. VAL.	RANK	AGG. % USE	RANK	IMP. VAL.	RANK	AGG. % USE	RANK	IMP. VAL.	RANK	AGG. % USE	RANK	IMP. VAL.	RANK	SEASON OF HIGHEST USE
Balsam fir	±	-	-	-	1.6	9	.056	7	10.8	3	.103	4	4.8	7	.052	9	winter
Red maple													0.8		.009		winter
Mountain maple	6.1	5	.046	6	1.2	-	.023	-	5.2	7	.052	9	4.3	8	.043	10	summer
Alders					1.5	10	.046	10					2.1	-	.039	-	fall
Juneberries	1.6	9	.037	7	4.3	6	.049	8	5.0	8	.080	7	3.8	9	.058	7	winter
Yellow birch													0.1	-	.001	-	winter
White birch	12.3	3	.133	4	2.6	8	.084	4	8.1	6	.083	6	7.7	5	.098	3	year-long
Leatherleaf													0.1	-	.001	-	winter
Beaked hazel	0.3	10	.008	10	15.5	3	.098	3	19.7	2	.132	2	12.6	3	.085	4	winter
Round leafed dogwood													1.0	-	.008	-	winter
Red-osier	2.4	8	.030	9	17.6	2	.143	2	8.3	5	.086	5	8.6	4	.078	6	fall
Bush honeysuckle													0.1		.002		summer
Labrador tea													0.1		.001		fall
Black spruce													0.1		.001		winter
Jackpine													0.2		.008		fall-winter
Red-white pine													0.2		.004		winter
Balsam poplar													0.1		.014		winter
Quaking aspen	32.1	1	.228	2	6.5	4	.065	6	10.6	4	.104	3	15.8	2	.133	2	summer
Fire cherry	10.9	4	.144	3	6.1	5	.074	5	3.2	10	.046	10	6.4	6	.084	5	summer
Chokecherry													1.2		.023		
Mountain ash	2.9	7	.055	5	3.6	7	.046	9	3.9	9	.058	8	3.5	10	.053	8	
Roses													0.1		.001		fall
Raspberries													0.1		.001		
Willows	26.2	2	.236	1	32.9	1	.237	1	20.6	1	.145	1	26.0	1	.200	1	all year
Red-berried elder													0.1		.001		winter
White cedar													0.1		.001		winter

A. Table 18-from Peek 1971

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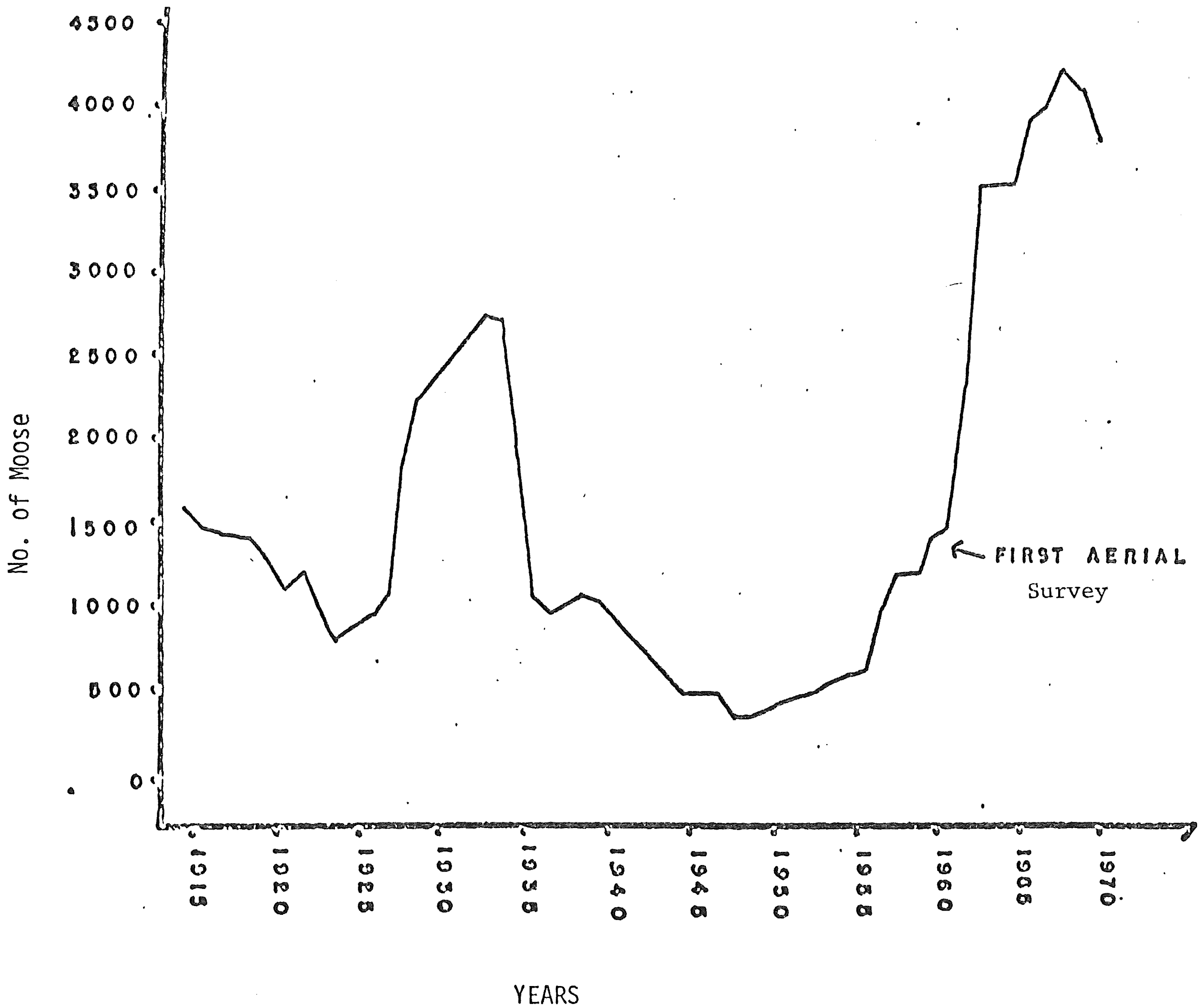
TABLE 8 Important browse species to moose from ten locations in eastern North America. A

REFERENCE	DATE	AREA	FIVE MOST IMPORTANT BROWSE SPECIES IN ORDER OF IMPORTANCE	REMARKS
This study	1971	Northeast Minnesota	Willows, aspen, white birch, beaked hazel, fire cherry	Moderately high moose population feeding site examination technique.
Aldous & Krefting	1946	Isle Royale	Aspen, white birch, balsam fir, mountain ash, willows	High moose population (1945) Browse survey technique
Krefting	1951	Isle Royale	Balsam fir, white birch, mountain ash, aspen, willows	1948 higher moose population than 1945
Krefting	1951	Isle Royale	White birch, aspen, red-osier, willows, mountain ash	1950 lower moose population than 1945
Peterson	1953	St. Ignace Island, Ont.	Balsam fir, white birch, mountain ash, red-osier, mountain maple	1947-48 most important species rather than most palatable
Dyer	1948	Maine	Balsam fir, mountain maple, mountain ash, white birch, fire cherry	1940's, browse survey technique
Telfer	1967	Nova Scotia	Mountain maple, yellow birch, sugar maple, red maple, Canada honeysuckle	1963 light browsing pressure, stem counts in spring (his Fig.3)
Pimlott	1953	Newfoundland	White birch, balsam fir, mountain maple, mountain ash, fire cherry	Stem count method, heavy browsing pressure
Dodds	1960	Newfoundland	Balsam fir, white birch, raspberry, elderberry, juneberries.	High moose density, cutover area 1953, 56, 57.
Dodds	1960	Newfoundland	Balsam fir, willows, alders, mountain maple, rhododendron	Low moose density, stem count method.

A. Table 21-from Peek 1971.

Figure 1. Moose population estimates based on Superior National Forest Records[A]



[A] (from Peek 1971, His Fig. 1, p2)

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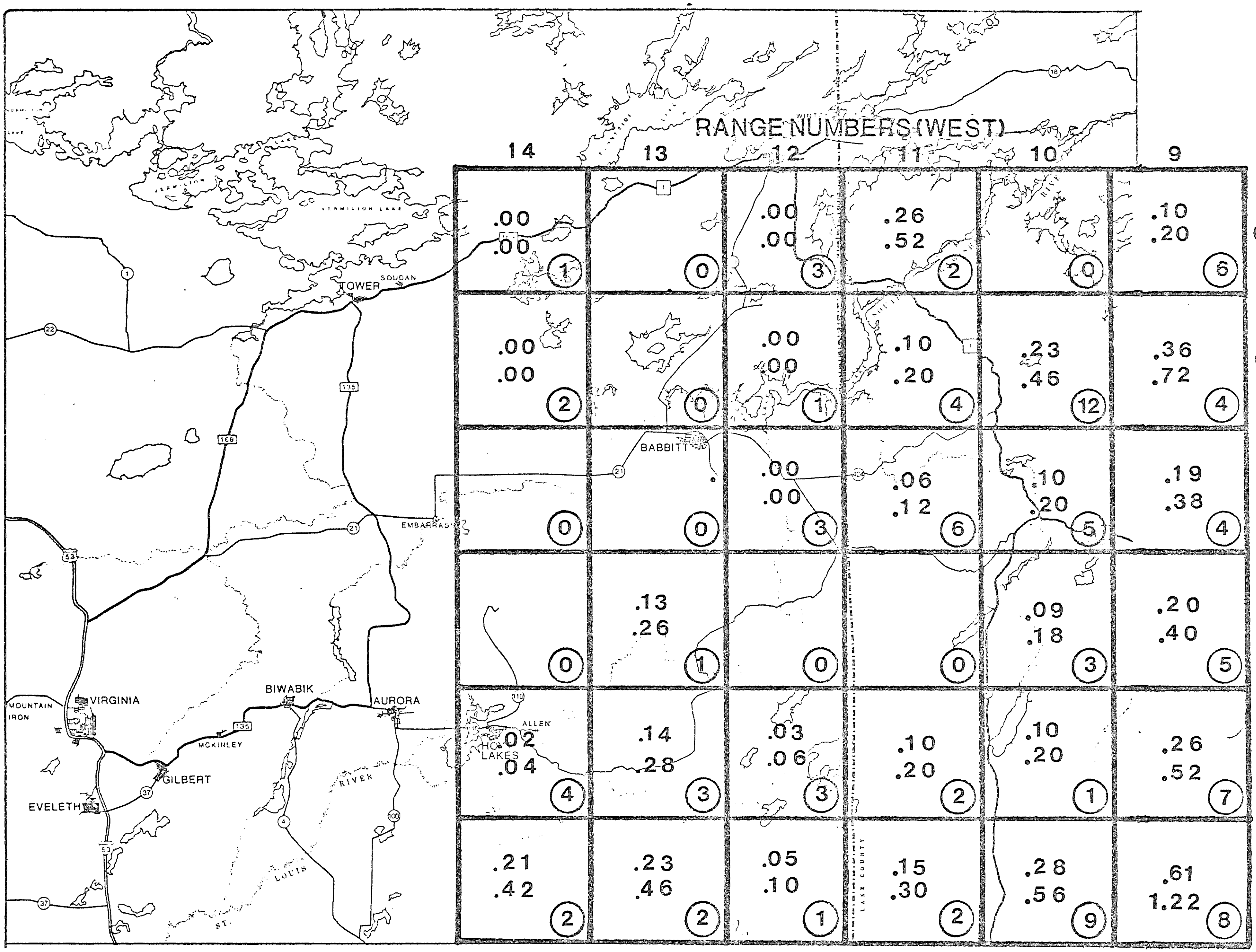
Figure 2. Winter moose densities on the eastern two-thirds of Study Area from MDNR aerial census (1959-60 through 1976-77)A.



A. Data provided by B. Berg (Res. Biologist, MDNR, Grand Rapids). Top value is actual mean number of of moose observed per km^2. Bottom value is mean adjusted by the visability correction factor (e.g. actual number observed x 2). Circled values are the number of times the township or portions of the township were censused. No census conducted during 1967-68 and 1969-70.

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Figure 3. Distribution of 1977 Moose Hunting Zones on Study Area[A]

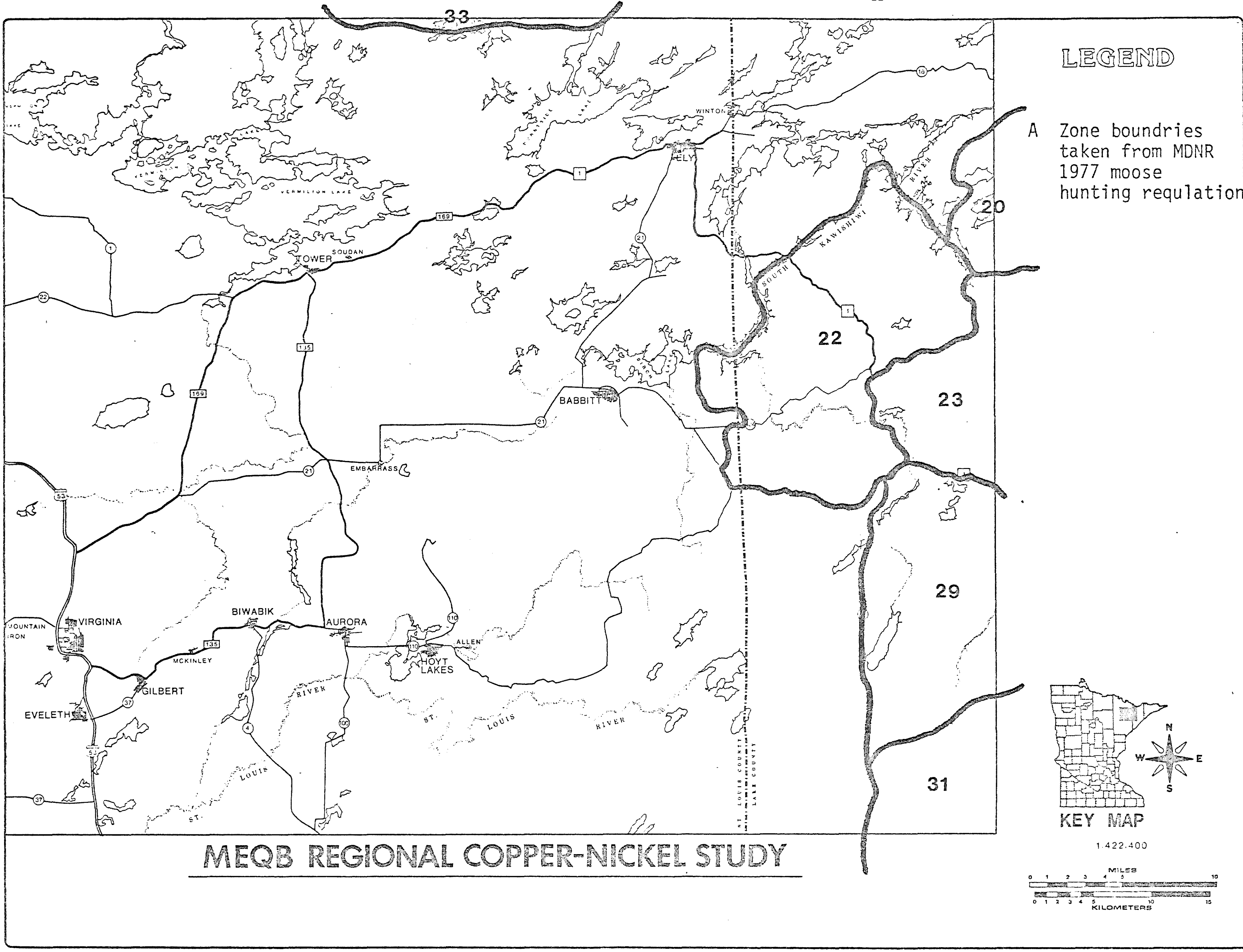
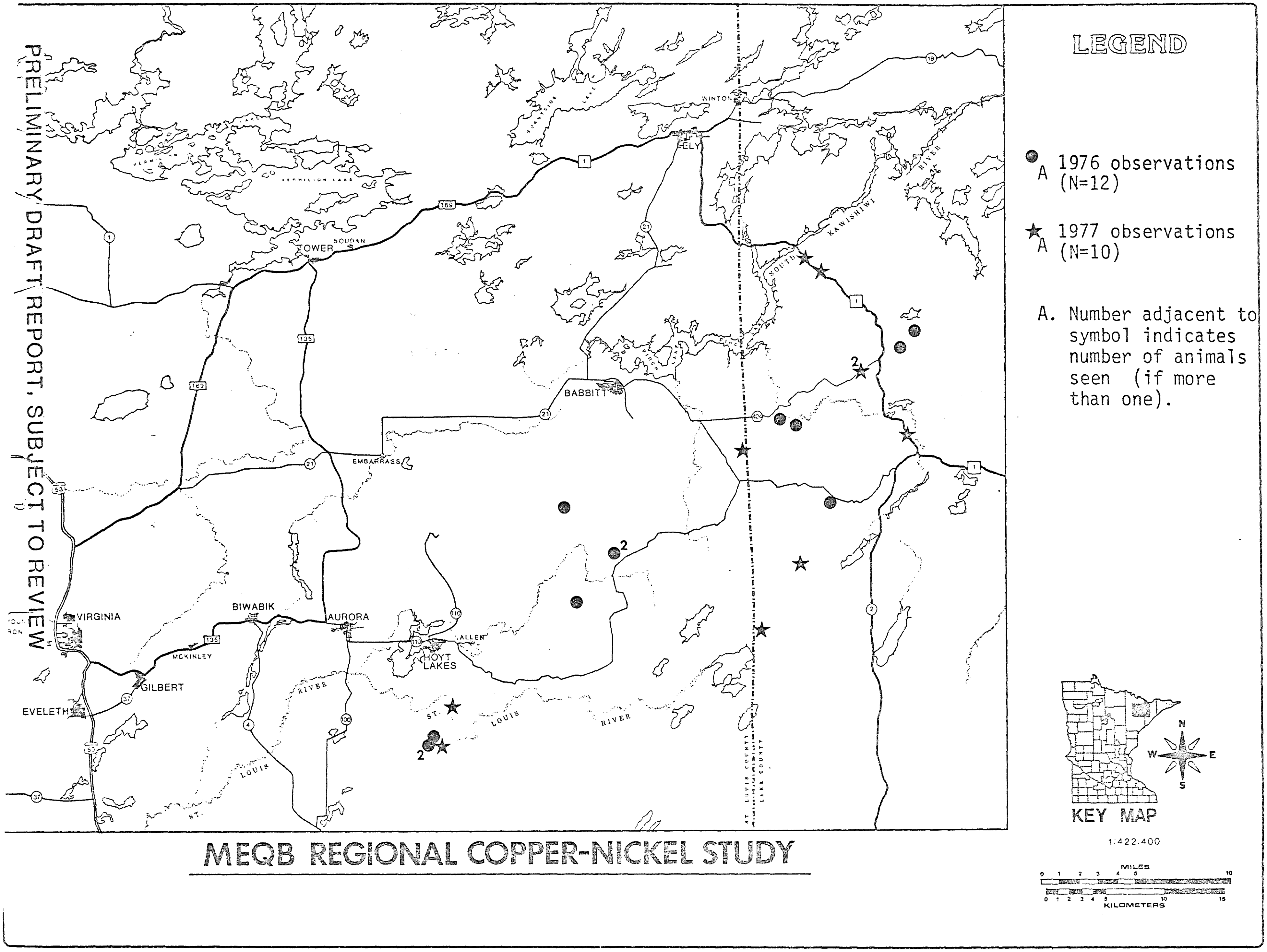


Figure 4. Moose observations made by members of the Copper-Nickel Study [A]



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APPENDIX A

WINTER DENSITIES AND DISTRIBUTION

OF

DEER AND MOOSE IN NORTHEASTERN MINNESOTA

Theodore J. Floyd [1/]

Department of Entomology, Fisheries, and Wildlife

University of Minnesota

St. Paul

Abstract: An aerial census for deer (Odocoileus virginianus) and moose (Alces alces) was completed in the winter of 1977-78 in northeastern Minnesota. A stratified random sampling technique with optimal allocation of sample plots was used. Uncorrected census results were 0.8 deer and 0.1 moose per square kilometer. The accuracy of the census was improved for deer by estimating numbers of animals missed within census plots. Moose results were adjusted using values from the literature. Corrected results are 2.3 deer and 0.3 moose per square kilometer. Deer and moose distributions were determined from aerial transects flown prior to the census. Distribution patterns and population densities may not be valid for times of the year other than the census period because of seasonal habitat changes.

1/ Current mailing address: 18 East Booundary Street,
Ely, Minnesota 55731

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Defining strata requires prior knowledge of distributions and densities of the population.

After strata have been defined, sample sizes must be allocated for each stratum. Cochran (1967) defines two types of sample allocation: proportional and optimal. Optimal allocation is desirable when large differences exist between stratum means and is made proportional to both the stratum area and its variance. This requires knowledge of strata variances prior to the census. Often variances are not known and other estimates must be substituted. Population estimates can serve this purpose with the assumption that differences in strata densities reflect, in roughly the same proportions, the difference between strata variances.

Strata were defined from deer and moose distribution observed from the air along transects 2.6 kilometers (one mile) apart. Transect flights proceeded in a north-south direction. Trails and sightings of moose and deer were plotted on topographic maps by an observer watching from one side of the plane.

Transect data also provided the data for optimally allocating sample plots within strata. Previous studies (Bell et al. 1973, Peek 1971, Siniff and Skoog 1964) had established that estimates of strata densities could be successfully substituted for strata variances. The census design used here assumed that numbers of animals and trails, recorded from transects, within strata would be equally effective in reflecting strata variances. Table 1 illustrates the necessary computations for optimally allocating plots among strata.

Sample plots were approximate square miles (2.6 square kilometers) with boundaries based on identifiable geographic landmarks where possible. Unlike plots based on a grid system, boundaries easily identified from the air reduced the possibility of mistakenly counting animals which may or may not have been in the plot.

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Census flights were begun on the 28th of December and completed on the 16th of March. Eighty plots were intensively searched at altitudes of from 60 to 150 meters (200 to 500 feet) above ground with a Piper PA-18A-150 Super Cub. Plots were searched in a series of overlapping circles so that each piece of ground was observed at least once. Both pilot and passenger functioned as observers. When deer or moose were sighted, the pilot was requested to circle until observers were satisfied that as many animals as possible were counted.

RESULTS AND DISCUSSION

Deer-Moose Distribution

Deer distribution was classified as high, medium, and low density range (Figure 2). Moose distribution was classified as high and low density (Figure 3). Data needed to stratify the areas in figures 2 and 3 were gotten from recording trails and animals sighted during transect flights. Comparison of figures 2 and 3 reveals little overlap between high density deer and moose range during winter.

High density deer range comprised 16% of the total area and contained 48% of all trails and animals observed. Medium density range occupied 21% of the area and included 24% of the trails and animals observed. The rest of the area (63%) was low density range which included 28% of all trail and animal observations. In census plots, 140, 29 and 36 deer were observed in high, medium and low density strata respectively (Table 3).

High density deer range was located along the southern shores of White Iron and Farm Lakes surrounding the Kawishiwi river area (Figure 2). It also included an area extending approximately eight miles southwest of Birch Lake and the City of Babbitt. A third area of high density range existed in the southern end of the study area south and southeast of Hoyt Lakes and north of the Whiteface Reservoir. Medium density deer range primarily occupied zones surrounding high density area in the northern half of the study area, while in the southern one-third it occupied most of the area. Nearly all of the area east of a line extending lengthwise northeast-southwest through the center of the study area was low density.

High density moose range was mostly confined to the northeast one-third of the study area. A small portion was located about eight miles east of Hoyt Lakes (Figure 3). It comprised 14% of the total area and contained 68% of the total moose trail and animal observations recorded during transect flights and 33% (Table 3) of all moose observed in census plots.

Deer-Moose Density

Deer and moose densities were determined similarly, the methodology of which is illustrated in Table 2. Table 3 presents results for both deer and moose. Appendix 1 presents initial plot data from which values in Table 2 and 3 were calculated. Plot densities ranged from zero to 14 deer and zero to five moose per plot. Eighty plots were sampled for deer and moose. For deer 20, 14, and 46 plots were optimally allocated for sampling in high, medium, and low density strata respectively (Table 1). For moose 21 of high and 59 plots of low density strata were allocated. Each plot averaged 20 minutes for completion. The average area per plot was 2.6 square kilometers (one square mile).

Of 205 deer observed, 140 (68%) were in high, 29 (14%) were in medium, and 36 (18%) were located in low density plots (Table 3). These values projected for each stratum result in uncorrected figures of 654, 267 and 299 deer in high, medium and low density strata respectively for an overall uncorrected estimate of 1,221 deer in 1542.4 square kilometers (595.5 square miles).

It is acknowledged that a number of factors affect the observability of animals in aerial censues (Norton-Griffiths 1976, Caughley et al. 1976, LeResche

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and Rausche 1974, Pennywick and Western 1972). Probably in this area the factor most affecting census accuracy is forest cover type. Deer in coniferous cover are easily missed. Floyd et al. (submitted and included as Appendix II) describe a technique for correcting deer census results in an area included in this census. We assumed the correction factor includes the overall effects of all types of biases encountered during the census. The method was followed in this census and a correction factor was applied to results listed in Table 3 for deer. With the observers used, approximately 34% of all deer in each plot were actually observed, resulting in a correction factor of 2.92 (the reciprocal of 34%),(Table 4).

The corrected population estimate for the study area is 3567.7 deer (Table 3). The corrected mean is 2.3 deer per square kilometer (6.0 deer per square mile).

A total of 30 moose were observed in 80 sample plots, 10 (33%) in high density and 20 (67%) in low density range. The uncorrected projected total is 217 moose in 1542 square kilometers (Table 3), 40 moose in high density and 177 in low density stratum.

It should be assumed that moose are subject to observability biases similar to deer, although not necessarily of the same magnitudes. A moose correction factor was not determined for this study using techniques described by Floyd et al. (submitted). Instead, in analyzing data presented by LeResche and Rausche (1974), I assumed that about 50% of all moose in plots were not observed. Thus uncorrected results in Table 3 were multiplied by two.

The corrected moose population estimate in 1542 square kilometers is 434 moose (Table 3). This results in a mean of 0.3 moose per square kilometer (0.7 per square mile).

Various studies, including research done in this area (Hoskinson and Mech, 1976, Nelson 1977), have shown that deer exhibit seasonal migration patterns and that summer and winter ranges may differ. Thus it should be assumed that results presented here reflect population densities and distribution of deer in their winter range and may not hold true for other times of the year. This census was not begun until after a sample of radio-monitored deer had settled on their winter range (Nelson, personal communication).

In northeastern Minnesota there is a lack of data on seasonal habits of moose. To my knowledge it is not known whether winter and summer ranges differ. I am assuming that, like deer, moose were present on their winter range when the census was made. Thus as is the case with deer, census results may not be valid during other times of the year.

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FIGURES

TABLES

APPENDICES

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Table 1. Example of computations required for optimally allocating sample size within strata. Taken from deer data.

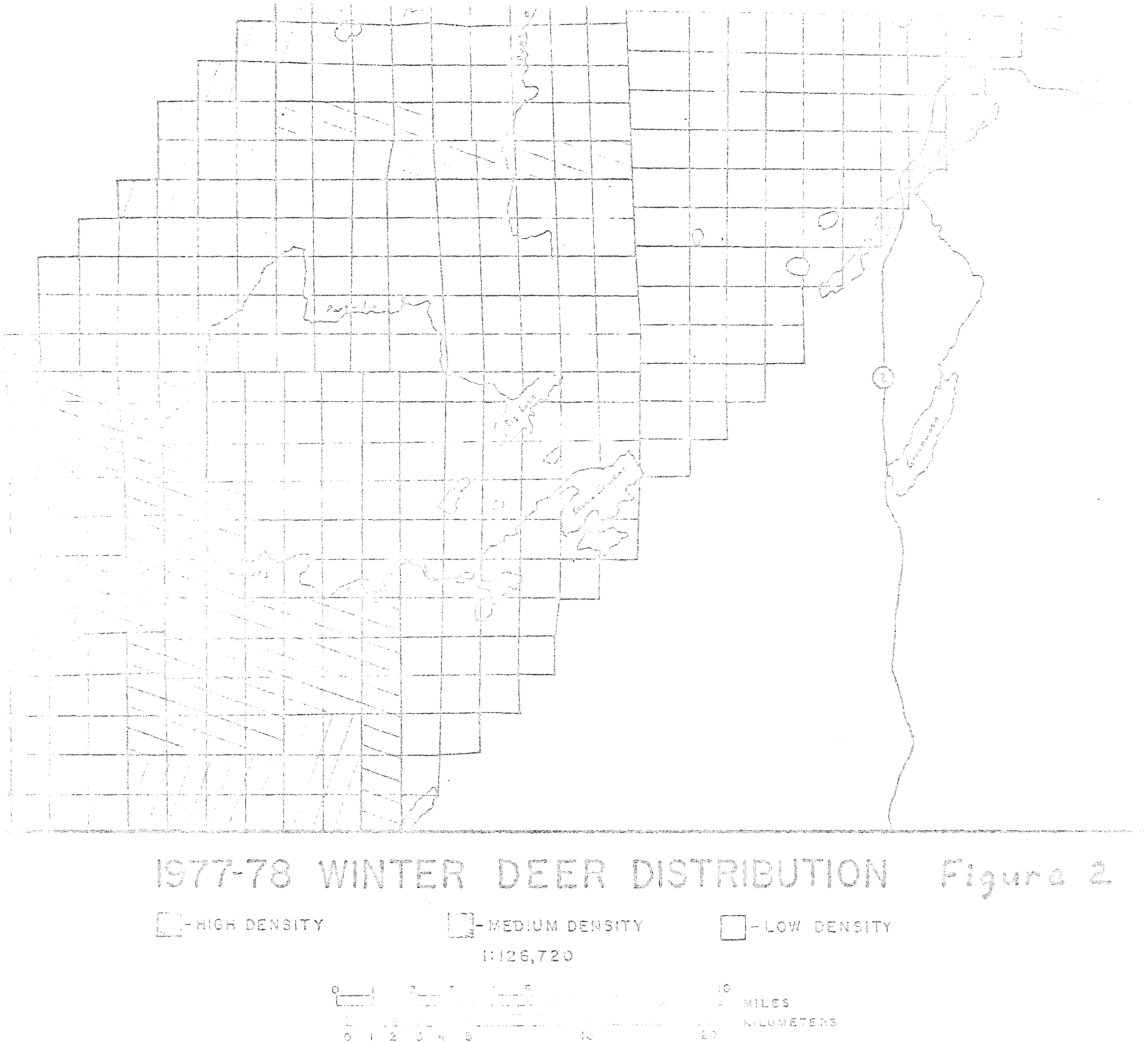
Stratum Density	N	W	s	W s	W s as a proportion	Optimal allocation of sample units 1/
High	94.1	0.158	697	110.1	0.25	20
Medium	127.6	0.214	356	76.2	0.17	14
Low	373.8	0.628	404	253.7	0.58	46
Totals	595.0	1.000		440.0	1.00	80

Definitions:

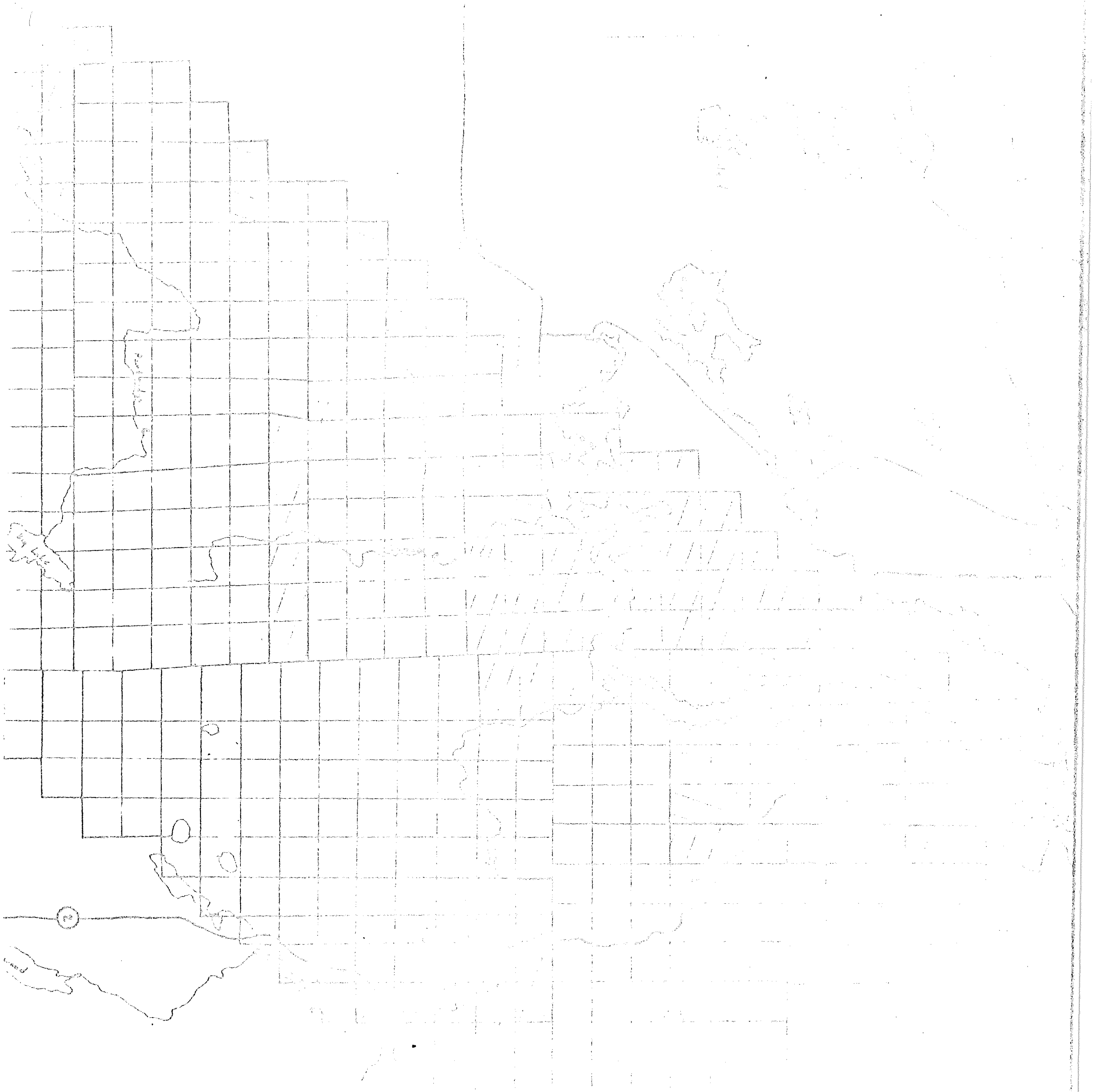
- N = Total number of possible sample units 2/ per stratum.
- W = Proportion of possible sample units per stratum .
- s = Number of trail and animal sightings within strata from transect data. Used in place of standard deviation.
- W s = Product of W and s .

1/ Optimal allocation values represent the number of sample units chosen for the census (80) multiplied by W s as a proportion.

2/ A sample unit was one square mile (2.59 square kilometers).



1977-78 WINTER DEER DISTRIBUTION Figure 2



1977-78 WINTER MOOSE DISTRIBUTION Figure 5

-HIGH DENSITY

-LOW DENSITY

1:126,720

0 1 2 3 4 5 10 MILES

0 1 2 3 4 5 10 20 KILOMETERS

Table 2. Example of calculations required to derive a population estimate and variance. Taken from deer data.

Stratum Density	n	N	w	W	x	x	s^2	x /w	(W ^{2}s ^{2}/ n)(1-w)
High	52.2	243.7	0.214	0.158	140	2.7	14.2	653.9	0.014
Medium	35.9	330.5	0.109	0.214	29	0.8	15.6	267.3	0.045
Low	116.5	968.2	0.120	0.628	36	0.3	2.7	299.3	0.020
Totals	204.6	1542.4		1.000	205			1220.5	0.079

Total population estimate X = (x /w) = 1220.5 deer

Population mean X = X /N = 0.8 deer/kilometer^2 (2.1 deer/mile^2)

Variance of the population estimate S ^{2} = (W ^{2} s ^{2}/ n)(1-w)[1/] = 0.079

Definitions:

- n = Amount of area (kilometers^2) sampled in each stratum.
- N = Amount of total area included in each stratum.
- N = Total area included in study area (N).
- w = Proportion of each stratum sampled (n /N).
- W = Proportion of area included in each stratum (N /N).
- x = Number deer observed per stratum.
- x = Sample mean number of deer per stratum (x /n).
- s^2 = Strata variance = (x - x)^2/n -1.

[1/] The quantity 1-w is a population correction factor which may be ignored if less than 0.1.

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Table 3. Results of the 1977-78 deer-moose aerial census.

Density Strata	DEER					MOOSE				
	Area Counted		Deer Seen			Area Counted		Moose Seen		
	Km^2	% of Stratum	No.	Per Km^2	Projected Total	Km^2	% of Stratum	No.	Per Km^2	Projected Total
High	52.19	21.41	140	2.68	653.9	54.55	25.06	10	0.18	39.9
Medium	35.87	10.85	29	0.81	267.3	- 1/	-	-	-	-
Low	116.50	12.03	36	0.31	299.3	149.39	11.28	20	0.13	177.3
Totals	204.56		205		1220.5	203.94		30		217.2

Correction factor 2/ x 2.92
Corrected total 3567.7
Deer/Km^2 4/ 2.3
Deer/$mile^2$ 6.0

Correction factor 3/ x 2
Corrected total 434.4
Moose/Km^2 4/ 0.28
Moose/$mile^2$ 0.73

1/ The distribution and density of moose did not warrant a medium density stratum.

2/ From Table 4.

3/ A value chosen from LeResche and Rausch 1974.

4/ Study area was 1542.4 $kilometers^2$ (595.5 $miles^2$).

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Table 4. Results of deer observability tests.

Test Date	Weather 1/	Known No. of Collared Deer	No. Collared 2/ Deer Observed	Percent Observed	Correction Factor 3/
February 21, 1978	Fair	11	1	9.1	
February 28, 1978	Fair	5	2	40.0	
March 10, 1978	Good	11	4	36.4	
March 24, 1978	Poor	11	6	54.5	
Totals		38	13	34.2	2.92

1/ Weather was poor when any of the following conditions prevailed: winds at 10 mph or above, temperature below -28°C, a low cloud cover or snow falling. When temperature was above -10°C, winds were light or calm, cloud cover was light, and there was no precipitation, conditions were considered good.

2/ Number of radio-tagged deer observed by both pilot and passenger.

3/ Reciprocal of percent observed.

APPENDIX I. Plot location and statistics.

Plot Location	Minutes for Completion	Area Km^2	MOOSE Stratum Density	MOOSE Number Observed	DEER Stratum Density	DEER Number Observed
T.62-R.11-Sec.3	21	2.1	Low	0	High	2
" " Sec.9	28	2.7	Low	2	High	0
" " Sec.17	26	2.2	Low	0	High	4
" " Sec.22	25	2.5	Low	0	High	7
T.62-R.12-Sec.25	17	2.3	Low	0	Medium	0
T.62-R.11-Sec.31	24	3.2	Low	0	High	6
" " Sec.35	30	2.7	Low	1	High	4
T.61-R.11-Sec. 5	20	2.4	Low	0	High	6
" " Sec. 1	18	2.7	High	5	Low	0
" " Sec. 7	21	2.9	Low	3	High	2
" " Sec. 9	24	2.7	Low	0	High	4
T.61-R.10-Sec. 7	16	2.5	High	0	Low	0
" " Sec.10	14	2.4	High	0	Low	0
" " Sec.17	25	2.8	High	0	Low	0
" " Sec.15	20	2.6	High	0	Low	0
" " Sec.13	22	3.2	High	0	Low	0
T.61-R. 9-Sec.17	17	2.9	High	3	Low	0
T.61-R.11-Sec.23	15	2.0	High	0	Low	0
T.61-R.12-Sec.25	24	2.8	Low	1	Medium	0
T.61-R.11-Sec.27	22	2.8	High	2	Low	0
" " Sec.25	15	2.6	High	0	Low	0
" " Sec.31	14	2.8	Low	3	Medium	0
T.61-R.10-Sec.31	23	2.6	High	0	Low	2
T.60-R.12-Sec. 2	21	2.5	Low	0	Medium	13
T.60-R.13-Sec.11	12	2.5	Low	0	High	9
T.60-R.12-Sec. 7	18	2.6	Low	0	High	14
T.60-R.11-Sec.10	20	2.6	High	0	Low	4
" " Sec.11	21	2.7	High	0	Low	0
T.60-R.10-Sec. 9	16	2.9	Low	0	Low	0
T.60-R.13-Sec.13	25	2.8	Low	0	High	9
T.60-R.11-Sec.15	18	2.7	High	0	Low	0

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Plot Location	Minutes for Completion	Area Km^2	MOOSE Stratum Density	MOOSE Number Observed	DEER Stratum Density	DEER Number Observed
T.60-R.10-Sec.18	22	2.5	High	0	Low	0
T.60-R.13-Sec.21	31	2.6	Low	0	High	10
" " Sec.22	20	2.3	Low	0	High	9
T.60-R.12-Sec.21	19	2.5	Low	0	Low	0
" " Sec.24	15	2.6	Low	3	Low	0
T.60-R.13-Sec.29	27	2.9	Low	0	High	7
T.60-R.11-Sec.26	23	2.4	High	0	Low	6
" " Sec.35	20	2.6	High	0	Low	0
T.60-R.10-Sec.31	18	2.6	High	0	Low	3
T.59-R.12-Sec.4	21	2.2	Low	0	Medium	0
T.59-R.10-Sec. 6	23	2.4	High	0	Low	1
T.59-R.13-Sec. 8	20	2.3	Low	0	Low	0
" " Sec.11	17	2.3	Low	0	Low	0
T.59-R.12-Sec.12	21	2.2	Low	0	Low	0
" " Sec.18	30	3.4	Low	2	Low	4
" " Sec.13	19	2.7	Low	0	Low	0
T.59-R.13-Sec.22	19	2.4	High	0	Low	0
T.59-R.11-Sec.23	14	2.3	Low	0	Low	0
T.59-R.13-Sec.27	11	2.6	High	0	Low	0
T.59-R.12-Sec.28	16	2.3	Low	0	Low	0
T.59-R.14-Sec.35	20	2.6	Low	0	Low	1
T.58-R.12-Sec. 4	14	2.3	Low	0	Low	2
T.59-R.11-Sec.31	17	2.4	Low	0	Low	0
T.58-R.13-Sec. 5	20	2.3	Low	0	Low	7
T.58-R.12-Sec. 4	14	1.8	Low	0	Low	0
T.58-R.11-Sec. 5	17	2.0	Low	0	Low	0
T.58-R.14-Sec.11	20	2.3	Low	0	Medium	2
T.58-R.12-Sec.12	20	2.7	Low	0	Low	0
T.58-R.14-Sec.15	20	2.7	Low	0	Medium	2
" " Sec.13	25	2.9	Low	0	Medium	0
" " Sec.20	26	2.8	Low	0	High	14
" " Sec.23	20	1.6	Low	0	Low	2
" " Sec.24	18	2.2	Low	0	Medium	1

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Plot Location	Minutes for Completion	Area Km^2	MOOSE Stratum Density	MOOSE Number Observed	DEER Stratum Density	DEER Number Observed
T.58-R.12-Sec.22	17	1.9	Low	0	Low	0
T.58-R.14-Sec.30	22	2.6	Low	0	High	8
" " Sec.31	23	2.7	Low	0	High	10
" " Sec.32	25	2.3	Low	0	High	10
" " Sec.33	21	2.5	Low	0	Medium	0
" " Sec.34	26	2.5	Low	0	Medium	9
T.58-R.13-Sec.36	15	2.5	Low	3	Low	2
T.57-R.13-Sec. 5	26	2.6	Low	0	Medium	0
T.57-R.12-Sec. 6	18	2.8	Low	0	Low	0
T.57-R.14-Sec. 9	21	2.6	Low	0	Low	0
T.57-R.13-Sec. 7	25	2.9	Low	0	Medium	2
T.57-R.12-Sec. 7	18	2.8	Low	0	Low	0
T.57-R.14-Sec.23	15	2.8	Low	2	Low	0
" " Sec.24	17	2.7	Low	0	Medium	0
T.57-R.12-Sec.19	22	2.8	Low	0	Low	2
T.57-R.14-Sec.36	24	3.0	Low	0	High	5
Totals	1624	204.4	80	30	80	205
Means	20	2.6	-	-	-	-

APPENDIX II

Floyd, T.J., L.D. Mech, and M.E. Nelson. 1978.
An improved method of censusing
deer in deciduous-coniferous forests.
Submitted - J. Widl. Manage.

AN IMPROVED METHOD OF CENSUSING DEER IN DECIDUOUS-CONIFEROUS FORESTS

Aerial censusing has been used to determine densities of many large mammals, including deer (Odocoileus virginianus) in agricultural areas or deciduous forests (Saugstad 1942, Morse 1946, Petrides 1953, Sanderson 1953, Berner pers. Comm.). However, observability of deer from the air remains a problem in northern coniferous forests. LeResche and Rausch (1974) determined that even with the much larger and more observable moose (Alces alces) during ideal snow conditions, experienced observers only counted 68 percent of a known number of animals; inexperienced observers counted 43 percent. Caughley (1974) and Caughley et al. (1976) suggested that the best solution to the problem of observability in aerial censuses is to measure the magnitude of the biases that exist, and correct estimates accordingly. This paper describes an attempt to measure observability bias in an aerial census of deer in deciduous-coniferous habitat and to produce an accurate estimate of numbers.

STUDY AREA

The study was conducted in a 393 to 399 km^2 portion of the Superior National Forest (SNF) in Lake County, Minnesota lying northeast to northwest of Isabella. The area included parts of Townships 59, 60, and 61 North in Ranges 8, 9, and 10 West of the Fourth Principle Meridian.

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The vegetation of the study area is mostly maturing coniferous-deciduous forest. Few unmixed stands remain except in lowlands, which occupy about one-third of the area and are dominated by white and black spruce (Picea glauca and mariana). Balsam fir (Abies balsamea), red pine (Pinus resinosa) jack pine (Pinus banksiana), aspen (Populus tremuloides), and birch (Betula papyrifera) predominate in the uplands. About 25 percent of the upland consists of red pine and jack pine plantations. Much of the area has been cutover since 1935 (Peek et al. 1976), and is still being logged on a small scale.

Deer had declined in the region from 1968 through 1974, and an area of more than 3,000 km^2 just north of the study area has been devoid of wintering deer since 1972 (Mech and Karns 1977). Some deer immigrate into the study area to winter, usually by December (Nelson 1977), but there is no evidence that deer resident in the study area emigrate in winter. Thus our winter estimates probably exceed the actual number of deer inhabiting the study area for most of the year.

METHODS

Our census technique involved two basic steps: (1) aerially counting deer in census plots, and (2) testing the observability of deer in test plots similar to the census plots. We conducted three censuses, from 7 December 1975 through 4 January 1976, from 25 January through 11 February 1977, and from 13 February through 3 March 1978. Maximum snow depths during the three censuses were 61, 46, and 73 cm, while minimum temperatures were -37C, -40C, and -35C. The counts were based on stratified random sampling with optimal allocation of sample plots, a type of sampling particularly applicable to populations with clumped distributions (Cochran 1967). Census stratification and plot allocation were based on aerial strip surveys of deer and tracks in transects .8 km apart, involving 7 hours of flying. Plots within high, medium, and low density strata were chosen at random. Several workers have used this design in estimating populations of big game animals and describe the technique in greater detail (Peek et al. 1976; Siniff and Skoog 1964).

Our censuses were made under clear to bright-cloudy light conditions at altitudes from 60 to 150 meters above ground from a Piper PA-18A-150 Super Cub aircraft. The Super Cub proved highly advantageous because of its maneuverability and ability to fly at low speeds and altitudes.

Both pilot and passenger (senior author) searched the plots intensively in a series of over-lapping circles such that each piece of ground was observed at least once. Whenever a deer was sighted, the pilot was requested to circle until the observer was satisfied that as many animals as possible were observed. Census plots were approximately 2.6 km^2 each with boundaries based on identifiable landmarks such as ridges or streams, and averaged 17 minutes each for completion. We censused 40 to 45 plots each year.

We used radio-tagged deer (Hoskinson and Mech 1976; Nelson and Mech in prep.) to test our observability bias in the census. Thirty radio-tagged deer with color-coded collars were available, ten in winter 1975-76, four in 1976-77, and 16 in 1977-78 (Nelson 1977). The collars did not seem conspicuous enough to increase the observability of the deer. Test plots of 1.3 to 2.6 km^2 containing radioed deer were located on maps by an impartial observer and a pilot other than the census pilot (Table 2). Test plots were then searched within the next few hours by the senior author without redio telemetry, using the same pilot, plane, and search techniques as in the counts. In several instances the same deer were used during different days but only if their locations changed between trials. The test plots were located in the same region as the census area, although not

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actually within the census area. Weather and cover variation among plots and tests was similar to that during counts. Thus we assumed that the proportion of collared deer missed in the test plots approximated the proportion of deer missed in the census plots. Correcting census data with the figures thus derived gave an estimate of the actual deer density.

RESULTS AND DISCUSSION

Deer were observed under forest conditions varying from open canopy to an estimated 80 percent closed canopy. In winters 1975-76, 1976-77, and 1977-78, 51, 55, and 69 deer were seen during the censuses. However, the low density stratum constituted an increasing proportion of the cen us area each year, from 62 percent in 1975-76 and 63 percent in 1976-77 to 79 percent in 1977-78. Furthermore, the number of deer seen in the low density stratum dropped from .16/km^2 in 1975-76 through .15/km^2 in 1976-77 to 0 in 1977-78 (Table 1). Therefore, when these densities are projected to the entire study area the mean number of deer seen actually decreased from .40 deer per km^2 in 1975-76 to .33 in 1976-77 and .20 in 1977-78.

The observability tests indicated that 56 percent of the deer were seen during the first winter, and 50 percent during the second and third (Table 2). Correcting the census results by multiplying them times the reciprocals of the observability figures for each year yields total estimates of .70, .66, and .40 deer per km^2 (Table 1).

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The observability of collared deer remained remarkably constant between test days and between winters despite variable weather (Table 2). The results of the observability tests indicate that, with the intensive search method of counting deer under the conditions in our study, approximately half of the deer are seen.

To apply our technique for correcting aerial censuses of deer over large areas, we suggest that observability tests be made several times during the census, because ground and weather conditions can change throughout the census, and that deer observability be tested in different cover types, with separate correction factors applied for each type.

Although observability tests add substantial expense to a deer census, they increase the accuracy of the results considerably. Furthermore monitoring the movements of the radioed deer provides significant insight into seasonal migration patterns and distribution, phenomena that other deer census methods have failed to consider. Such insight puts census data into both seasonal and areal perspective.

It is not yet clear whether our census technique is sensitive enough to make precise year-to-year comparisons. However, it certainly is accurate enough to provide an excellent indication of gross deer density and to document the fact that in the present study area, deer numbers are exceptionally low.

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Theodore J. Floyd, Department of Entomology, Fisheries, and Wildlife, University of Minnesota, St. Paul, Minnesota 55108[1].

L. David Mech, U. S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, Maryland 20811[2].

Michael E. Nelson, Department of Entomology, Fisheries, and Wildlife, University of Minnesota, St. Paul, Minnesota 55108[3].

Recieved .

Accepted .

---

1 Mailing address: 18 E. Boundary Street, Ely, MN 55731.

2 Mailing address: North Central Forest Experiment Station, 1992 Folwell Avenue, St. Paul, MN 55108.

3 Mailing address: 404 - 16th Street, Apt. 11, Hibbing, MN 55746.

Table 1. RESULTS OF THREE AERIAL CENSUSES

	1975-76					1976-77					1977-78 1/				
	Area counted		Deer seen			Area counted		Deer seen			Area counted		Deer seen		
Density Strata	km^2	% of stratum	No.	Per km^2	Projected Total	km^2	% of stratum	No.	Per km^2	Projected Total	km^2	% of stratum	No.	Per km^2	Projected Total
High	50.8	41	40	.79	97.6	56.4	71	37	.66	52.1	72.0	88	69	.96	78.4
Medium	4.5	15	3	.67	20.0	18.2	26	11	.60	42.3	-	-	-	-	-
Low	49.5	21	8	.16	38.1	46.8	19	7	.15	36.8	33.0	11	0	0	0
	104.8			Total	155.7	121.4			Total	131.2	105.0			Total	78.4
			corrected factor 2/		x 1.77			correction factor 2/		x 2.00			correction factor 2/		x 2.00
			corrected total		276			corrected total		262			corrected total		157
			deer/km^2		.70 3/			deer/km^2		.66 3/			deer/km^2		.40 3/

1/ Because of increase d winter severity, deer were more concentrated, so there was no medium density stratum.

2/ From Table 2.

3/ Study area was 393 km^2 in 1975-76, 399 km^2 in 1976-77, and 395 in 1977-78.

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TABLE 2. RESULTS OF DEER OBSERVABILITY TESTS

Test Date	Weather[1]	Known Number of Collared Deer	Number Collared[2] Deer Observed	Percent Observed	Correction Factor[3]
January 8, 1976	Fair	6	3	50.0	
January 9, 1976	Good	10	6	60.0	
Total 1976		16	9	56.3	1.79
February 3, 1977	Fair to poor	4	2	50.0	
February 9, 1977	Good	4	2	50.0	
Total 1977		8	4	50.0	2.00
February 28, 1978	Fair	7	4	57.0	
March 12, 1978	Good	3	1	33.0	
March 15, 1978	Fair	6	3	50.0	
Total 1978		16	8	50.0	2.00

1/ Weather was considered poor when any of the following conditions prevailed: winds high, temperature below -28° C, cloud cover low, or snow falling. When temperature was above -10° C, winds were light or calm, cloud cover was light, and there was no precipitation, conditions were considered good.

2/ Number of radio-tagged deer observed using both pilot and passenger.

3/ Reciprocal of percent observed.

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