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AN ASSESSMENT OF A WILDLIFE HABITAT EVALUATION METHODOLOGY FOR ALASKA

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A

THESIS

Presented to the Faculty of the
University of Alaska in Partial Fulfillment
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for the Degree of

MASTER OF SCIENCE

By

Raphael Stephen Mulé, B.S.

Fairbanks, Alaska

December 1982

AN ASSESSMENT OF A WILDLIFE HABITAT
EVALUATION METHODOLOGY FOR ALASKA

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ABSTRACT

This study evaluated accuracy and precision of habitat quality scores (HSI values) generated by models from the USFWS' Terrestrial Habitat Evaluation Criteria Handbook - Alaska (Konkel 1980). Models examined included moose (*Alces alces*), caribou (*Rangifer tarandus*), beaver (*Castor canadensis*), mink (*Mustela vison*), spruce grouse (*Canachites canadensis*), common redpoll (*Carduelis flammea*), and green-winged teal (*Anas crecca carolinensis*). Each model was tested in 1 or more of the following habitat types: coniferous forest, deciduous forest, mixed forest, low shrub, herbaceous sedge-grass, mat and cushion tundra, and freshwater aquatic. Precision was assessed by comparison of sample data and the HSIs calculated from those data among 3 teams that used models to estimate habitat quality. Precision for sample data was variable, but precision for HSIs was acceptably high. Accuracy, based on comparison of HSIs generated by handbook models with species expert habitat quality ratings, was unacceptably low for most models.

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INTRODUCTION

The need for sound wildlife habitat assessment methodologies has become increasingly important with the current trends toward maximum exploitation of our natural resources. Although such trends may be more apparent in the continental United States, many federal, state, borough, and native lands in Alaska will be subject to heightened developmental pressures. Large scale projects such as the Trans-Alaskan Oil Pipeline, the proposed Alaskan Natural Gas Pipeline, and the Susitna Hydroelectric Project, as well as numerous smaller projects, have had or will have major and long-term effects on wildlife habitat in Alaska. To effectively mitigate habitat losses accruing from such projects biologists must be able to accurately and quantitatively evaluate the suitability of various habitats to support wildlife populations. This project was implemented to examine the effectiveness of the Habitat Evaluation Criteria Handbook - Alaska (Konkel ed. 1980) as part of the Habitat Evaluation Procedures (USFWS 1979) for assessing wildlife habitat in Alaska.

BACKGROUND

The following federal legislation has either stated or implied that fish and wildlife resources be given approporiate consideration in planning all development projects impacting federal lands: the Fish and Wildlife Coordination Act of 1934 (16

U.S.C. 661-666c) and its amendment in 1958 (P.L. 85-624:72 stat. 563), the Principles and Standards for Planning Water and Related Land Resources (U.S. Water Resources Council 1973), the National Environmental Policy Act of 1969 (42 U.S.C. 4321-4347), and the Forest and Rangeland Renewable Resources Planning Act of 1974 (16 U.S.C. 1601-1610). Thus, federal agencies such as the USFWS, U.S. Forest Service, Bureau of Land Management, and Army Corps of Engineers have been leaders in the development of habitat assessment methodologies. The Endangered Species Act of 1973 (16 U.S.C. 1531-1543) and various permit and licensing programs have further involved federal agencies, particularly the USFWS, in environmental planning and impact assessment. The Action Report (White 1971) stipulated that the USFWS develop a non-economic methodology for assessing effects of land use projects on wildlife resources.

Numerous habitat assessment methodologies have evolved in response to this need. These include systems proposed by Hamor (1970), Dee et al. (1972), Daniel and Lamaire (1974), Graber and Graber (1976), Thomas et al. (1976), U.S. Army Corps of Engineers (1976), U.S. Forest Service and Missouri Department of Conservation (1976), Whitaker and McCuen (1976), Whitaker et al. (1976), Flood et al. (1977), Lines and Perry (1978), Pettinger et al. (1978), Bramble and Byrnes (1979), Adams (1980), Kling (1980), Anderson (1981), Asherin et al. (1981), Short and Burnham (1982), and others.

The Habitat Evaluation Procedures or HEP (USFWS 1976) are based on the Missouri System developed by Daniel and Lamaire (1974) which incorporated several concepts introduced by Hamor (1970) (Sparrowe and Sparrowe 1977). The USFWS felt that the Missouri system provided the best framework on which to base their system. The main purpose for development of such a system was to allow wildlife habitat values to be quantified in a manner comprehensible to all parties involved in the planning process. These values would also be easily incorporated into the existing mitigation procedural structure.

Schamberger and Farmer (1978) discussed the application of HEP to project planning and impact evaluation in some detail. A number of fish and wildlife species are chosen for the assessment. The study area is divided into habitat types, mapped, and sampling sites selected for the field evaluation. An index of existing conditions is determined by assessing the quality of the habitats for each species using 1 of 2 approaches discussed below. A given habitat type receives a numerical rating for each species called a Habitat Suitability Index (HSI), which ranges from 0.0 to 1.0. Values known as Habitat Units are calculated for each species and habitat type by multiplying the HSIs by the number of acres that a particular habitat type covers in the project area. The Habitat Units are the values actually utilized in the planning process. Based on various sources of information, projections of future habitat conditions are made with and without the project, and Habitat Units are calculated under each condition. The differences between present Habitat Units and future Habitat Units, both with and without the project, become the basis for judging the effects of the project on each species. If the project is implemented, mitigation for habitat loss is also based on the Habitat Units.

As mentioned above, determination of the habitat quality scores (HSIs) for each species and habitat type is performed in 1 of 2 ways. Early HEP systems (USFWS 1976) had the HSIs based on subjective habitat evaluations conducted by teams of biologists. These biologists may or may not have been experts concerning a particular species and its habitat requirements. The HSIs were simply personal opinions of the quality of habitats for supporting populations of certain wildlife species. This approach was criticized because it was felt that habitat scores obtained in such a manner would not be replicable among different groups of biologists. Also, the scores might be biased in favor of more persuasive team members. Holmberg (1977) found statistically significant differences among mean habitat scores given by several teams of biologists in 28% of the comparisons he made.

It was apparent that a more precise methodology for obtaining the habitat suitability scores was needed. A second approach was developed and introduced in the Missouri Handbook (Flood et al. 1977). With this system habitat suitability scores are determined by predefined habitat criteria. These habitat criteria are derived primarily from information in the literature, but with some personal input from species experts. As such, the same set of criteria are used by all persons involved in a particular habitat assessment project. Persons using this system produced less variable habitat quality scores than did those scoring habitat on a strictly subjective basis (Flood 1977).

The USFWS adopted the Missouri Handbook (Flood et al. 1977) approach and initiated programs to develop similar handbooks for other areas of the U.S. based on Bailey's (1976) ecoregions. These Habitat Evaluation Criteria (HEC) Handbooks are to be used as an integral part of the more comprehensive HEP system. The Terrestrial Habitat Evaluation Criteria Handbook - Alaska (Konkel 1980) was developed for assessing habitat suitability for selected wildlife species in the Alaska region. This handbook will be known hereafter as the Alaska HEC Handbook.

THE MODELS

Alaska HEC Handbook species-models have been developed for selected wildlife species in Alaska for the various habitat types in which these species are known to occur. The species modeled were chosen on the basis of their ecological, socioeconomic, and/or aesthetic importance. For each species in a given habitat type environmental parameters (biotic and/or abiotic) are used to estimate habitat quality in a quantitative manner. Bivariate plots have been constructed for each parameter with the level of the parameter (X-axis) corresponding to a Suitability Index (Y-axis) ranging from 0.0 to 1.0. The plots may be in the form of curvelinear graphs or histograms. Habitat types are sampled to provide estimates for the parameters specified by a particular model in the handbook. The corresponding Suitability Indices are obtained from the appropriate graph using the parameter estimates. These Suitability Indices are used to calculate a Habitat Suitability Index (HSI) from the proper Life Requisite equation. The equations combine the Suitability Indices in either a multiplicative or geometric fashion; these will be explained in detail in the methods section. There may be 1 or several Life Requisite equations, each yielding an HSI value, depending on which life requirements (food, cover, reproduction, etc.) a particular habitat provides for the species under consideration. The HSI values obtained range from 0.0 to 1.0, with 0.0 representing habitat of no value to the species and 1.0 indicating the highest quality habitat available. The lowest Life Requisite HSI value is selected as the overall HSI for the site based on the limiting factor concept (Pianka 1974). This is done for several sites in the habitat and the HSIs for all sites are averaged to obtain an overall HSI for each species and habitat type. The moose (Alces alces) model for mixed coniferous-deciduous forest habitat is presented in Appendix 1 as an example. Additional information concerning HEP and the Alaska HEC models can be found in Konkel (1980) and Byrne (1982).

A revision of the Alaska HEC Handbook model for moose was made in 1980. Although the revised model (Konkel, pers. comm.) presents the habitat criteria in a different format than the original, the basic principles underlying the 2 are similar. This model is reproduced in Appendix 2.

For each species modeled in the Alaska HEC Handbook, narratives containing the species' life history and habitat requirements precede the actual habitat models. An example (for moose) is given in Appendix 3.

OBJECTIVES

Because the models in the HEC Handbook were developed in a non-empirical manner, it cannot be assumed that these models will produce accurate and repeatable estimates of habitat quality unless validated through field testing. The overall objective of this study was to experimentally examine the effectiveness of the Terrestrial Habitat Evaluation Criteria Handbook - Alaska (Konkel 1980) for evaluating wildlife habitat in Alaska. Specifically, this was accomplished by:

1. Assessing precision of the handbook by comparing sample data and the habitat suitability scores (HSI values) calculated from those data among 3 teams that utilized selected handbook models to generate the scores.
2. Determining accuracy of the handbook by comparing habitat suitability estimates (HSI values) produced by selected handbook models to habitat quality ratings obtained from species experts.

APPROACH

On the Kenai Peninsula in 1979, 6 randomly selected 1-ha plots were sampled in each of the following habitat types: coniferous forest, deciduous forest, mixed forest, low shrub, mat and cushion tundra, and freshwater aquatic. Three 2-person teams of biologists visited all plots and each team independently gathered the information required by the HEC models for generation of the habitat quality scores (HSI values). Some parameters were estimated by sampling 12 subplots within the 1-ha plots; the estimates were data of the ratio-type. These data were later combined and/or averaged to obtain the appropriate plot level parameter estimates required by the models. Other parameters were sampled from the 1-ha plot level only, and these estimates consisted of ratio- and nominal-type data.

Precision of the handbook was assessed by among and between team comparisons of the subplot sampled data, the subplot sampled data combined and/or averaged to the plot level, the plot sampled data, and the model HSI values generated by the data.

In addition, species experts rated the habitat quality of these plots on the same scale as the HSI values, but without use of the handbook. Handbook accuracy was evaluated by comparing the teams' HSI values with the species experts' ratings. It was assumed that the experts' ratings were accurate estimates of the actual habitat quality.

In 1980 low shrub and herbaceous sedge-grass habitats were sampled on the Copper River Delta, and mat and cushion tundra habitat was evaluated in the Nelchina Basin. Eight randomly located 1-ha plots were sampled in each habitat type. Results from 1979 indicated that precision testing was not necessary in 1980. Accuracy assessment was again based on comparison of model generated habitat scores with species experts' ratings. However, because precision testing was not involved only 1 set of team HSI values were obtained for this purpose.

The moose model was assessed for precision in coniferous forest, deciduous forest, mixed forest, low shrub (Kenai Peninsula only), and mat and cushion tundra (Kenai only); accuracy was evaluated in coniferous, deciduous, and mixed forest habitats. The caribou (Rangifer tarandus) model was tested for precision in low shrub (Kenai only) and mat and cushion tundra (Kenai only), and for accuracy in mat and cushion tundra (Kenai and Nelchina Basin). Accuracy and precision of the beaver (Castor canadensis) model was assessed in freshwater aquatic habitat. The mink (Mustela vison) model was not tested for precision; accuracy was evaluated in low shrub (Copper River Delta only) and herbaceous sedge-grass. Precision and accuracy of the spruce grouse (Canachites canadensis) model was assessed in coniferous and mixed forest habitats. The common redpoll (Carduelis flammea) model was tested for accuracy and precision in coniferous forest, deciduous forest, mixed forest, low shrub (Kenai only), and mat and cushion tundra (Kenai only). Accuracy of the green-winged teal (Anas crecca carolinensis) model was assessed in low shrub (Copper Delta only) and herbaceous sedge-grass habitats; precision was not examined for this model.

There may be some questions pertaining to the use of species expert ratings as the basis for assessing handbook accuracy. Admittedly, there is the possibility that the expert ratings are, in fact, inaccurate estimates of the true habitat quality. Ideally, accuracy testing would involve a correlation of habitat quality as determined by the HEC Handbook with population level estimates or habitat use data for each species under consideration. In the former case both the population level and the habitat would have to be monitored over an extended period of time. Since the population might be limited by any number of factors in addition to habitat, information on other population regulating mechanisms such as weather, predation (human and non-human), immigration and emigration, disease, parasites, etc. would be needed to effectively evaluate the relationship between the population level and the HEC scores. In the latter situation habitat use information should come from location data such as that obtained through radio-telemetry studies. This information could then be compared to habitat quality estimates obtained using the HEC models. Both types of studies would of necessity be intensive, long-term, site-specific, and probably species-specific. Since the present study was limited to 2 field seasons and attempted to validate models for several species in a wide variety of generalized habitats, gathering the above types of information was beyond the scope of the project. The utilization of species expert habitat quality ratings appeared to be the only other feasible method of assessing model accuracy.

In order to strengthen the realiability of the estimates, I had hoped to acquire the services of at least 2 experts per species-model for rating habitat quality at the sample sites. However, due to various extenuating circumstances, I was able to obtain the opinions of only 1 expert for each species except caribou. Two experts rated caribou habitat; their assessments of the area as winter range were in accord, but they disagreed regarding its value as non-winter habitat. The disparity in their estimates, however, did not affect the overall evaluation of the model. Byrne (1982) found that when 2 or more experts rated habitat quality for the same species in his study area their scores were within 0.100 (on a scale of 0.000 to 1.000) of one another. This suggests that species experts can concur in their estimation of habitat quality.

STUDY AREAS

KENAI PENINSULA

In 1979 4 study sites on the Kenai Peninsula in southcentral Alaska (Figure 1) were chosen, based on the availability of various habitat types previously selected for sampling. Habitat type designation was based on the Level II classification of Dyrness and Viereck (1979) and scientific nomenclature of flora follows Hultén (1974) unless names are cited from other publications.

The Kenai is divided into 2 distinct physiographic regions: the Kenai lowlands on the west are similar to much of non-mountainous interior Alaska; the Kenai Mountains on the east are snow-capped and heavily glaciated (Spencer and Hakala 1964). The northern portion of the lowlands is a 7680 km^2 area composed of flats, low ridges, hillocks, and muskegs with over 1000 lakes. Elevation generally varies from sea level to 150 m, but benchlands between Skilak and Tustumena lakes rise to 600 m (Sigman 1977). Glaciers at one time or another covered most of the Kenai Peninsula with the last major glaciation occurring during the Wisconsin Age (Péwé et al. 1965). The lowlands are mantled with glacial deposits that vary widely in texture and are overlain by well- to poorly drained silt loams and water laid sands and gravels. Windblown silt covers uplands throughout the area. The Kenai Mountains rise to 1800 m in elevation and are a southerly extension

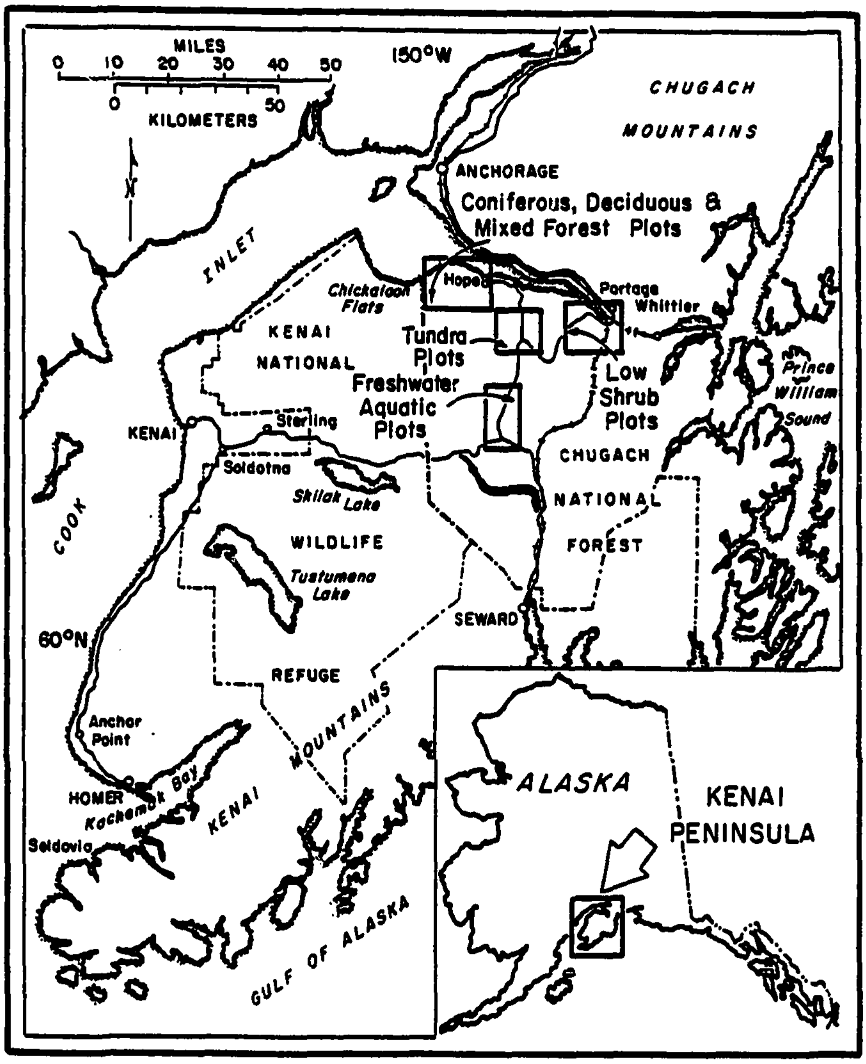

Figure 1. Kenai Peninsula, 1979 study area, with locations of sample sites. The boxes in the upper map correspond to areas covered by Figures 1, 2, 3, 4, and 5; the arrows point to specific areas where sample plots were located.

of the Chugach Mountains, the 2 of which form a complex known as the Kenai-Chugach Range.

Climate varies considerably on the Kenai with either maritime, transitional, or continental climates prevailing depending on location. The climate is maritime on the Prince William Sound coast, changing to transitional on the Cook Inlet Coast, then rapidly shifting to continental moving inland from Cook Inlet or westward over the Kenai Mountains.

Most of the Kenai is free of permafrost with a few isolated masses present locally; mean annual temperature is generally 1°C or above (Ferrians 1967). The Kenai fault, an extension of the Chitina Valley fault, runs from northeast to southwest along the western base of the Kenai Mountains (Stoneley 1967). The presence of this fault resulted in a 0.75-2.25 m subsidence of the southwest coast and a 1.20 1.80 m uplift of the Prince William Sound coast during the 1964 earthquake (Grantz et al. 1964).

The better drained sites of the northern lowlands are dominated by forests of white spruce (*Picea glauca*), paper birch (*Betula papyrifera*), and quaking aspen (*Populus tremuloides*). Wetter sites and those that have been burned repeatedly are generally occupied by poplars (*Populus balsamifera balsamifera* and *P. b. trichocarpa*), black spruce (*P. mariana*), willows (*Salix* spp.), and green alder (*Alnus crispa*). The numerous muskegs are dominated by sphagnum moss (*Sphagnum* spp.), various low shrubs, and some black spruce (Spencer and Hakala 1964 and Bishop and Rausch 1974 *In* Sigman 1977).

The middle elevations of the Kenai Mountains and the eastern and southern peninsula to Homer (Figure 1) are dominated by forests of western hemlock (*Tsuga heterophylla*), mountain hemlock (*T. mertensiana*), and Sitka spruce (*P. sitchensis*).

The upper elevations throughout the Kenai Mountains not perennially covered by snow and/or ice are dominated by alpine tundra and barren ground. The alpine tundra is dominated by the low woody shrubs and mat-like plants of the family Ericaceae, arctic willow (*S. arctica*), various sedges of the genus *Carex*, and some forbs and grasses.

Wetlands on the Kenai can be classified into 2 major types: salt and brackish water marshes found in tidal flats and other areas of low relief near the coast, and freshwater wetlands found inland around lakes, ponds, and other poorly drained areas. The former are found near Portage, in the Homer-Anchor Point area, and at Chickaloon Flats (Figure 1), while the latter are found throughout the Kenai in lowlands.

A significant factor affecting the species composition and distribution of habitat types on the Kenai Peninsula is the past occurrence of wildfires. Major fires occurred in the period from 1890 to 1910, in 1926, 1947 (Spencer and Hakala 1964), and 1969. The largest of these, in June 1947, burned 125,455 hectares in the heart of the northern lowlands. Regrowth in the burned area has been variable depending on micro-topography, soils, and pre-existing vegetation types. Oldemeyer et al. (1977) described the regrowth in the burned areas.

The most notable effect of these vegetation changes was the increase in moose numbers. Spencer and Chatelain (1953) and Spencer and Hakala (1964) documented drastic increases in moose numbers on the Kenai National Wildlife Refuge following major burns. Spencer and Hakala (1964) believed that moose were not an important part of the Kenai ecosystem until the turn of this century. They stated that up until that time caribou were the most numerous ungulates on the Kenai, but because of fire, overhunting, and blockage of migration routes their numbers declined, until they were extirpated around 1913. However, Murie (1935) and Skoog (1968) felt that caribou were never particularly abundant on the Kenai because of the marginal range found there (deep snows in the mountains, steep terrain, and a rather limited above-timberline zone of sedge meadows and heath-lichen stands). The Kenai may have received periodic influxes of caribou due to unusual migratory movements of interior herds or may have been an overflow area when the Nelchina herd experienced high population pressures from 1848-1885. Regardless, widespread fires definitely did destroy large portions of the limited caribou winter range found mostly in the lowland spruce forests.

In the 1960s and early 1970s moose reached their highest recorded densities on the Kenai, due primarily to the effects of the 1947 burn. Since that time, however, moose numbers have declined considerably. Mid-winter aerial surveys indicated that the moose population on the northern two-thirds of the Kenai National Wildlife Refuge decreased from an estimated 7900 in 1971 to 3500 in 1975 (Kenai National Moose Range Files. In Oldemeyer et al. 1977).

Several factors have been implicated as causes of the decline; these include overhunting, the severe winters of 1970-71 and 1971-72, increased predation by wolves (*Canis lupus*) and black bears (*Ursus americanus*), and decreased carrying capacity of the moose range in the 1947 burn. The latter is the only factor that has been substantially documented to date. Oldemeyer et al. (1977) reported on results of their moose habitat studies. Apparently, the optimum moose diet consists of a variety of browse species. The vegetation complex of the 1947 burn has shifted from that of a multi-species assortment of birch, willows, aspen, and alder to one dominated by a single species, paper birch. They feel that the 1947 burn is well beyond the 20-year productive life for moose estimated by Spencer and Hakala (1964) and is now marginal moose range. At present, however, moose numbers on the Kenai National Wildlife Refuge appear to be on the increase in apparent response to a series of mild winters and the 1969 burn reaching an optimum level of browse production (Ed Bangs, pers. comm.).

Caribou are once again present on the Kenai Peninsula because of a successful restocking program by personnel of the Alaska Department of Fish and Game. Burris and McKnight (1973) summarized the results of that program. As of this writing, there are 2 groups of caribou on the Kenai Peninsula : the American Pass band which numbers approximately 250 animals and the lowlands band containing 65-80 animals (Davis, pers. comm.). Both groups appear to be at or near the estimated carrying capacity of their respective ranges, and current population levels will be maintained through limited harvesting.

Chickaloon Flats

The first study site was in the forested uplands beginning just southeast of Chickaloon Flats and extending to the northwestern front of the Kenai Mountains (Figure 1). The area is located at 60°53'N, 149°59'W and lies in the Chugach National Forest near the northwest corner of the Kenai National Wildlife Refuge. Access to the area was by 4-wheel drive vehicle via a gas pipeline service road from the Sterling Highway to Turnagain Arm, crossing parts of both the Refuge and the National Forest.

The area is a heavily forested, hilly upland ranging in elevation from 30 m near the edge of Chickaloon Flats to 600 m at treeline in the mountains. Two major streams drain the area, the Big and Little Indian creeks. Three major forest types are found in the area: coniferous forest, deciduous forest, and mixed coniferous-deciduous forest. All 3 types were sampled during the study.

The coniferous forest habitat type was found at the lower elevations near Chickaloon Flats. Plots in this habitat (Figure 2)

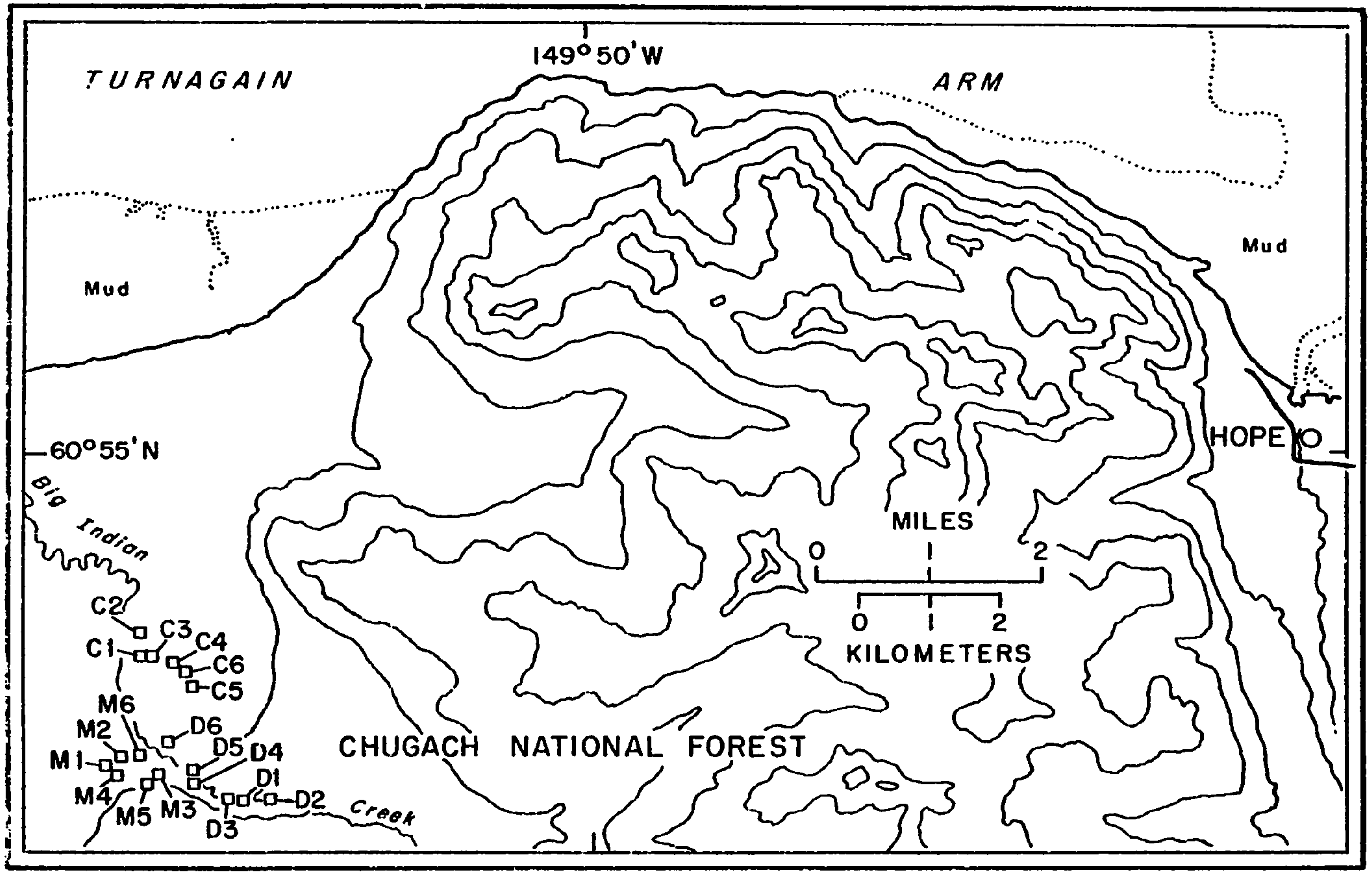

Figure 2. Chickaloon Flats study site, Kenai Peninsula, with plot locations for coniferous (C), deciduous (D), and mixed (M) forest habitats.

were dominated by black spruce (89% of all trees) with small proportions of white spruce (9%) and paper birch (2%). Stands were generally dense (average of 2753 trees/ha) and trees small (average diameter of 9.2 cm, average height of 8.0 m). Shrub densities were low with 4329 stems/ha and average cover of only 5%. Shrub height averaged 1.1 m. Shrub species composition consisted primarily of lowbush cranberry (*Vaccinium vitis-ideae*), wild rose (*Rosa acicularis*), Labrador tea (*Ledum palustre*), alders, willows, and black spruce seedlings and saplings. Ground cover was dominated by mosses with an average cover of 79%. Forbaceous plant cover was low (only 5%) and consisted primarily of the following species: *Equisetum* spp., twinflower, (*Linnaea borealis*) and wintergreens (*Pyrola* spp.). Sedge and grass cover was virtually nill. Lichen cover was only 0.17% and consisted mainly of reindeer lichens (*Cladina* spp.), small cup lichens (*Cladonia* spp.), *Stereocaulon* spp., and the foliose lichen, *Peltigera* spp.

Deciduous forest habitat occurred primarily along a narrow strip of uplands bordering Big Indian Creek. Plots (Figure 2) indicated the dominant tree species were paper birch (64% of all trees) and quaking aspen (14%), with white spruce (19%) and black spruce (3%) as sub-dominants. Trees in this habitat were considerably larger than those in coniferous forest, averaging 15.2 cm in diameter and 13.4 m in height. Tree density was lower than in coniferous forest with an average of 1400 trees/ha. Shrub densities were higher than in coniferous forest averaging 14,745 stems/ha and 12% cover, though the understory was still quite open. Shrubs included crowberry (*Empetrum nigrum*), willows, alders, highbush cranberry (*Viburnum edule*), lowbush cranberry, and seedlings and saplings of aspen, birch, white spruce, and black spruce. Ground cover consisted of mosses (9%) a variety of forbs (22%), few grasses (1%), and large amounts of litter (85%).

Mixed coniferous-deciduous forest habitat was the most widespread type and sample plots (Figure 2) revealed an almost even mixture of white spruce (53% of all trees) and paper birch (45%) with a small proportion of mountain hemlock (2%). Trees were large (22.0 cm in diameter, 14.2 m in height) and openly spaced (471 trees/ha) which allowed development of a dense shrub understory averaging 26,574 stems/ha and 34% cover. Shrub species consisted primarily of alders, devil's club (*Echinopanax horridum*), rusty menziesia (*Menziesia ferruginea*), highbush cranberry, lowbush cranberry, wild rose, and spruce and birch seedlings and saplings. Shrub height averaged 1.3 m. Ground cover was composed of mosses (18%), forbs (17%), grasses (5%), and large amounts of litter (71%).

Palmer Creek

The second study site on the Kenai Peninsula was a portion of the Kenai Mountains between Palmer Creek and the Resurrection Trail about 16 km south of the town of Hope at 60°49'N, 149°33'W

(Figure 1). The area was selected for sampling mat and cushion tundra habitat (Figure 3). Elevations in the area ranged from 600 m in the creek bottom to 1200 m at the ridge tops. Habitats varied from a narrow shrub zone dominated by willows and alders along the creek, through a grass-sedge-forb zone, to mat and cushion tundra at the upper elevations. The mat and cushion tundra habitat was dominated by dwarf shrubs (25% average cover), lichens (29%), forbs (7%), graminiforms (5%), and mosses (6%), with numerous patches of rocks and barren ground (10%). The shrub cover was composed of willows, mountain avens (*Dryas* spp.), and various ericaceous shrubs such as crowberry, lowbush cranberry, alpine bearberry (*Arctostaphylos alpina*), and alpine azalea (*Loiseleuria procumbens*). The lichen cover included reindeer lichens, *Cetraria islandica*, *Ce. cucullata*, *Cladonia gracilis*, *Cl. amaurocraea*, and *Thamnolia vernicularis*. The graminiform layer consisted primarily of grasses of the genus *Calamagrostis* and various *Carex* sedges. The sparse cover of forbs consisted mainly of forget-me-not (*Myosotis alpestris*), *Anemone* spp., and gentians (*Gentiana* spp.).

Turnagain Pass

The third study site on the Kenai Peninsula was an area north of Turnagain Pass on the Seward Highway at 60°48'N, 149°14'W

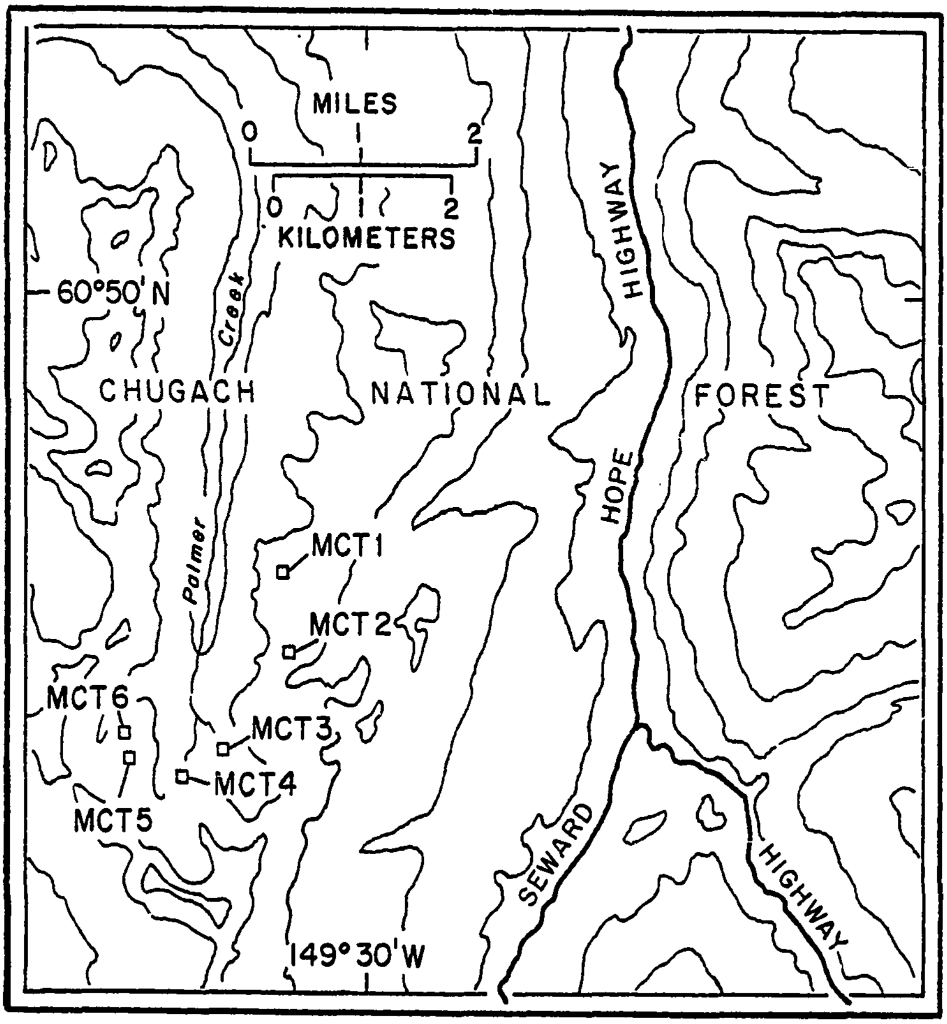

Figure 3. Palmer Creek study site, Kenai Peninsula, with plot locations for mat and cushion tundra (MCT) habitat.

(Figure 1). Elevation at the site was approximately 300 m. The area is drained by Granite Creek and its small tributaries, Tincan and Lyon creeks. The gravelly substrate laid down by these streams supports the extensive shrub stands sampled at this location (Figure 4). Shrubs in these stands were intermediate in height (averaging 1.4 m) and high in density (average of 43,461 stems/ha and 53% cover). Willows were the dominant species, comprising 99% of all stems, but a few alder shrubs and poplar seedlings also occurred. No trees were found in this habitat type. Ground cover consisted of litter (57% cover), forbs (30%), graminiforms (9%), and mosses (19%). Forbs were mainly twinflower, Alaska spiraea (*Spiraea beauverdiana*), *Ranunculus* spp., and *Epilobium* spp. Graminiforms consisted primarily of *Festuca* spp. and *Poa* spp.

Summit Lakes

The final study site on the Kenai Peninsula was the area around and including Upper and Lower Summit lakes along the Seward Highway (Figure 1). The lakes are located at 60°48'N, 149°14'W at an elevation of about 400 m. The complex freshwater aquatic habitat selected for sampling (Figure 5) is formed by interspersion of the lakes with creeks such as Summit and Canyon.

Beaver activity in the area has resulted in extensive flooding and formation of wet meadows and flooded shrublands. Streams were small (3 to 4 m wide, 0.5 to 1.0 m deep), and flowed slowly

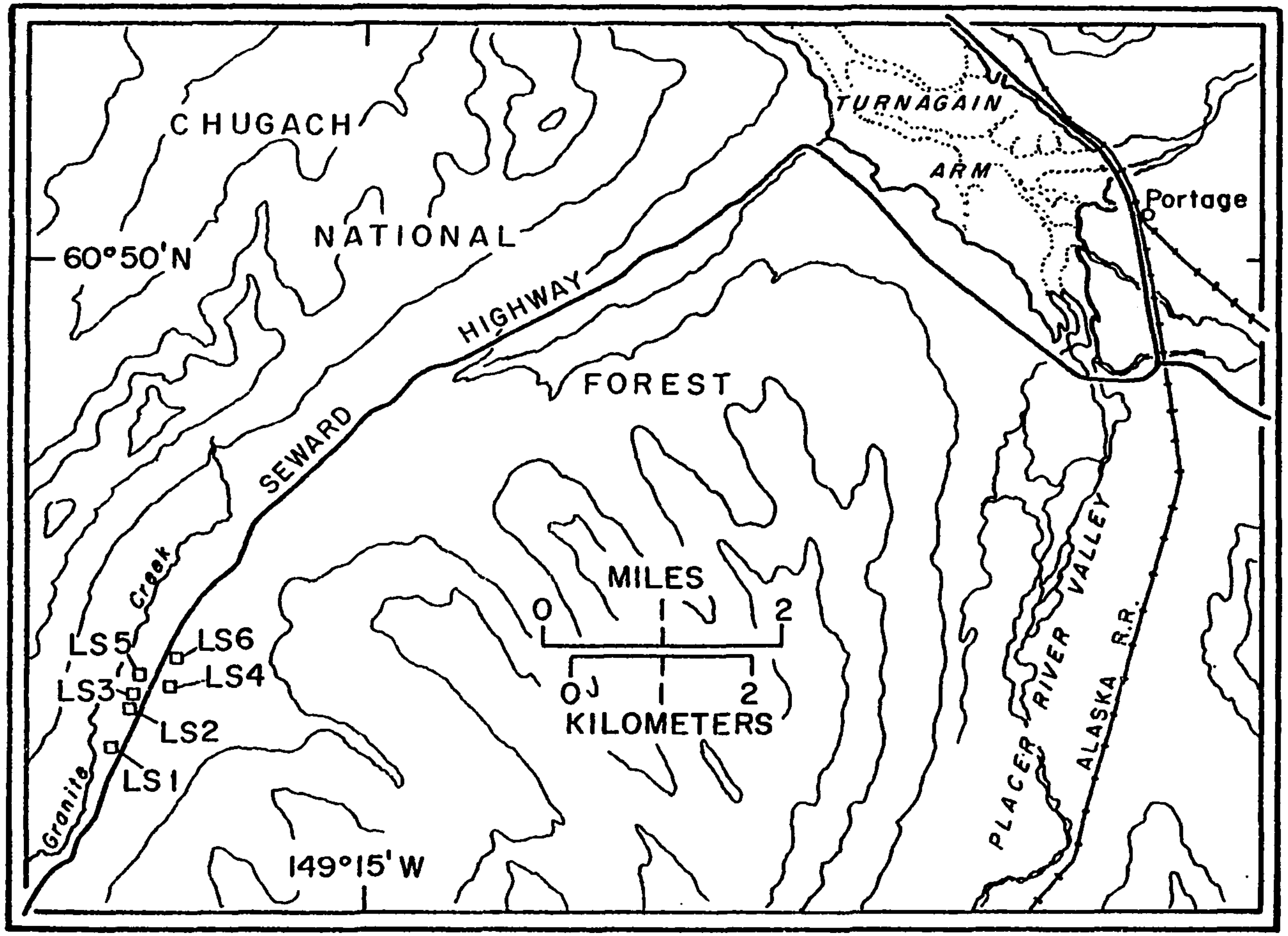

Figure 4. Turnagain Pass study site, Kenai Peninsula, with plot locations for low shrub (LS) habitat.

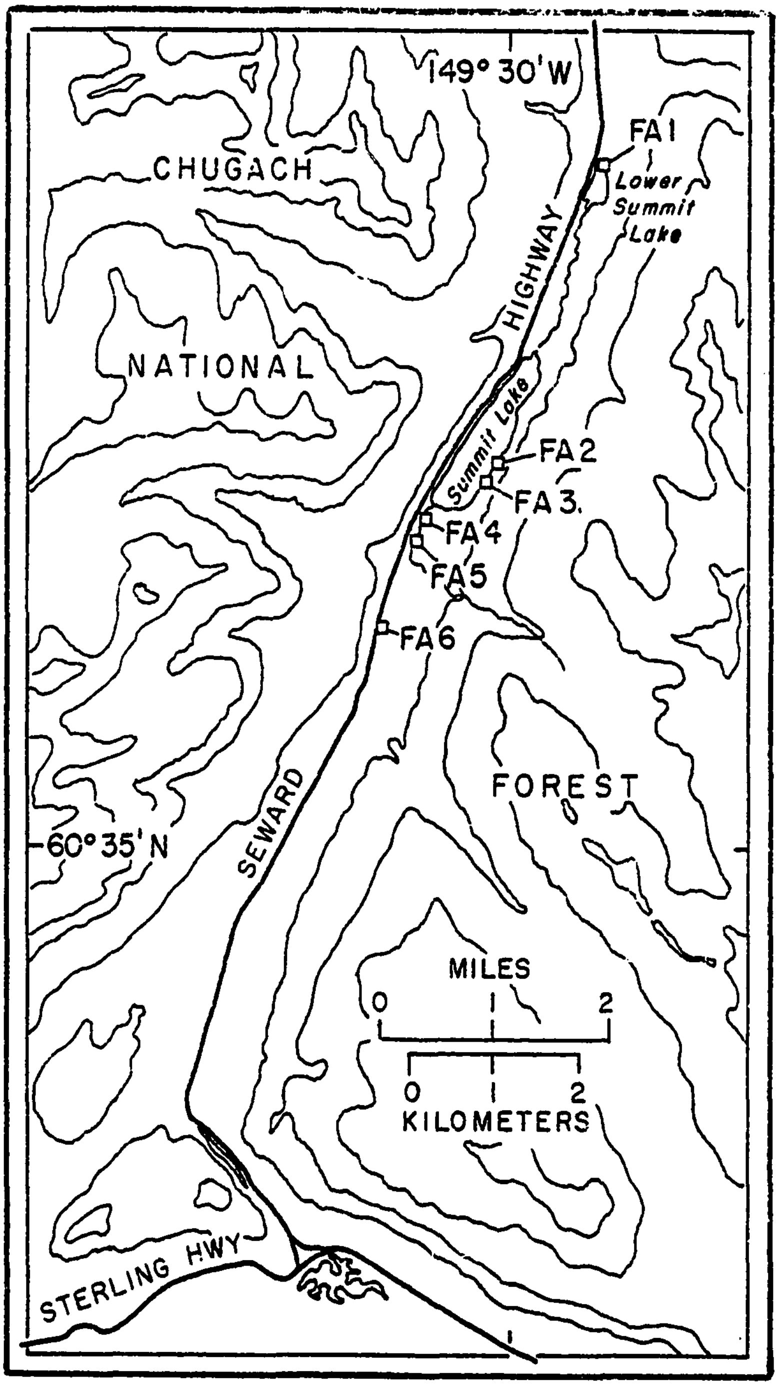

Figure 5. Summit Lakes study site, Kenai Peninsula, with plot locations for freshwater aquatic (FA) habitat.

(0.3 - 0.9 m/sec) through the wide valley along a gentle gradient of 1 to 3%. Stream channel beds were generally lined with loose, soft, fine-textured materials with some small rocks. Stream banks were well vegetated with little evidence of slumping or erosion.

Aquatic vegetation in the streams was sparse with 0-5% average cover. Streamside vegetation consisted of a few white spruce trees (average of 15 trees/ha) and dense stands of shrubs (45,625 stems/ha and 36% cover). Shrub stands were dominated by willows (77% of all stems) with lesser proportions of poplar and birch seedlings and saplings. The wet meadows were dominated by _Carex_ sedges and cottongrasses (_Eriophorum_ spp.).

Upper Summit Lake is an oligtrophic, rectangular-shaped lake about 2.3 km long and 0.5 km wide. Water depth varied from 1 - 10 m. Aquatic plants covered approximately 25% of the surface area. The lake is bordered on the west by the Seward Highway and on the east by steep mountain slopes that allow only a narrow shrub-woodland zone along the edge of the lake.

These shrub stands were dense, averaging 53,264 stems/ha and 38% cover. Species composition consisted primarily of willows (69% of all stems) with some birch, alder, and poplar seedlings and saplings. A few trees (5 stems/ha), primarily balsam poplar (87% of all trees), white spruce (8%), and paper birch (5%), were intermixed among the shrubs.

Lower Summit Lake is triangular-shaped, about 0.5 km long and

0.4 km across at the widest part. Maximum water depth was approximately 6 m. Aquatic vegetation was more abundant than in Upper Summit Lake, averaging 50% cover. Vegetation surrounding the lake was similar to that found around Upper Summit Lake.

COPPER RIVER DELTA

The first study area in 1980 was the Copper River Delta (CRD), which lies between 60° and 60°30'N and 144° and 146°00'W along the coast of Prince William Sound near Cordova, Alaska (Figure 6). This extensive 650+ km^2 wetland is a delta formed primarily by the deposition of sediments from the Copper River. The Copper River transports one-fourth the sediment and a greater amount of sand than the Mississippi River, but with only one-sixth the discharge (Galloway 1976). Considerable deposition of glacial outwash material has also contributed to the delta building process. The geomorphology of the CRD is the product of wave actions on these Copper River and glacial outwash sediments (Senner 1977).

The CRD is bordered on the south by the waters of The Gulf of Alaska and on the north by the rugged, glaciated mountains of the Chugach Range and associated smaller ranges. The Chugach Mountains are bisected longitudinally by the Chugach-Fairweather fault (Stoneley 1967). Indeed, the CRD has a long history of seismic activity. Previous subsidence of the area is indicated by the

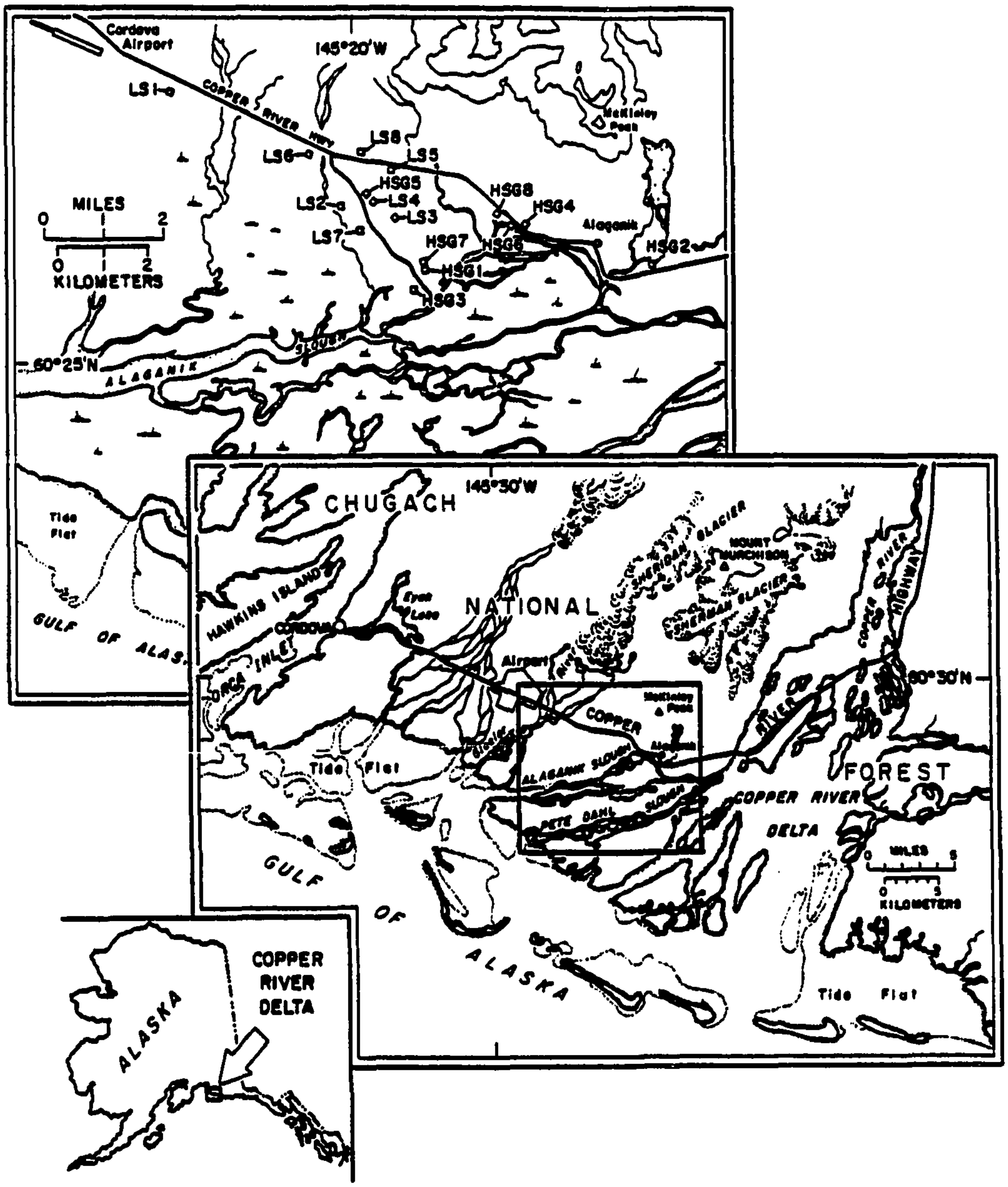

Figure 6. Copper River Delta (center map), 1980 study area, with plot locations for low shrub (LS) and herbaceous sedge-grass (HSG) habitats (upper map).

existence of 2 buried forest horizons visible in slough banks (Bromley 1976). Reimnitz and Marshall (1965) determined that the CRD was subsiding at a rate of 2.5 to 3.8 cm/year before the Great Alaska Earthquake of 1964. The earthquake interrupted this pattern of subsidence by uplifting the delta between 1.8 and 3.0 m (Reimnitz 1966).

The maritime climate of the CRD is typical of coastal southcentral Alaska, and is characterized by high annual precipitation, short cool summers, and long cool winters. Bromley (1976) summarized weather data for the western CRD for the months of April, May, and June in 1974 and 1975. Additional weather information can be found in Mickelson et al. (1980).

Plant communities on the CRD have been described by Crow (1968) and Potyondy et al. (1975). Mickelson et al. (1980) used a classification scheme similar to that suggested by Kessel (1979) to describe habitat types on the eastern CRD.

This study was conducted on the western CRD. Bromley (1976) described habitat types found in this area. The coastline is composed of mud and sand flats. Just inland from the coast, meadow habitats consisting primarily of sedge (Carex spp.) communities predominate. Further inland, the habitat is dominated by shrub marshes consisting of sweet gale (Myrica gale), mountain alder (A. crispa), and various willow species. An alder-Sitka spruce community becomes dominant about 11 km from the coast. Interspersed throughout the area are numerous sloughs and ponds.

It should be noted that the vegetation complex of the CRD is in a state of change due to the uplifting that occurred during the 1964 earthquake. This uplifting has resulted in better drainage and reduced levels of tidal inundation on the delta. Soils have become more mesic and soil salinity has decreased (Crow 1968, In Bromley 1976). Conditions have become more favorable for the growth of woody plants and, at present, the supratidal marsh is being invaded by shrub-spruce communities (Mickelson et al. 1980).

Two habitat types were sampled on the western CRD: low shrub and herbaceous sedge-grass (called shrub marsh and supratidal wet meadow, respectively, by Mickelson et al. 1980). Extensive areas of wet low shrub habitat are found on the western CRD between the coastal sedge-dominated habitats and the upland coniferous forest zone. Plots in this habitat type (Figure 6) averaged 70% shrub cover of roughly equal proportions of willows, mostly S. barclayi but some S. sitchensis, and sweet gale. Shrubs averaged 1.0 to 1.5 m in height. Forb cover averaged 10% and consisted primarily of marsh fivefinger (Potentilla palustris), Epilobium palustre, Rubus arcticus stellatus, wintergreens, and Equisetum spp. Graminiform cover averaged 25% and was composed of sedges, primarily C. lyngbyaei, with a lesser proportion of grasses, mostly Deschampsia spp. Mosses covered significant portions of the plots.

Closer to the coast and in the more poorly drained inland areas near sloughs and ponds was found the herbaceous sedge-grass habitat. Sample plots (Figure 6) indicated dominance by sedges, mainly *C. lyngbyaei*. Grasses, primarily *Deschampsia* spp., *Festuca* spp., and *Eriophorum* spp., were also abundant. Forbs comprised a small percentage of the total ground cover, but included numerous species such as marsh fivefinger, vetchling (*Lathyrus palustris pilosus*), *Caltha palustris asarifolia*, buckbean (*Menyanthes trifoliata*), water hemlock (*Cicuta douglasii*), and *Equisetum* spp. Numerous willow and sweet gale shrubs were found on some plots, indicative of the aforementioned shrub invasion of the wet meadow habitats.

The vast wetlands and coastal mudflats of the CRD are host to a wide variety of avian species which utilize the delta for breeding and/or staging. The delta provides breeding habitat for several waterfowl and shorebird species including the entire known breeding population of the dusky Canada goose (*Branta canadensis occidentalis*) (Bromley 1976) and numerous pairs of trumpeter swans (*Cygnus buccinator*). Many terrestrial bird species also breed on the delta. The CRD is important as a staging area in spring and fall for water birds migrating through the Pacific Flyway. It is one of the few sizeable areas between Washington state and Alaska that provide suitable staging habitat for these birds (Mickelson et al. 1980). For some species the CRD may be a critical habitat. Senner (1977) concluded that the CRD is a critical habitat for western sandpipers (*Calidris mauri*) and dunlins (*C. alpina*). Significant portions of their entire populations pass through the CRD and adjacent areas in the first 2 weeks of May, largely utilizing the system's littoral zone.

Several species of mammals are also found on the CRD. These include moose (introduced on the western CRD in 1949 and more recently spreading to the eastern CRD), brown bear (*U. arctos*), wolf, coyote (*C. latrans*), red fox (*Vulpes fulva*), mink, beaver, muskrat (*Ondatra zibethicus*), and a variety of small mammals. Additional information on the status and abundance of mammals and birds utilizing the CRD can be found in Isleib and Kessel (1973), Isleib (1979), Mickelson et al. (1980), Murphy (1981), Hawkings (1982), and Herter (1982).

NELCHINA BASIN

The second study area in 1980 was the Nelchina Basin, a 45,000 km^2 area bounded on the north by the summit of the Alaska Range, on the east by the Copper River and Wrangell Mountains, on the south by the Glenn Highway and Chugach Mountains, and on the west by the Parks Highway (Figure 7). The Nelchina Basin has a varied topography that ranges from spruce-covered lowlands and bog basins containing numerous lakes and streams, to brush-covered foothills, to alpine sedge meadows and tundra, to steep rugged mountains rising to over 3000 m. The basin is most noted for the Nelchina Caribou Herd, whose "center of habitation" lies within the boundaries of the basin (Skoog 1968). The study site was an area just south of the Denali Highway and extending 50 to 65 km east of Cantwell, Alaska (Figure 7). The Denali Highway is a 200 km long

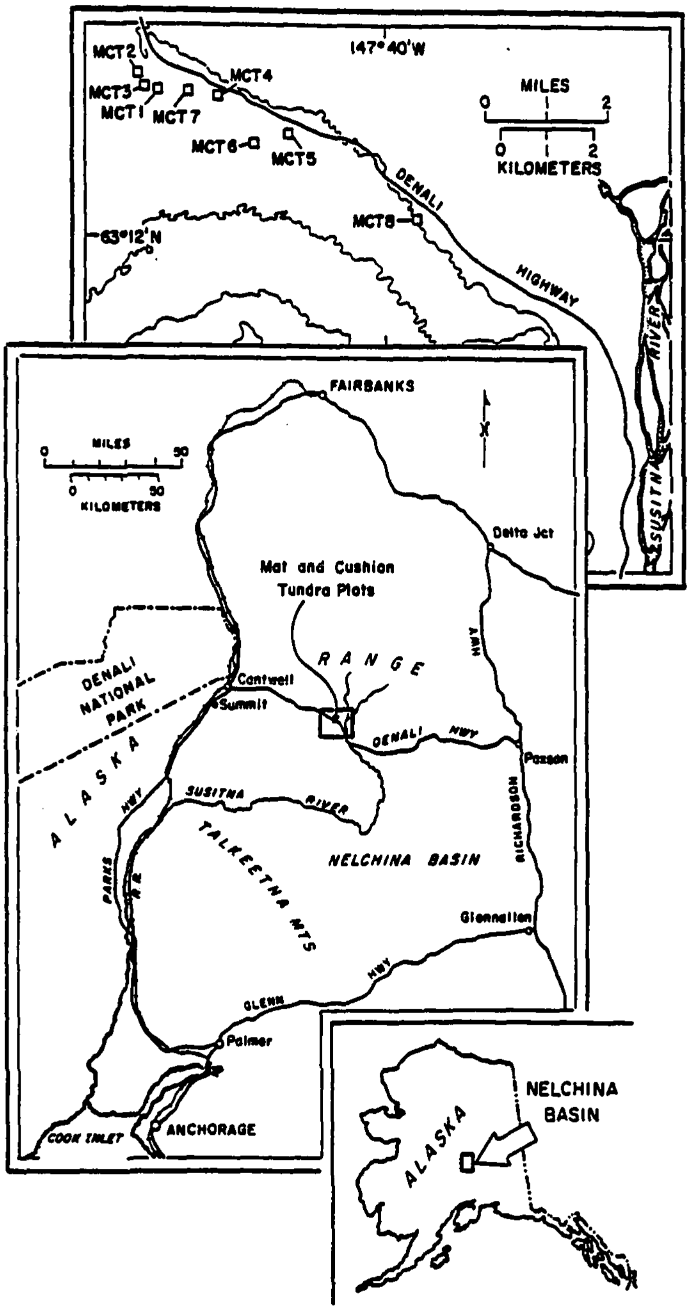

Figure 7. Nelchina Basin (center map), 1980 study area, with plot locations for mat and cushion tundra (MCT) habitat (upper map).

gravel road that traverses the northern portion of the Basin from east to west between Paxson and Cantwell. The site was selected for sampling the extensive and easily accessible tundra habitat found in the area.

Skoog (1968) provided detailed description of the Nelchina Basin area. The present physiography of the basin, with wide variations in elevation, slope, and exposure, is due partly to the complex drainage system. The region is drained by 3 major systems. The northern portion of the basin drains into the Tanana-Yukon River System via the Nenana River in the northwest and the Delta River in the northeast. The southeastern quarter is drained by the Copper River. The remaining and largest portion of the basin is drained by the Susitna and Matanuska Rivers. Numerous smaller streams and rivers are components of each of these systems. Poorly drained areas interspersed throughout the lowlands contain hundreds of lakes and ponds.

The climate of the Nelchina Basin is essentially continental, resembling that of interior Alaska except for generally milder temperatures and higher precipitation. Detailed climatological information can be found in Skoog (1968).

The sampled area was part of the Deadman Lake Range Unit (Skoog 1968), lying in the northwest portion of the Basin and bounded on the north by the Denali Highway, on the east and south by the Susitna River, and on the west by the Chulitna Mountains (Figure 7). The 3500 km^2 area consists mainly of rolling hills above timberline, ranging in elevation from 730 m to 1800 m.

Snowfall in the area is generally moderate, with snow depths rarely exceeding 60 cm on level ground. Winds are also moderate; areas blown completely free of snow are uncommon, though snow cover on exposed slopes may be reduced to less than 25 cm. Snow usually persists well into May in level areas, but may be gone from south- and east-facing slopes in early April.

Habitats in this unit consisted primarily of the following types: dwarf heath (27% of the total area), dwarf birch (26%), sedge meadow (19%), willow (8%), and bunchgrass (8%) (Skoog 1968). The present study was concerned with the dwarf heath type which I called mat and cushion tundra. This habitat type is found primarily on xeric sites above timberline, extending to over 1525 m in elevation and dominating the wind-swept alpine zone. Plots in this type (Figure 7) were dominated by a wide variety of dwarf and prostrate shrubs including dwarf birch, arctic willow (*S. arctica*), diamondleaf willow (*S. pulchra*), highbush cranberry, lowbush cranberry, Labrador tea, crowberry, alpine bearberry, cassiope (*Cassiope tetragona*), white mountain avens (*Dryas octopetala*), diapensia (*Diapensia lapponica*), and alpine azalea. The sedges *Carex bigelowii* and *Kobresia myosuroides* were very common and often co-dominant with the dwarf shrubs. Forbs were uncommon and consisted primarily of lousewort (*Pedicularis* spp.) and bistort (*Polygonum bistorta plumosum*). The grass *Hierochloe alpina* was common. Lichens were very abundant, consisting mainly of *Cladina* spp., *Cladonia* spp., and *Cetraria* spp. Overuse by caribou of the preferred lichen species was evident (Klein, pers. comm.).

Deterioration of the lichen range throughout the Nelchina Basin has been documented by Skoog (1968) and Pegau (1975).

The continuity of the dwarf heath habitat type at the study site was disrupted by willow, dwarf shrub, and sedge meadow habitats, which occurred in the numerous drainages and wet depressions found throughout the area. A few plots bordered sedge meadows and contained plants such as coltsfoot (*Petasites* sp.), cottongrass, and *Equisetum* spp. that were not found on the drier sites.

The Nelchina Basin is host to a wide variety of mammalian and avian fauna. Skoog (1968) listed mammals found in the area and Kessel et al. (1982) discussed avian utilization of the region. Of particular importance is the Nelchina caribou herd which ranges widely over the basin and now numbers approximately 20,000 animals (Davis, pers. comm.). The herd usually calves south of the study site in lower above-timberline (900 to 1350 m) areas east of the Talkeetna Mountains. Though not generally used as a calving area, the study site is utilized by large segments of the herd in mid- to late summer, fall, and winter (Skoog 1968).

Additional information regarding the Nelchina Basin and the Nelchina caribou herd can be found in Skoog (1968), Pegau and Hemming (1972), Bos (1975), Hemming (1975), Pegau (1975) and Doerr (1979).

METHODS

SAMPLING PROCEDURES

HEC Handbook models for moose, caribou, beaver, mink, spruce grouse, common redpoll, and green-winged teal were selected for assessment based on their ecological and socio-economic importance. Various habitat types corresponding to the above models were selected for sampling based on their availability in the different study areas. Habitat type designation was at Level II in the vegetation classification scheme of Dyrness and Viereck (1979). Six habitat types were sampled on the Kenai Peninsula in 1979: coniferous, deciduous, and mixed forests at Chickaloon Flats; mat and cushion tundra at Palmer Creek; low shrub in an area north of Turnagain Pass; and freshwater aquatic at Summit Lakes. Two habitat types were sampled on the Copper River Delta in 1980: low shrub and herbaceous sedge-grass. Mat and cushion tundra habitat was sampled in the Nelchina Basin in 1980. These habitat types and locations were described in the previous section.

In 1979 the 3 teams which gathered the information required by the HEC Handbook consisted of myself and my wife Suzette Mulé, Peter and Belle Mickelson of the University of Alaska, Fairbanks (UAF), and Lana Shea and various assistants from the USFWS. In 1980 the single team consisted of myself and Suzette Mulé. Data were collected for calculation of HSI values for the following species and associated habitat types: moose - coniferous, deciduous, and mixed forests, mat and cushion tundra, low shrub on the Kenai, and low shrub and herbaceous sedge-grass on the CRD; caribou - coniferous forest, low shrub, mat and cushion tundra on the Kenai and mat and cushion tundra in the Nelchina Basin; beaver - freshwater aquatic on the Kenai; mink - herbaceous sedge-grass and low shrub on the CRD; spruce grouse - coniferous forest and mixed forest on the Kenai; common redpoll - coniferous, deciduous, and mixed forests, and low shrub on the Kenai; green-winged teal - herbaceous sedge-grass, low shrub on the CRD.

An attempt was made to obtain the services of at least 2 experts per species for rating habitat quality at each site. However, due to various extenuating circumstances we were able to obtain only 1 expert for each species except caribou. The experts and the species and habitat types which they rated were as follows: Dr. Wayne Regelin - moose on the Kenai in coniferous, deciduous, and mixed forests; Dr. John Thilenius - moose on the CRD in herbaceous sedge-grass and low shrub; Jim Davis - caribou on the Kenai in coniferous forest and mat and cushion tundra and in the Nelchina Basin in mat and cushion tundra; Dr. David Klein - caribou in the Nelchina Basin in mat and cushion tundra; John Hakala - beaver on the Kenai in freshwater aquatic; John Burns - mink on the CRD in herbaceous sedge-grass and low shrub; Dr. Robert Weeden - spruce grouse on the Kenai in coniferous and mixed forests; Michael Spindler - common redpoll on the Kenai in coniferous, deciduous, and mixed forests, and low shrub; Dr. Calvin Lensink - green-winged teal on the CRD in herbaceous sedge-grass and low shrub. The addresses of the above persons are listed in the personal communications section.

Species expert ratings were not acquired for all sites for which Handbook ratings were obtained. This was due to logistical concerns and time limitations imposed by the species experts. Thus, accuracy testing was not performed for all species and habitats for which precision testing was conducted. This will be further detailed in the results section.

One-ha square plots were randomly selected from aerial photographs on 1:63,360 U.S. Geological Survey topographic maps. In 1979 6 plots were selected in each habitat type and in 1980 8 plots were chosen. Distances and bearings to the plots were calculated from known points to facilitate location on the ground. Plots were physically located on the ground by pacing with a compass. I felt that pacing was generally as accurate as taping for measuring distances under the terrain and conditions encountered. All plots were oriented with boundaries in due north-south and east-west directions.

On each plot data were collected for estimating the various habitat parameters required by the appropriate species-models. Some variables, henceforth called subplot variables, were sampled on a series of subplots within the 1-ha plots. Other variables, henceforth called plot variables, were estimated only once per 1-ha plot. The decision to subsample or not was based on the nature of the variable and the perceived difficulty of obtaining a reliable estimate with a single sample per 1-ha plot. Subplot variables were those such as percent cover for various vegetative components of the habitat (grasses, herbs, forbs, shrub canopy, tree canopy, etc.), stem counts, tree heights, tree diameters, numbers of plant species, and others. These variables were usually estimated with data of the ratio type, i.e. the values were numerical units where both the interval size and the ratio between measurements are important. All such variables are given on pages 54, 55, 56 and 57. Some subplot variables were estimated with nominal-type data; these are shown on page 67. Plot variables were generally those for which the particular model required the selection of an easily identified class or category, such as Stream Bank Suitability for beaver or Edaphic Conditions Within Stand for moose. These variables yielded estimates of nominal-type data, i.e. the number or letter assigned to the observation serves only as a name for the category to which the observation belongs; all are shown on pages 67 and 68. Some plot variable estimates were data of the ratio-type. Examples are Distance to Food Source and Maximum Water Depth for beaver; these are shown on page 66. The subplot data were later averaged to the plot level required by the HEC models. Also, some subplot variables were combined to obtain estimates for certain model parameters. The combined and/or averaged variables can be found on pages 63 and 64; the estimates were ratio-type data. Each data type required different statistical analyses as discussed in the following section.

The subsampling scheme was similar to that described by Ohmann and Ream (1971). Ground cover estimates were made on 1 m^2 subplots within the 1-ha plots; shrub estimates were made on 1.25 m radius circular plots nested over the 1 m^2 subplots; tree data were obtained with the point-center-quarter method, again using the same centerpoint as above. Twelve subplots were sampled in each 1-ha plot. The first subplot was randomly located with the remaining 11 subplots situated at 25 m intervals, resulting in a configuration of 3 rows (running due north-south) of 4 subplots. Each team obtained the required estimates and measurements on the subplots, then completed those estimates for which subsampling was not required. Teams always worked independently of one another, though the plots and subplots were the same for all teams.

The sampling scheme was modified somewhat for the freshwater aquatic habitat evaluation for beaver. For streamside vegetation sampling, 1-ha plots were located randomly along the stream such that one-half of the plot fell on either side of the stream. On each side of the stream there were 2 rows of 3 subplots spaced 25 m apart with the first subplot located randomly.

For the lakeside vegetative sampling, 1-ha plots were randomly located along the edge of the lake. Two rows of 6 subplots spaced 25 m apart were established, again with the first subplot randomly located. Other aquatic habitat parameters such as Water Depth, Substrate Type, etc. were sampled appropriately.

After the data required by the HEC models had been collected, the species experts rated the corresponding plots. The experts rated habitat quality without the aid of the HEC Handbook using their knowledge of a species and its habitat needs, with the ratings on the same scale as the HSI values in the models. Experts generally gave 2 estimates, a non-winter habitat rating and a winter range rating which represented overall values for the habitats. However, some experts did not give overall ratings, but gave ratings for each factor (such as food, cover, water, etc.) separately.

DATA ANALYSIS

All computer operations except the calculation of the HSI values were performed on the University of Alaska Computer Network (UACN), which utilizes dual Honeywell 66/40 computers and a Time Sharing System. The subplot data were summarized to the plot level needed by the HEC models using a series of computer programs obtained from Joan Foote (pers. comm.) of the U.S. Forest Service's Institute of Northern Forestry. These summarized data and the other data already at the plot level were the basis for calculating HSI values (done by Mr. Greg Konkel, USFWS, Anchorage office).

Two methods of calculating the HSI values were used, a multiplicative mean method and a geometric mean method. The first method (used in the current edition of the HEC Handbook) is simply the product of the appropriate Suitability Indices. The second method is based on the nth root of the product of the appropriate Suitability Indices, where n is the number of Suitability Indices in the equation. The HSI values generated with the geometric mean are higher than with the multiplicative mean, except when the HSI is determined by 1 Suitability Index, all Suitability Indices are 1.000, or 1 or more of the Suitability Indices are 0.000; in these cases the values are the same with both methods. With the multiplicative mean approach a life requisite equation containing 2 or more Suitability Indices less than 1.000 will produce an HSI that is lower than any single Suitability Index in the equation. This is because the cumulative effect of multiplying fractions is a product that is lower than the individual factors in the equation. A related effect is that the HSI decreases as the number of Suitability Indices in the equation increases. This supposedly represents the synergistic effect that 2 or more habitat parameters in a sub-optimum condition can have on the overall habitat suitability. I felt that it would be useful to examine HSI values calculated using each approach, so all analyses were performed on both sets of HSI values.

Precision testing involved 3 components of the data set. The first component involved whether the 3 teams showed any significant differences in the actual sample data collected at both the subplot and plot levels. The next component was concerned with the subplot data that were averaged and/or combined to ascertain if among team differences at the subplot level were masked by this process. The final component involved whether the 3 teams had significant differences in the HSI values generated by the models.

A probability level of $\leq .05$ was used for all significance testing unless otherwise noted.

A two-way analysis of variance (ANOVA) was chosen as the most effective statistical procedure for examining precision of the subplot data. Program 2V of the Biomedical Computer Programs (BMDP) (Dixon and Brown 1979) was used, with some adjustment for a random effects model. The two-way ANOVA was appropriate because of the replication obtained by subsampling within the 1-ha plots (the sampling units). A two-way ANOVA should be used, if possible, because it provides information concerning 2 grouping factors, whereas a one-way ANOVA yields information about only 1 factor. The grouping factors used in this case were the teams and the 1-ha plots.

For each subplot variable the two-way ANOVA yielded tests of significance of difference (F-values) of means among teams and plots, and for team-plot interactions. The team F-value is a test for significance of difference among team means, which indicates the level of precision (or variability) among the teams' data sets. The plot F-value tests for significance of difference of means among plots, and is a indication of the variability among the plots. Both tests are independent of one another, such that significance or non-significance of the F-values for 1 grouping factor has no effect on the other. The team-plot interaction F-value, on the other hand, tests for interactions among teams and plots and is dependent on both. While the team and plot F-values test only for differences among the <u>means</u> of the teams and plots, the team-plot interaction F-value tests for differences among teams in the <u>patterns</u> of their data. It is possible for the ANOVA to yield non-significant

F-values for both teams and plots, but a significant F-value for team-plot interaction. Such a situation would indicate that there is some significant difference among teams having to do with the plot-by-plot arrangement of each team's data, even though the means among teams or plots do not differ significantly. Thus, the interaction value is important because it validates the results of the other tests.

Initially, the ANOVA was performed on data for each of the appropriate subplot variables within each habitat type separately (using teams and plots as the grouping factors). This resulted in the tests of significance given above. Then an ANOVA was performed with all the habitats pooled together using teams and habitats as the grouping factors. This was a means of examining the variables across all habitat types. The ANOVA yielded tests of significance of difference of means among teams and habitats, and team-habitat interaction values.

In addition to the ANOVA, a Discriminant Function Analysis was performed on the subplot data for each habitat type using BMDP program 7M. This analysis allowed statements to be made about the differences, or lack thereof, among the teams' data sets as a whole rather than on a variable by variable basis as with the ANOVA. In a simplified sense the discriminant analysis was used as a multivariate ANOVA. Additional information concerning Discriminant Function Analysis can be found in Davis (1973) and the BMDP Manual (Dixon and Brown 1979).

For the nominal-type data from plot variables, two-way contingency tables of frequency distributions (Conover 1971) were constructed for each variable and habitat type. Rows in the tables were the classes or categories of choice for each variable, and columns were the 3 teams. Chi-square tests for independence of rows and columns (indicating whether team choices were similar or dissimilar) were performed to test for precision among teams using a program called RCTEST (Edward C. Murphy pers. comm.).

Some plot variable estimates were data of the ratio type; all of these were for the beaver model in freshwater aquatic habitat. A subsampling scheme was not used for these variables. Thus, because there was no within-plot replication a two-way ANOVA was not possible. A one-way ANOVA was performed to test for differences of means among teams using the SPSS/ONEWAY program (Nie et al. 1975). A Discriminant Function Analysis (BMDP/7M) was also performed on these data.

The second aspect of precision testing was to examine the plot level data that had been averaged and/or combined from the subplot data. This was to determine how much of the variability observed among the teams' subplot data was obscured by this process. A one-way ANOVA (SPSS/ONEWAY) was performed for each variable within habitat types to test for among-team differences; a Discriminant Function Analysis (BMDP/7M) was also performed.

The final, and most important, component of precision assessment involved examination of the HSI values calculated from the sample data for each team. Within each habitat type a one-way

ANOVA (SPSS/ONEWAY) was performed on each of the life requisite HSI values. In addition, a Student-Newman-Keuls (SNK) multiple range test was performed following each ANOVA to determine which team(s) differed significantly from the other team(s) when the F-value was significant.

Although it was not appropriate to perform a two-way ANOVA within habitats to test for interaction between teams and plots, interaction could be examined in another manner. For each species within a given habitat type the differences between pairs of team HSI values were calculated on a plot-by-plot basis for all life requisites. The absolute values of these differences were taken and the average of the absolute differences was calculated to produce a value henceforth called the mean absolute difference. The absolute values of the differences were used in computing the means so that positive and negative differences in the same data set would not cancel out. Mean absolute differences were calculated for all possible team pairings.

The mean absolute difference is sensitive to differences between teams on a plot-by-plot basis, while the one-way ANOVA only detects differences between the means of the teams' HSI values. Thus, the mean absolute difference yields information similar to that obtainable from the interaction value in a two-way ANOVA, although it is not possible to compare all 3 teams at once. It is also useful in establishing a standardized level of acceptable between team deviation in HSIs that does not change depending on the variances involved, as does the F-value from an ANOVA. The mean absolute difference is a measure of the differences that can be considered consequential from the standpoint of HEP.

A maximum mean absolute difference of 0.100 was selected as an acceptable level of precision among teams. The 0.100 level was chosen because it allows a maximum range in the teams' HSI values of 0.200. To illustrate, for a given species, life requisite, and habitat type, if 1 team's HSI values were 0.500 on all 6 plots and the other team's HSI values varied from 0.400 to 0.600, the 2 teams' ratings would be accepted as precise. Any level greater than 0.100 would permit an unreasonably large range of precision. The difference between HSIs of 0.400 and 0.600 may not be consequential, but the differences between ratings of 0.350 and 0.650 (if the acceptable level was 0.150) or 0.300 and 0.700 (if the level was 0.200) are too substantial to accept.

Accuracy of the HEC Handbook was assessed by comparing the team habitat quality ratings (HSI values) with ratings obtained from species experts. Experts usually gave 2 ratings for each plot, a non-winter habitat quality value and a winter habitat quality value. In these cases the expert winter range value was compared with the winter range life requisite HSI value from the appropriate model; the expert non-winter rating was compared with each of the remaining life requisite HSI values. For those models which experts gave habitat quality scores for each life requirement separately, direct comparisons were made between the expert ratings and the corresponding life requisite HSIs.

For reasons previously discussed, mean absolute differences between team HSI values and species expert ratings were calculated for each species and habitat type in the same manner as for precision testing. For data from 1979 mean absolute differences were calculated between scores for each team and the species expert, and the average of the team scores and the species expert. For 1980 data average differences were calculated between 1 set of team HSI values (since precision was not tested) and the species expert(s) ratings. A maximum mean absolute difference of 0.100 between team(s) and expert(s) was selected as an acceptable level of accuracy.

Pearson's Produce-moment Correlation Coefficients were calculated for those variables which yielded significant team-expert F-values and/or unacceptable team-expert average differences. The purpose was to explore the possibility of applying some correction factor to inaccurate HSI values as a means of improving the HEC models. The SPSS/SCATTERGRAM program was used for the analysis. For each habitat type correlations were made between team(s) HSI values (3 teams and team average for 1979, 1 team for 1980) and species expert(s) ratings.

One of the assumptions made when using an analysis of variance (as with most other parametric statistical tests) is that all sample data sets exhibit the normal distribution. Unfortunately, much of the subsample data were not normally distributed. Two data transformations were performed in an attempt to rectify the problem, but certain variables responded better to the natural log transformation, others to the arcsine transformation, and others were more normally distributed with no transformation. Because neither transformation worked well on all the variables, the ANOVAs were performed on the subplot variable data in the untransformed state. Although I accepted these results as valid, it should be known that this assumption was violated in some cases. However, ANOVA is a robust statistical procedure and considerable deviation from this assumption can be tolerated before the results are adversely affected; precisely how much deviation can be tolerated is not known. The plot data (excluding certain beaver parameters) were analyzed using a chi-square test which does not require any assumptions regarding normality or homogeneity of variances. The plot sampled data for beaver, the averaged and/or combined data, and the HSI values and species expert ratings were normally distributed.

The Bartlett's Test and the F-max test (Sokal and Rohlf 1969) are commonly used to test for homogeneity of variances, another requirement of ANOVA. For certain variables these tests (SPSS/ONEWAY) indicated significant non-homogeneity of sample variances, which could result in an inaccurate test statistic. Non-parametric tests are often used when the assumptions of homogeneity of variances and normality of the distributions are severely violated. However, the appropriate non-parametric tests are not reliable when there are many ties in the data (Conover 1971); such was the case with much of the subsample data which contained numerous 0 values. Also, there are no non-parametric tests that are directly comparable to a two-way ANOVA and SNK, and in cases where the required assumptions hold entirely or even approximately true, the ANOVA is generally the more efficient statistical test for detecting departures from the null hypothesis (Sokal and Rolhf 1969). Therefore, I used ANOVA as the most desirable alternative. The Discriminant Function Analysis was used with similar justification. The mean absolute difference analysis was not subject to these considerations.

RESULTS AND DISCUSSION

AMONG-TEAM PRECISION OF SAMPLE DATA

Because there were so many variables sampled (both subplot and plot), several of which were used for more than 1 species-model, precision among teams of the sample data is not discussed on a species basis as is precision and accuracy of the model HSI values. Instead, sample data precision results are presented according to the data-type groups (as previously discussed) to which variables belong. Unless otherwise noted, a probability level of $\leq .05$ was used for all significance testing in this and the following sections.

Subplot Ratio-type Data

Two-way ANOVA - Results of the two-way ANOVA of subplot data for ground cover, shrub, and tree variables are given in Tables 1, 2, and 3, respectively. The tree variables, distance to and diameter of trees 1, 2, 3 and 4, refer to measurements taken on trees in each of the 4 subplot quadrants with the point-center-quarter procedure. All other variables should be self-explanatory.

The two-way ANOVA on subsample data yielded variable results

Table 1. F-values from two-way ANOVA with team and plot or team and habitat grouping factors for subplot ground cover variables of ratio-type data. The species for which the variable was measured is given in parentheses. Degrees of freedom vary. A dash indicates the variable was not measured in that habitat type.

HABITAT TYPE	SOURCE	% COVER NON-VEGETATED (Moose, Caribou)	% COVER LITTER (Moose)	% COVER MOSS (Caribou, C. Redpoll)	% COVER HERBS (Moose, Beaver)	% COVER GRAMINIFORMS (Caribou, C. Redpoll)	% COVER FORBS (Caribou, Moose)	% COVER VASCULAR PLANTS (Moose)	% COVER WOODY AND HERBACEOUS VEGETATION (S. Grouse)	% COVER LICHENS AND VASCULAR VEGETATION (Caribou)	% COVER *Cetraria islandica* (Caribou)	% COVER *Cetraria cucullata* (Caribou)	% COVER *Cladonia amaurocraea* (Caribou)	% COVER *Cladonia gracilis* (Caribou)	% COVER *Thamnolia vermicularis* (Caribou)	% COVER REINDEER LICHENS (Caribou)	% COVER SMALL CUP LICHENS (Caribou)	% COVER OTHER FRUTICOSE LICHENS (Caribou)	NUMBER OF PLANT SPECIES (Moose)	HEIGHT OF GROUND VEGETATION (S. Grouse)
CONIFEROUS	Team	3.36*	1.51	3.19*	3.52*	1.00	2.52	-	1.31	4.86*	0.00	0.00	1.00	0.00	.454	1.43	2.83	0.00	4.83	8.90
FOREST	Plot	1.36	6.80*	11.8*	22.2*	2.39*	4.07*	-	19.8*	28.6*	0.00	0.00	1.00	0.00	.727	4.02*	1.57	0.00	25.1*	5.51*
	Team-Plot	.980	.430	.380	.470	1.17	1.05	-	.802	.717	0.00	0.00	1.00	0.00	1.10	.930	1.07	0.00	1.41	2.16*
DECIDUOUS	Team	.774	7.65*	2.13	14.8*	1.11	8.53*	-	23.1*	-	-	-	-	-	-	-	-	-	7.85*	7.66*
FOREST	Plot	.902	19.0*	18.7*	30.7*	2.98*	14.4*	-	9.67*	-	-	-	-	-	-	-	-	-	10.2*	5.84*
	Team-Plot	1.03	.290	.330	.510	1.31	.830	-	.458	-	-	-	-	-	-	-	-	-	1.31	1.04
MIXED	Team	1.00	11.5*	.672	2.36	5.72*	3.82*	-	6.06*	-	-	-	-	-	-	-	-	-	29.2*	4.60*
FOREST	Plot	1.00	3.29*	10.4*	19.4*	6.13*	.544	-	6.94*	-	-	-	-	-	-	-	-	-	14.7*	3.34*
	Team-Plot	2.20*	1.40	.500	.750	.270	3.15*	-	1.22	-	-	-	-	-	-	-	-	-	.412	1.96*
LOW	Team	-	25.5*	.869	31.4*	11.6*	21.8*	-	-	-	-	-	-	-	-	-	-	-	2.15	-
SHRUB	Plot	-	2.59*	2.58*	6.04*	8.43*	9.91*	-	-	-	-	-	-	-	-	-	-	-	1.50	-
	Team-Plot	-	2.25*	.920	.920	1.18	.620	-	-	-	-	-	-	-	-	-	-	-	1.10	-
MAT AND	Team	.237	4.73*	2.12	11.3*	10.8*	-	51.2*	-	42.0*	8.50*	.587	1.00	3.46*	1.60	19.5*	5.43*	.377	-	-
CUSHION	Plot	4.61*	4.23*	3.46*	12.3*	5.89*	-	26.4*	-	95.9*	4.77*	.867	4.00*	.987	10.7*	18.1*	2.30	5.37*	-	-
TUNDRA	Team-Plot	.237	1.47	.800	.260	.250	-	1.70	-	.077	1.79	4.89*	.500	.940	.920	.120	1.73	1.26	-	-
FRESHWATER	Team	-	-	-	4.49*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.1*
AQUATIC	Plot	-	-	-	2.99*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.93*
	Team-Plot	-	-	-	.980	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.54*
ALL HABITAT	Team	.157	.667	.470	.609*	2.28	.417	-	2.21	.803	1.00	1.00	3.00	1.00	1.15	1.16	1.67	1.00	1.48	7.70*
TYPES	Habitat	.744	24.4*	799.*	51.3*	8.46*	8.17*	-	21.5*	195.*	12.3*	5.10*	1.00	1.25	177.*	61.0*	7.37*	564.*	3.67*	6.80*
POOLED	Team-Hab.	1.75	25.3*	.850	4.13*	3.94*	11.1*	-	3.77*	3.02*	9.58*	2.21	.330	3.25*	1.13	2.20	6.11*	.410	3.43*	13.1*

*The F-value exceeds the critical value at $p < .05$.

Table 2. F-values from two-way ANOVA with team and plot or team and habitat grouping factors for subplot shrub variables of ratio-type data. The species for which the variable was measured is given in parentheses. Degrees of freedom vary. A dash indicates the variable was not measured in that habitat type.

HABITAT TYPE	SOURCE	% COVER OF BERRY PRODUCING PLANTS < 6 INCHES (S. Grouse)	% COVER OF BERRY PRODUCING PLANTS > 6 INCHES (S. Grouse)	% COVER OF LOW SHRUBS (Moose)	% COVER OF TALL SHRUBS (C. Redpoll)	% COVER OF ALL SHRUBS (Moose)	SHRUB HEIGHT (Moose)	% COVER OF WILLOW (C. Redpoll, Moose)	NUMBER OF WILLOW STEMS (C. Redpoll, Moose)	% COVER OF BIRCH (C. Redpoll, Moose)	NUMBER OF BIRCH STEMS (C. Redpoll, Moose)	% COVER OF ALDER (C. Redpoll, Moose)
CONIFEROUS	Team	3.45*	0.35	.487*	1.73*	2.30	1.60	1.99	2.50	1.50	0.00	1.77
FOREST	Plot	12.6*	.970	9.04*	2.60*	3.98*	1.73	1.00	1.00	1.00	0.00	1.10
	Team-Plot	1.25	1.58	.338	1.84*	1.30	11.5*	1.57	.800	.923	0.00	1.48
DECIDUOUS	Team	-	-	5.64*	4.32*	2.10	6.01*	4.08*	0.00	3.10*	3.33*	1.49
FOREST	Plot	-	-	16.9*	5.59*	3.57*	.856	2.24*	0.00	2.05	2.67*	4.80
	Team-Plot	-	-	.217	.700	.705	1.71	.741	0.00	.883	.619	.928
MIXED	Team	1.71	.560	3.46*	1.71	4.55*	4.60*	0.00	0.00	1.67	1.52	1.02
FOREST	Plot	16.6*	.910	13.1*	3.68*	17.2*	3.34*	0.00	0.00	2.33*	3.35*	1.05
	Team-Plot	.270	.950	.415	.550	.303	1.96*	0.00	0.00	.600	.511	.762
LOW	Team	-	-	59.7*	5.05*	38.2*	7.05*	30.8*	55.6*	0.00	0.00	1.03
SHRUB	Plot	-	-	1.54	6.11*	1.88	2.88*	1.17	6.92*	0.00	0.00	4.29*
	Team-Plot	-	-	.496	.360	.375	2.93*	.517	.350	0.00	0.00	1.42
MAT AND	Team	-	-	-	-	-	-	2.22	-	1.00	-	1.00
CUSHION	Plot	-	-	-	-	-	-	7.64*	-	1.00	-	1.00
TUNDRA	Team-Plot	-	-	-	-	-	-	.271	-	1.00	-	1.00
FRESHWATER	Team	-	-	-	-	5.21*	.892	9.04*	1.88	.827	.250	2.14
AQUATIC	Plot	-	-	-	-	12.2*	3.18*	150.*	23.5*	52.2*	53.6*	89.0*
	Team-Plot	-	-	-	-	.993	4.11*	.080	.694	.152	.141	.134
ALL HABITAT	Team	.229	.883	1.86	.187	10.2*	1.16	3.36*	1.73	.836	1.96	2.35
TYPES	Habitat	.931	64.6*	20.4*	22.4*	80.0*	.251	108.*	31.1*	19.9*	53.3*	59.6*
POOLED	Team-Hab.	2.95	.560	9.84*	2.59*	1.84	8.54*	3.83*	6.32*	.304	.139	.612

Table 2. Continued

HABITAT TYPE	SOURCE	NUMBER OF ALDER STEMS (C. Redpoll, Moose)	% COVER OF POPLAR (C. Redpoll, S. Grouse, Moose)	NUMBER OF POPLAR STEMS (C. Redpoll, S. Grouse, Moose)	% COVER OF ASPEN (C. Redpoll, S. Grouse, Moose)	NUMBER OF ASPEN STEMS (C. Redpoll, S. Grouse, Moose)	% COVER OF *Vaccinium* spp. (C. Redpoll, Moose)	% COVER OF BLACK SPRUCE SEEDLINGS (C. Redpoll)	NUMBER OF BLACK SPRUCE SEEDLING STEMS (C. Redpoll)	% COVER OF OTHER SPECIES (C. Redpoll, Moose)	NUMBER OF OTHER SPECIES STEMS (C. Redpoll, Moose)
CONIFEROUS	Team	.463	0.00	0.00	0.00	0.00	-	7.72*	7.39	2.78	5.33*
FOREST	Plot	.731	0.00	0.00	0.00	0.00	-	1.00	1.00	2.59*	3.02*
	Team-Plot	1.34	0.00	0.00	0.00	0.00	-	5.33*	7.15*	1.64	.709
DECIDUOUS	Team	1.00	.884	.660	2.20	2.90	-	9.74*	20.3*	.450	9.55*
FOREST	Plot	1.00	.942	.830	6.87*	30.4*	-	1.00	1.00	7.61*	16.2*
	Team-Plot	1.00	1.02	1.06	.467	.137	-	.737	.498	.518	.164
MIXED	Team	6.76*	0.00	0.00	0.00	0.00	-	1.47	1.30	3.49*	2.20
FOREST	Plot	3.40*	0.00	0.00	0.00	0.00	-	1.00	1.00	11.3*	24.9*
	Team-Plot	.340	0.00	0.00	0.00	0.00	-	2.76*	2.62*	.682	.163
LOW	Team	1.01	1.50	.952	0.00	0.00	-	0.00	0.00	0.00	0.00
SHRUB	Plot	2.00	3.81*	2.00	0.00	0.00	-	0.00	0.00	0.00	0.00
	Team-Plot	1.95*	.398	.667	0.00	0.00	-	0.00	0.00	0.00	0.00
MAT AND	Team	-	0.00	-	0.00	-	10.4*	1.00	-	20.2*	-
CUSHION	Plot	-	0.00	-	0.00	-	6.79*	1.00	-	36.2*	-
TUNDRA	Team-Plot	-	0.00	-	0.00	-	.268	1.00	-	.210	-
FRESHWATER	Team	.942	1.48	.728	0.00	0.00	-	0.00	0.00	2.03	.682
AQUATIC	Plot	34.5*	2.70*	4.57*	0.00	0.00	-	0.00	0.00	20.6*	67.1*
	Team-Plot	.168	.678	.717	0.00	0.00	-	0.00	0.00	1.08	.328
ALL HABITAT	Team	.455	1.61	1.35	.998	.984	-	3.00	2.47	2.76	2.50
TYPES	Habitat	4.08*	4.85*	7.98*	10.5*	30.1*	-	.994	.998	77.4*	144.*
POOLED	Team-Hab.	1.15	.858	.474	.992	.381	-	12.4*	16.7*	1.61	.603

*The F-Value exceeds the critical value at $p < .05$.

Table 3. F-values from two-way ANOVA with team and plot or team and habitat grouping factors for subplot tree variables of ratio-type data. The species for which the variable was measured is given in parentheses. Degrees of freedom vary. A dash indicates the variable was not measured in that habitat type.

HABITAT TYPE	SOURCE	CONIFEROUS TREE CANOPY COVER (C. Redpoll, S. Grouse)	DECIDUOUS TREE CANOPY COVER (C. Redpoll, S. Grouse)	ALL TREES CANOPY COVER (C. Redpoll, S. Grouse, Moose)	DECIDUOUS SAPLING HEIGHT (Moose)	DISTANCE TO TREE 1 (C. Redpoll)	DIAMETER OF TREE 1 (C. Redpoll)	DISTANCE TO TREE 2 (C. Redpoll)	DIAMETER OF TREE 2 (C. Redpoll)	DISTANCE TO TREE 3 (C. Redpoll)	DIAMETER OF TREE 3 (C. Redpoll)	DISTANCE TO TREE 4 (C. Redpoll)	DIAMETER OF TREE 4 (C. Redpoll)	HEIGHT OF TREES (C. Redpoll, S. Grouse, Moose)
CONIFEROUS	Team	.407	.500	1.21	2.91*	3.50*	.642	3.71*	.389	.566	3.09*	1.18	.309	30.0*
FOREST	Plot	3.98*	5.57*	3.25*	11.2*	61.9*	4.20*	1.89	15.8*	13.0*	4.88*	21.0*	6.08*	25.7*
	Team-Plot	.566	.920	.594	.274	.151	1.11	.766	.310	.162	.554	.160	.242	.436
DECIDUOUS	Team	4.67*	6.96*	8.02*	5.39*	.717	2.33	.061	1.02	.912	.544	.984	5.69*	6.03*
FOREST	Plot	28.2*	16.2*	11.8*	4.78*	27.4*	22.6*	13.8*	12.4*	31.8*	1.14	12.7*	22.5*	14.4*
	Team-Plot	.221	.629	.575	.559	.249	.186	.350	.402	.158	.901	.447	.201	.560
MIXED	Team	9.26*	14.0*	15.2*	3.54*	3.62*	4.55*	1.13	.325	2.21	1.86	1.73	.261	3.43*
FOREST	Plot	35.3*	49.1*	32.7*	12.3*	5.83*	14.2*	15.2*	9.33*	4.90*	7.58*	.658	3.20*	2.98*
	Team-Plot	.163	.171	.234	.617	.254	.230	.340	.499	.470	.281	.452	.480	2.88*
LOW	Team	0.00	1.69	1.69	28.4*	-	-	-	-	-	-	-	-	-
SHRUB	Plot	0.00	1.02	1.02	.564	-	-	-	-	-	-	-	-	-
	Team-Plot	0.00	.801	.801	.580	-	-	-	-	-	-	-	-	-
MAT AND	Team	-	-	-	29.6*	-	-	-	-	-	-	-	-	-
CUSHION	Plot	-	-	-	33.4*	-	-	-	-	-	-	-	-	-
TUNDRA	Team-Plot	-	-	-	.166	-	-	-	-	-	-	-	-	-
FRESHWATER	Team	-	-	-	-	.513	.842	1.19	1.34	.043	1.29	1.94	2.97	-
AQUATIC	Plot	-	-	-	-	13.9*	8.65*	36.1*	86.9*	31.5*	28.1*	323.*	44.4*	-
	Team-Plot	-	-	-	-	1.10	1.24	.340	.150	.331	.301	.081	.201	-
ALL HABITAT	Team	.453	3.36*	1.88	8.24*	.210	1.06	5.01*	6.01*	1.83	2.24	.434	4.50*	6.17*
TYPES	Habitat	107.*	216.*	115.*	121.*	161.*	284.*	424.*	4046.*	375.*	396.*	110.*	739.*	259.*
POOLED	Team-Hab.	.999	1.53	2.30*	1.29	.666	.808	.407	.098	.323	.425	.639	.260	2.67*

*The F-value exceeds the critical value at $p < .05$.

as indicated by the F-values in Tables 1, 2, and 3. There were a considerable number of significant differences for all grouping factors in all habitat types for all variable types (ground cover, shrub, and tree). However, few patterns are obvious so it is difficult to generalize. One fairly consistent pattern was the high number of significant F-values for the habitat grouping factor with habitats pooled, indicating that there were significant differences in the samples between habitats (regardless of team). This was not unexpected, as the basis for sampling habitats separately was because of anticipated variation among different habitat types. Somewhat disconcerting, though, was the considerable number of significant differences for the plot grouping factor for tests within habitats. This is indicative of extensive variation among plots in the same habitat. It suggests a need for a finer breakdown of habitat types than Level II in Dyrness and Viereck's (1979) system, or an increase in the number of plots sampled per habitat.

Team precision, based on the F-values with team as a grouping factor, varied highly from variable to variable and habitat to habitat. Coniferous forest had relatively fewer significant among-team differences than other habitats; i.e., the same variable often had significant team F-values in other habitats, but not in coniferous forest. This is probably because coniferous forest was somewhat less complex in our study area than the other habitats (with the exception of mat and cushion tundra), thus reducing the difficulty of sampling. The other habitat types generally exhibited relatively more significant among-team differences than coniferous forest, with mixed forest and low shrub having slightly more than deciduous forest, mat and cushion tundra, and freshwater aquatic.

The team-plot and team-habitat interaction F-values provide insight into the patterns of the team subsample data. Results of this test were quite variable and often not in agreement with the team F-values. A significant interaction F-value essentially invalidates the conclusion of no significant difference among teams, as indicated by a non-significant team F-value. The means of the estimates may not have been significantly different among teams, but the patterns of the estimates may have been different. This situation was common throughout, but especially so when the habitats were pooled. Many variables that yielded significant team F-values within habitats showed non-significant team F-values with habitats pooled due to the averaging that occurred in the analysis (since plot was the grouping factor within habitats and habitat was the grouping factor with habitats pooled). However, most of these non-significant team F-values were invalidated by significant interaction F-values.

The results from the Discriminant Function Analysis of subsample variables within habitats are given in Table 4. Approximate F-values are for among team tests with all variables of a particular type in the discriminant function. These results were similar to those obtained from the ANOVA (Tables 1, 2 and 3) in that among team precision was low. The discriminant analysis did

Table 4. Approximate F-values from Discriminant Function Analysis with all variables in the function for each subsample variable type. F-value is equivalent to F-value from a multivariate ANOVA. The degrees of freedom are in parentheses. The number of variables in the discriminant function are in brackets. A dash indicates that such variables were not measured in the habitat type.

	SUBSAMPLE VARIABLE TYPE		
HABITAT TYPE	Ground vegetation, shrub, and tree percent cover estimates	Shrub percent cover estimates and stem counts	Tree measurements
CONIFEROUS FOREST	1.52* (44,384) [22]	5.70* (16,412) [8]	2.87* (18,436) [9]
DECIDUOUS FOREST	3.18* (30,398) [15]	2.23* (26,402) [13]	.960 (18,386) [9]
MIXED FOREST	4.90* (34,394) [17]	1.30 (16,412) [8]	1.52 (18,410) [9]
LOW SHRUB	11.1* (26,260) [13]	9.37* (12,394) [6]	-
MAT AND CUSHION TUNDRA	3.95* (34,370) [17]	1.76* (12,416) [6]	-
FRESHWATER AQUATIC	4.54* (4,424) [2]	1.19 (20,408) [10]	.734 (16,421) [9]

* The F-value exceeds the critical value at $p \leq .05$.

reveal an interesting pattern that was masked in the univariate tests by the multitude of variables. Percent cover and other ocular estimates, whether for ground vegetation, shrub classes, or trees, yielded significant among-team multivariate F-values in all habitat types. Similarly, percent cover estimates and stem counts for individual shrub species showed significant among team differences in all habitats except mixed forest and freshwater aquatic. Conversely, tree estimates obtained with the aid of measuring devices (diameter, height, distance between) yielded non-significant differences among teams in all habitats except coniferous forest. If tree height had been left out of the analysis the multivariate F-value for the coniferous forest would have also been non-significant.

Averaged and/or Combined Subplot Ratio-type Data

One-way ANOVA - As stated previously, there was an extensive amount of variability among teams (low precision) in the subsample data. However, the HEC models require a single estimate per plot for each parameter so the subsample data had to be averaged to the plot level. Also, subplot data for several variables had to be combined to obtain the appropriate parameter estimates specified by the models. Thus, it was necessary to examine the subplot data after it had been averaged and/or combined to the plot level to determine if among-team subsample variability was obscured by the averaging process. A one-way ANOVA was performed on the averaged and/or combined data within each habitat type.

Results of the one-way ANOVA are given in Table 5 under the heading "ANOVA". There were no significant F-values for coniferous forest or mixed forest and only 3 in deciduous forest indicating a masking of among-team variability because of averaging. Low shrub habitat still exhibited a high level of among-team variability with 5 of 7 variables yielding highly significant F-values. Mat and cushion tundra had only 1 averaged value, Percent Cover of Forbs, and this yielded a significant F-value.

Discriminant Function Analysis - As with the subplot data, it was useful to examine the combined and/or averaged data in a multivariate mode. A Discriminant Function Analysis was performed on the data within each habitat. Results of this analysis are given in Table 5 under the heading "Discriminant Analysis". No test was possible in mat and cushion tundra because there was only 1 variable.

These results support the impressions gained from the univariate analysis. The multivariate F-values for averaged and/or combined data were non-significant in coniferous forest and mixed forest, significant in deciduous forest at $p \leq .01$, and highly significant in low shrub with $p \leq .001$.

Plot Ratio-type Data

Freshwater aquatic was the only habitat for which there was

Table 5. F-values from one-way ANOVA and Discriminant Function Analysis of subplot variables for which data was combined and/or averaged to the plot level. Degrees of freedom for the one-way ANOVA are 2,15. Degrees of freedom for the discriminant analysis vary and are given in parentheses following the F-value. The species-model to which the variable applies is given in parentheses next to the variable name. A dash indicates the parameter did not apply in that habitat type.

HABITAT TYPE	ANOVA													
	% TREE AND TALL SHRUB CROWN COVER (C. Redpoll)	% COMBINED WHITE SPRUCE AND BIRCH IN STAND COMPOSITION (S. Grouse)	% POPULUS IN STAND COMPOSITION (S. Grouse)	% SPRUCE IN STAND COMPOSITION (S. Grouse)	% BLACK SPRUCE IN TOTAL SPRUCE (S. Grouse)	% CONIFEROUS TREE CANOPY COVER (C. Redpoll)	% ALDER, WILLOW AND BIRCH IN TREE & SHRUB CANOPY COVER (C. Redpoll)	% TREE CANOPY COVER (S. Grouse)	NUMBER OF TREES PER 2.47 ha (C. Redpoll)	HEIGHT OF MAJORITY OF TREES (Moose, C. Redpoll)	% SHRUB AND SAPLING CROWN COVER (Moose)	% SHRUB AND SAPLING CROWN COVER > .915 m (S. Grouse)	% SHRUB & DECIDUOUS SAPLING CROWN COVER UNDER 3.05 m OR DBH < 4.06 cm (Moose)	% SHRUB CROWN COVER UNDER 3.05 m (Moose)
CONIFEROUS FOREST	.521	-	-	.114	.153	.208	.093	.701	.571	2.70	1.09	1.09	.444	-
DECIDUOUS FOREST	1.44	-	-	-	-	.128	.221	-	.008	1.06	2.03	0	4.25*	-
MIXED FOREST	1.77	.411	0.00	.515	-	1.15	1.08	1.19	.146	2.05	.230	.230	.458	-
LOW SHRUB	-	-	-	-	-	-	33.9*	-	-	-	-	-	-	107.*
MAT AND CUSHION TUNDRA	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 5. Continued.

HABITAT TYPE	ANOVA												DISCRIMINANT ANALYSIS
	% SHRUB CROWN COVER (Moose)	% TALL SHRUB CROWN COVER (C. Redpoll)	AVERAGE SHRUB & DECIDUOUS SAMPLING HEIGHT (Moose)	AVERAGE SHRUB HEIGHT (Moose)	BRUSH DENSITY (stems per 4.02 m^2) (C. Redpoll)	% FORBS IN GROUND COVER (Caribou)	% GRAMINIFORM COVER (C. Redpoll)	% MOSS IN GROUND COVER (C. Redpoll)	% GROUND COVER OF LOW-GROWING WINTER FORAGE (Moose)	% COVER OF BERRY PRODUCING PLANTS (S. Grouse)	% HERBACEOUS AND WOODY GROUND COVER $<$ .915 m (S. Grouse)	AVERAGE HEIGHT OF GROUND VEGETATION IN OPENINGS AT LEAST 4.57 m WIDE (S. Grouse)	ALL VARIABLES (All Species)
CONIFEROUS FOREST	-	1.19	.180	-	5.51	1.22	.808	.684	1.53	.615	.199	3.39	1.99 (30,2)
DECIDUOUS FOREST	-	1.23	7.40*	-	1.86	-	.590	.276	5.00*	-	-	-	8.68* (26,2)
MIXED FOREST	-	.816	1.16	-	.202	-	.668	.232	1.67	.496	1.44	3.37	2.18 (30,2)
LOW SHRUB	105.*	2.90	-	2.21	23.0*	11.5*	5.90*	-	-	-	-	-	23.4* (30,2)
MAT AND CUSHION TUNDRA	-	-	-	-	-	3.73*	-	-	-	-	-	-	test not possible

*The F-value exceeds the critical value at $p \leqslant .05$.

ratio-type data from sampling at the plot only level. These variables were all for the beaver model. Results of a one-way ANOVA and Discriminant Function Analysis on these data are given in Table 6. There was only 1 significant F-value from the ANOVA, that for Percent Cover of Aquatic Forage. This is again indicative of the difficulty in obtaining percent cover estimates that have low variability among teams. The discriminant analysis yielded all non-significant F-values suggesting that, overall, among-team precision was high for ratio-type plot parameters.

Subplot and Plot Nominal-type Data

As previously discussed, several of the plot and subplot sampled variables yielded data of the nominal-type. Chi-square tests were performed on these data using two-way contingency tables for each variables within a habitat. The results of the chi-square analysis are given in Table 7. The tree species variables are subplot variables and were the species of tree recorded by each team in the 4 quadrants on subplots using the point-center-quarter procedure. All other variables were sampled at the plot level and are self-explanatory.

It is apparent from the results in Table 7 that precision among teams for these data is high, with only 2 variables in 2 habitat types (Sedge-grass Composition in mat and cushion tundra and Edaphic Mixture in Stand in deciduous forest) yielding significant chi-square values. This is not surprising, since it

Table 6. F-values from one-way ANOVA or Discriminant Function Analysis for plot parameters (no subsampling) of ratio-type data. All estimates were for beaver in freshwater aquatic habitat. The degrees of freedom are 2,15 for the ANOVA and 10,22 for the discriminant analysis.

	ANOVA						DISCRIMINANT ANALYSIS
	MAXIMUM WATER DEPTH IN WINTER	MAXIMUM WATER DEPTH IN SUMMER	RISE OR FALL FROM NATURAL WATER DEPTH	PERCENT COVER OF AQUATIC FORAGE	DISTANCE TO FOOD SOURCE	PERCENT OF SHORELINE MODIFIED BY HUMAN DEVELOPMENT	ALL VARIABLES
FRESHWATER AQUATIC HABITAT	1.12	1.12	.050	4.12*	.018	0.00	1.52

* The F-value exceeds the critical value at $p < .05$.

Table 7. Chi-square values for tests of independence between teams for tree species variables measured on subplots yielding nominal-type data and plot parameters (no subsampling) of nominal-type data. The species for which the variable was measured is given in parentheses under the name of the variable. The degrees of freedom for the test are given in parentheses next to the chi-square value. A dash indicates the variable was not measured in that habitat type.

HABITAT TYPE	SPECIES OF TREE 1 (C. Redpoll, S. Grouse, Moose)	SPECIES OF TREE 2 (C. Redpoll, S. Grouse, Moose)	SPECIES OF TREE 3 (C. Redpoll, S. Grouse, Moose)	SPECIES OF TREE 4 (C. Redpoll, S. Grouse, Moose)	SEDGE-GRASS COMPOSITION (Caribou)	SEDGE-GRASS COMPOSITION (Caribou)	LICHEN COVER (Caribou)	TREE CANOPY CLOSURE (Moose)	DOMINANT DECIDUOUS BROWSE SPECIES IN FOREST (Moose)	HERBACEOUS GROUND COVER (Moose)	INTERSPERSION WITH FEEDING HABIT (Moose)	PLANT SPECIES DIVERSITY (Moose)	EDAPHIC MIXTURE IN STAND (Moose)	EXTERNAL EDGE OF STAND (Moose)
CONIFEROUS FOREST	.001(4)	.109(2)	.572(4)	.603(4)	0.00(1)	0.00(1)	.505(2)	2.43(4)	0.00 (1)	7.72(4)	9.43 (4)	1.33(2)	1.99 (4)	2.62(2)
DECIDUOUS FOREST	4.82 (8)	7.20 (8)	4.03 (8)	14.6 (6)	-	-	2.40 (2)	0.00(1)	.682(4)	10.6 (6)	.600(2)	1.34(2)	12.8* (2)	7.72(4)
MIXED FOREST	3.02 (6)	2.91 (8)	3.00 (8)	1.87 (6)	-	-	2.80 (4)	0.00(1)	1.31 (4)	6.11(4)	0.00 (1)	4.00(2)	.600(2)	3.33(4)
LOW SHRUB	-	-	-	-	12.8*(2)	0.00(1)	-	-	7.96 (4)	0.00(1)	0.00 (1)	1.33(2)	.600(2)	0.00(1)
MAT AND CUSHION TUNDRA	-	-	-	-	5.37(2)	0.00(1)	-	-	-	-	-	-	-	-
FRESHWATER AQUATIC	1.95 (4)	.584(4)	1.44 (8)	.282(4)	-	-	-	-	-	-	-	-	-	-

Table 7. Continued.

HABITAT TYPE	AVERAGE SIZE OF OPENINGS (S. Grouse)	HEIGHT OF MAJORITY OF TREES (S. Grouse)	DOMINANT FOREST TYPE (Moose)	DOMINANT DECIDUOUS BROWSE SPECIES (Moose)	SHRUB COMMUNITY (SPRING/SUMMER/FALL) (Caribou)	SHRUB COMMUNITY (WINTER RANGE) (Caribou)	DOMINANT VEGETATION IN MAT AND CUSHION TUNDRA (Moose)	MAT AND CUSHION TUNDRA TYPE (SUMMER FORAGE) (Caribou)	MAT AND CUSHION TUNDRA TYPE (WINTER RANGE) (Caribou)	INTERSPERSION WITH WILLOW HABITAT (Moose)	BANK SUITABILITY (Beaver)	VALLEY GRADIENT (Beaver)	VALLEY WIDTH (Beaver)	SINUOSITY OF LOTIC WATER BODY (Beaver)	SUBSTRATE TYPE (Beaver)
CONIFEROUS FOREST	8.40(6)	1.77 (4)	-	-	-	-	-	-	-	-	-	-	-	-	-
DECIDUOUS FOREST	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MIXED FOREST	5.96(4)	.600(2)	3.33(4)	-	-	-	-	-	-	-	-	-	-	-	-
LOW SHRUB	-	-	-	0.00(1)	0.00(1)	0.00(1)	-	-	-	-	-	-	-	-	-
MAT AND CUSHION TUNDRA	-	-	-	-	-	-	0.00(1)	.600(2)	.600(2)	0.00(1)	-	-	-	-	-
FRESHWATER AQUATIC	-	-	-	-	-	-	-	-	-	-	2.02([illegible])	0.00(1)	2.02(2)	0.00(4)	3.08(6)

*The chi-square value exceeds the critical value at p < .05.

was assumed that the parameters chosen for plot-only sampling would be easier to estimate than those selected for subsampling. The tree species variables were subsampled but presented no significant problems regarding among-team precision. Teams could easily identify all species of trees in the study area, except for occasional confusion between white and black spruce in coniferous forest habitat.

Summary

Among team precision of the ratio-type subsample data, collected for deriving the plot-level estimates required by the models, was generally low (Tables 1, 2, 3, and 4). In general, percent cover and other ocular estimates showed lower levels of precision among teams than did estimates based on data gathered with the aid of simple measuring devices, such as tape measures for tree diameters and distances between trees. It is clear that the use of devices which minimize the effect of human error should improve the quality of the sample data. Unfortunately, a simple, inexpensive, and effective device for measuring various percent cover components is not yet available. Nominal-type estimates obtained on subplots were precise among teams (Table 7).

Some parameters appear to be inherently difficult to reliably estimate, with or without the aid of instruments. Tree height was measured with the Suunto Clinometer, a widely used and accepted device, yet among team variation in the estimates were high (Table

3). Number of plant species should have been easy to estimate, as the total number of plant species were simply counted on each 1 m^2 plot; however, the among-team F-values were significant for this variable in all habitats except low shrub (Table 1).

Byrne (1982), in a similar study evaluating the Alaska HEC Handbook, found that certain parameters could be estimated more precisely and accurately by subsampling as opposed to plot-only sampling. Nonetheless, he established that precise estimates among teams were difficult to obtain for many parameters even with subsampling. Ellis et al. (1978) found that participants in a field test of several habitat evaluation systems had difficulty in accurately estimating certain site characteristics ocularly.

For certain parameters problems with variability among the team estimates were probably due to poor definition of the variable being estimated or measured. There was some confusion among the teams as to the exact definition of a shrub stem, which undoubtedly contributed to the low among-team precision of the estimates (Tables 2 and 4). Some participants experienced similar difficulties in field tests conducted by Byrne (1982).

Much of the variability observed among the teams' subsample data was hidden by averaging to the plot level required by the HEC models. Many variables which exhibited significant among-team differences from the univariate ANOVA at the subplot level (Tables 1, 2, and 3) showed non-significant differences at the plot level (Table 5). Also, in coniferous and mixed forest habitats the multivariate F-values from the discriminant analysis were significant for several data types at the subplot level (Table 4), but non-significant at the plot level (Table 5). Deciduous forest yielded significant multivariate F-values at both the subplot and plot levels (Tables 4 and 5), though the number of significant univariate F-values was obscured by averaging from subplots to plots (Tables 1, 2, 3, and 5). Averaging did not seem to mask among-team variability in low shrub habitat; most of the F-values were significant for the subsample and averaged data in both the univariate and multivariate modes (Tables 1, 2, 3, 4, and 5). It appears that the low shrub habitat in our study area was inherently more difficult to sample than the other types, probably because of the extreme high density of the shrubs.

For those parameters which subsampling was not deemed necessary and the estimates (both ratio- and nominal-type data) were collected at the plot level, among-team precision was high in most cases (Tables 6 and 7). The ratio-type data collected at the plot level were for the beaver model; precision among teams' estimates was high for all parameters except Percent Cover of Aquatic Forage (Table 6), again illustrating the difficulty associated with estimating percent cover. The nominal-type data sampled at the plot level showed high precision among teams' estimates except for 2 parameters (Edaphic Mixture in Stand for moose in mixed forest and Sedge-grass Composition for caribou in low shrub) (Table 7). Byrne (1982) found similar results for the models he examined. These results indicate that for the Alaska HEC Handbook models tested by Byrne and myself the classes or categories describing the various habitat components are clearly worded and easily identified. Ellis et al. (1978) reported problems with participants estimating certain habitat characteristics because of subjectively worded criteria in 2 HEC Handbook-like approaches they examined.

The actual estimates entered into the HEC models, which consisted of the averaged and/or combined ratio-type data originally sampled on subplots (Table 5) and the ratio- and nominal-type data sampled on plots, (Table 6 and 7) were generally precise among teams except in low shrub habitat. It must be remembered, though, that many of the averaged estimates obscured variability present in the original sample data.

The variability within teams, as opposed to among teams, of the estimates has not yet been discussed. Variability within team estimates is not related to the habitat evaluation methodology employed per se, but is actually dependent upon the sampling techniques used to obtain those estimates. Byrne (1982) considered this aspect in some detail. The present study was concerned primarily with the repeatability of sample data and habitat quality estimates (HSI values) from a team-to-team standpoint. Within team variability was considered important only as it affected other statistics. Variability within teams might be reduced by modifying the actual sampling methods, increasing sample sizes, finer breakdown of habitat types into more homogeneous sample units, and practice by participating biologists with the sampling techniques and instruments used.

AMONG-TEAM PRECISION OF HANDBOOK MODEL HABITAT SCORES

The following discussion treats among team precision of the calculated HEC Handbook habitat quality scores (HSI values) on a species-by-species basis. Although the HEC species-models generally require the selection of the lowest HSI from among all the appropriate life requisite values as the overall HSI for the site, for the purposes of precision assessment all life requisite HSI values were included in the analyses and are presented here. The limiting factors were the same life requisites for the 3 teams in all cases except for the moose and common redpoll multiplicative models in low shrub, where 1 team had different limiting factors than the other 2.

In order that the reader thoroughly understand the approach used in precision testing, the discussion of the moose model is accompanied by tables containing complete results from the statistical analyses. But because the amount of information is prohibitive, detailed statistical test results for the other species-models are given in appendices, with the important aspects of those results described in the text.

Moose

Multiplicative Mean - Table 8 presents the results of one-way

Table 8. Mean team HSI values and F-values from one-way ANOVA and Discriminant Function Analysis among team HSIs for the multiplicative mean moose model by habitat type. The standard errors of the mean HSIs are in parentheses. The degrees of freedom for the ANOVA are 2,15. The degrees of freedom for the discriminant analysis are in brackets. All life requisites are included. A dash indicates the life requisite did not apply in that habitat type.

		ONE-WAY ANOVA													
		FOOD VALUE		FOOD VALUE (SPRING/ SUMMER/FALL)		COVER VALUE		COVER VALUE (SPRING/ SUMMER/FALL)		COVER VALUE (WINTER)		REPRODUCTIVE VALUE		WINTER RANGE VALUE	
HABITAT TYPE	TEAM	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE
CONIFEROUS FOREST	1	-		.002(.002)		.333(.025)		-		-		.132(.010)		.002(.002)	
	2	-	-	.002(.002)	4.93^a	.362(.002)	1.54	-	-	-	-	.153(.011)	.307	.000(.000)	1.81
	3	-		.025(.010)		.373(.014)		-		-		.128(.040)		.008(.005)	
DECIDUOUS FOREST	1	-		.010(.002)		-		.562(.024)		-		.245(.026)		.007(.002)	
	2	-		.007(.002)	3.80^b	-	-	.503(.037)	1.81	-	-	.203(.014)	2.19	.000(.000)	3.75^d
	3	-		.002(.002)		-		.482(.030)		-		.193(.012)		.003(.002)	
MIXED FOREST	1	-		.010(.003)		-		.580(.029)		.538(.046)		.233(.011)		.010(.000)	
	2	-	-	.010(.003)	.000	-	-	.510(.062)	3.70^b	.547(.040)	2.47	.205(.025)	3.99^b	.007(.002)	1.15
	3	-		.010(.003)		-		.402(.042)		.400(.067)		.160(.017)		.008(.002)	
LOW SHRUB	1	.428(.030)		-		.915(.006)		-		-		.367(.002)		-	
	2	.228(.019)	57.1^c	-	-	.750(.008)	163.^{c}	-	-	-	-	.302(.004)	148.^{c}	-	-
	3	.632(.029)		-		.975(.012)		-		-		.393(.005)		-	
MAT AND CUSHION TUNDRA	1	-		-		-		-		-		-		-	
	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	-		-		-		-		-		-		-	

Table 8. Continued.

		ONE-WAY ANOVA				DISCRIMINANT ANALYSIS
		INTERSPERSION VALUE		SUMMER RANGE VALUE		ALL LIFE REQUISITES
HABITAT TYPE	TEAM	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MULTIVARIATE F-VALUE
CONIFEROUS FOREST	1	.517(.032)		-		
	2	.565(.030)	1.07	-	-	2.75* [10,22]
	3	.503(.032)		-		
DECIDUOUS FOREST	1	.505(.024)		-		
	2	.583(.021)	6.78[e]	-	-	2.70* [10,22]
	3	.617(.021)		-		
MIXED FOREST	1	.500(.000)		-		
	2	.525(.025)	1.27	-	-	.926 [12,20]
	3	.540(.018)		-		
LOW SHRUB	1	.525(.025)		-		
	2	.513(.013)	.146	-	-	16.3* [8,24]
	3	.527(.017)		-		
MAT AND CUSHION TUNDRA	1	-		.052(.052)		
	2	-	-	.000(.000)	1.00	test not possible
	3	-		.000(.000)		

* The F-value exceeded the critical value at $p \leq .05$.

[a] Mean HSI of team three differed significantly ($p \leq .05$) from mean HSIs of teams one and two

[b] Mean HSI of team one differed significantly ($p \leq .05$) from mean HSI of team three

[c] Mean HSIs of all teams differed significantly ($p \leq .05$)

[d] Mean HSI of team one differed significantly ($p \leq .05$) from mean HSI of team two

[e] Mean HSI of team one differed significantly ($p \leq .05$) from mean HSIs of teams two and three

ANOVAs and Discriminant Function Analyses of team HSI values for each life requisite and habitat type. These results indicate that among-team precision for this model was low. Coniferous and deciduous forests yielded significant multivariate F-values and several significant univariate F-values (Food Value, Winter Range Value, Interspersion Value). Mixed forest had a non-significant multivariate F-value, but 2 significant univariate F-values (Cover Value and Reproductive Value). Low shrub yielded a highly significant ($p \leq .001$) multivariate F-value and all but 1 (that for Interspersion Value) of the univariate F-values were highly significant ($p \leq .001$). It must be noted, though, that in most cases the differences in mean team values were quite inconsequential at the HSI level, with the statistical significance resulting from the small variances involved.

Another indicator of among-team precision is the calculation of the absolute mean difference between team HSI values. This value reveals the differences between team scores on a scale that is meaningful from the standpoint of HEP. Table 9 contains the absolute mean differences between team HSIs for each life requisite in the appropriate habitat type. Coniferous forest had no life requisite with mean differences exceeding 0.100 and the averages for all variables were less than 0.100. Deciduous forest had only 1 mean difference greater than 0.100, that between teams 1 and 3 for Interspersion Value. The averages for all variables were less than 0.100. Mixed forest had mean differences exceeding 0.100 between team 3 and the other teams for Cover Value Spring/Summer/Fall and

Table 9. Mean absolute difference between team HSI values for the multiplicative mean moose model by habitat type. The standard errors of the mean differences are in parentheses. All life requisites are included. A dash indicates the life requisite did not apply in that habitat type.

HABITAT TYPE	TEAMS COMPARED	FOOD VALUE	FOOD VALUE (SPRING/ SUMMER/FALL)	COVER VALUE	COVER VALUE (SPRING/ SUMMER/FALL)	COVER VALUE (WINTER)	REPRODUCTIVE VALUE	WINTER RANGE VALUE	INTERSPERSION VALUE	SUMMER RANGE VALUE	AVERAGE FOR ALL LIFE REQUISITES
CONIFEROUS FOREST	1 and 2	-	.000(.000)	.032(.024)	-	-	.023(.014)	.002(.002)	.062(.024)	-	.024(.013)
	1 and 3	-	.023(.009)	.040(.024)	-	-	.100(.010)	.010(.005)	.040(.018)	-	.043(.013)
	2 and 3	-	.023(.009)	.018(.010)	-	-	.078(.016)	.008(.005)	.075(.020)	-	.040(.012)
DECIDUOUS FOREST	1 and 2	-	.003(.002)	-	.098(.036)	-	.058(.021)	.007(.002)	.078(.025)	-	.049(.017)
	1 and 3	-	.008(.003)	-	.087(.031)	-	.052(.020)	.003(.002)	.112*(.036)	-	.052(.018)
	2 and 3	-	.008(.002)	-	.048(.020)	-	.020(.007)	.003(.002)	.033(.021)	-	.022(.010)
MIXED FOREST	1 and 2	-	.003(.002)	-	.100(.031)	.062(.040)	.042(.012)	.003(.002)	.025(.025)	-	.039(.019)
	1 and 3	-	.007(.002)	-	.178*(.050)	.155*(.052)	.073(.019)	.002(.002)	.040(.017)	-	.076(.024)
	2 and 3	-	.007(.003)	-	.142*(.061)	.147*(.031)	.055(.025)	.002(.002)	.065(.023)	-	.070(.024)
LOW SHRUB	1 and 2	.200*(.023)	-	.165*(.005)	-	-	.065(.002)	-	.038(.026)	-	.117*(.014)
	1 and 3	.203*(.043)	-	.060(.014)	-	-	.027(.006)	-	.052(.025)	-	.086 (.022)
	2 and 3	.403*(.035)	-	.225*(.017)	-	-	.092(.007)	-	.013(.013)	-	.183*(.018)
MAT AND CUSHION TUNDRA	1 and 2	-	-	-	-	-	-	-	-	.052(.052)	-
	1 and 3	-	-	-	-	-	-	-	-	.052(.052)	-
	2 and 3	-	-	-	-	-	-	-	-	.000(.000)	-

* The mean absolute difference exceeded the .100 level of acceptability.

Cover Value Winter, but the averages for all variables were below 0.100. Low shrub habitat had mean differences exceeding 0.100 for all team-to-team pairings for Food Value and for the pairings between team 2 and the other teams for Cover Value. Also, the average for all variables was greater than 0.100 for the only life requisite (Summer Range Value) applicable to that habitat type.

The mean difference results (Table 9) indicate that among-team precision was high in all habitat types except low shrub. Also, the limiting factor (the lowest HSI value) was the same life requisite for all teams in all habitats with one exception. In low shrub team 2 had Food Value as the limiting factor whereas teams 1 and 3 had Reproductive Value (Table 8). Though there were statistically significant differences among teams' mean scores (Table 8), the actual magnitude of these differences was of little consequence from the standpoint of HEP.

Geometric mean - The same type of data as presented in Tables 8 and 9 are listed for the geometric mean moose model in Tables 10 and 11. All univariate F-values (Table 10) were non-significant for coniferous forest, mixed forest, and mat and cushion tundra; the multivariate F-value was significant only in coniferous forest. Low shrub again yielded highly significant ($p \leq .001$) univariate F-values for all but one life requisite (Interspersion Value) and a highly significant ($p \leq .001$) multivariate F-value. The limiting factor was the same life requisite for all teams in all cases.

Table 10. Mean team HSI values and F-values from one-way ANOVA and Discriminant Function Analysis among team HSIs for the geometric mean moose model by habitat type. The standard errors of the mean HSIs are in parentheses. The degrees of freedom for the ANOVA are 2,15. The degrees of freedom for the discriminant analysis are in brackets. All life requisites are included. A dash indicates the life requisite did not apply in that habitat type.

		ONE-WAY ANOVA													
		FOOD VALUE		FOOD VALUE (SPRING/ SUMMER/FALL)		COVER VALUE		COVER VALUE (SPRING/ SUMMER/FALL)		COVER VALUE (WINTER)		REPRODUCTIVE VALUE		WINTER RANGE VALUE	
HABITAT TYPE	TEAM	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE
CONIFEROUS FOREST	1	-		.315(.020)		.687(.020)		-		-		.602(.012)		.315(.014)	
	2	-	-	.333(.006)	.316	.708(.003)	.184	-	-	-	-	.623(.011)	.946	.303(.006)	2.39
	3	-		.403(.040)		.720(.009)		-		-		.562(.053)		.370(.037)	
DECIDUOUS FOREST	1	-		.392(.017)		-		.822(.012)		-		.698(.018)		.370(.010)	
	2	-	-	.365(.013)	3.43	-	-	.793(.020)	1.51	-	-	.668(.012)	1.99	.335(.005)	5.92^a
	3	-		.345(.004)		-		.783(.015)		-		.662(.011)		.343(.006)	
MIXED FOREST	1	-		.450(.015)		-		.832(.014)		.732(.033)		.693(.010)		.455(.013)	
	2	-	-	.445(.014)	4.24^b	-	-	.790(.037)	3.38	.738(.028)	2.84	.665(.023)	3.12	.430(.015)	.965
	3	-		.463(.015)		-		.732(.026)		.622(.051)		.630(.019)		.448(.010)	
LOW SHRUB	1	.842(.014)		-		.915(.006)		-		-		.605(.002)		-	
	2	.742(.011)	57.4^b	-	-	.750(.008)	163^b	-	-	-	-	.548(.003)	182^b	-	-
	3	.912(.009)		-		.975(.012)		-		-		.625(.003)		-	
MAT AND CUSHION TUNDRA	1	-		-		-		-		-		-		-	
	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	-		-		-		-		-		-		-	

Table 10. Continued.

		ONE-WAY ANOVA				DISCRIMINANT ANALYSIS
		INTERSPERSION VALUE		SUMMER RANGE VALUE		ALL LIFE REQUISITES
HABITAT TYPE	TEAM	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MULTIVARIATE F-VALUE
CONIFEROUS FOREST	1	.802(.016)		-		
	2	.825(.016)	.769	-	-	3.59* [10,22]
	3	.798(.017)		-		
DECIDUOUS FOREST	1	.797(.013)		-		
	2	.837(.011)	6.97[a]	-	-	2.17 [10,22]
	3	.853(.011)		-		
MIXED FOREST	1	.790(.000)		-		
	2	.803(.013)	1.55	-	-	1.63 [12,20]
	3	.815(.011)		-		
LOW SHRUB	1	.803(.013)		-		
	2	.798(.008)	.147	-	-	15.3* [8,24]
	3	.807(.011)		-		
MAT AND CUSHION TUNDRA	1	-		.000(.000)		
	2	-	-	.000(.000)	.000	test not possible
	3	-		.000(.000)		

* The F-value exceeded the critical value at $p < .05$.

[a] Mean HSI of team one differed significantly ($p < .05$) from mean HSIs of teams two and three.

[b] Mean HSIs of all teams differed significantly ($p < .05$).

Table 11. Mean absolute difference between team HSI values for the geometric mean moose model by habitat type. The standard errors of the mean differences are in parentheses. All life requisites are included. A dash indicates the life requisite did not apply in that habitat type.

HABITAT TYPE	TEAMS COMPARED	FOOD VALUE	FOOD VALUE (SPRING/ SUMMER/FALL)	COVER VALUE	COVER VALUE (SPRING/ SUMMER/FALL)	COVER VALUE (WINTER)	REPRODUCTIVE VALUE	WINTER RANGE VALUE	INTERSPERSION VALUE	SUMMER RANGE VALUE	AVERAGE FOR ALL LIFE REQUISITES
CONIFEROUS FOREST	1 and 2	-	.035(.006)	.022(.020)	-	-	.025(.014)	.012(.008)	.033(.013)	-	.065(.012)
	1 and 3	-	.105*(.042)	.033(.018)	-	-	.130*(.021)	.068(.037)	.020(.009)	-	.071(.025)
	2 and 3	-	.070(.041)	.015(.006)	-	-	.108*(.030)	.067(.038)	.037(.011)	-	.059(.025)
DECIDUOUS FOREST	1 and 2	-	.030(.007)	-	.052(.019)	-	.043(.015)	.035(.010)	.040(.012)	-	.040(.013)
	1 and 3	-	.057(.015)	-	.042(.016)	-	.040(.012)	.030(.009)	.057(.018)	-	.045(.014)
	2 and 3	-	.037(.010)	-	.030(.009)	-	.017(.006)	.018(.003)	.017(.011)	-	.024(.008)
MIXED FOREST	1 and 2	-	.022(.007)	-	.055(.023)	.047(.030)	.035(.014)	.025(.010)	.013(.013)	-	.033(.016)
	1 and 3	-	.037(.008)	-	.100(.029)	.123*(.043)	.063(.021)	.023(.006)	.025(.011)	-	.062(.020)
	2 and 3	-	.035(.017)	-	.082(.035)	.117*(.026)	.052(.021)	.028(.013)	.038(.013)	-	.059(.021)
MAT AND CUSHION TUNDRA	1 and 2	.100(.012)	-	.165*(.005)	-	-	.057(.002)	-	.022(.014)	0.00(.000)	.086(.013)
	1 and 3	.070(.017)	-	.060(.014)	-	-	.020(.004)	-	.030(.014)	0.00(.000)	.045(.012)
	2 and 3	.170*(.014)	-	.225*(.017)	-	-	.077(.005)	-	.008(.008)	0.00(.000)	.120*(.011)

* The mean absolute difference exceeded the .100 level of acceptability.

The mean differences between team HSI values (Table 11) indicate that precision among teams was acceptable for all habitats except low shrub. There were mean differences exceeding 0.100 in coniferous forest for Food Value Spring/Summer/Fall (between teams 1 and 3) and Reproductive Value (between team 3 and the other teams) but these differences barely exceeded the acceptable level. Also, the mean differences averaged for all life requisites were less than 0.100 for all team pairings in this habitat type. Deciduous forest and mat and cushion tundra had no mean differences exceeding 0.100. Mixed forest yielded mean differences greater than 0.100 for Cover Value Winter (between team 3 and the other teams), but the mean differences averaged for all life requisites were below the critical level for all team comparisons. Low shrub had mean differences that were quite large for Food Value (between teams 2 and 3) and Cover Value (between team 2 and the other teams). The mean differences averaged for all life requisites exceeded the 0.100 level for the team 2 to 3 comparison, though by only 0.020. Overall, among team precision was acceptable for this model in all habitats with the possible exception of low shrub.

Caribou

Multiplicative Mean - Results of a one-way ANOVA and discriminant analysis and mean absolute difference between teams for HSI values from the multiplicative mean caribou model are given in Appendices 4 and 5. Univariate F-values were non-significant for all life requisites in the 3 habitat types (Appendix 4). The limiting factor was the same life requisite for all teams in all habitats. All multivariate F-values were also non-significant.

Mean differences between team HSI values exceeded the acceptable level of 0.100 for Winter Range Value in mat and cushion tundra for the teams pairing between team 1 and other teams, but only by 0.010 (Appendix 5). The mean differences averaged for all life requisites were less than 0.100 for all team comparisons in all habitats. These results indicate that among team precision was high for this model.

Geometric Mean - Appendices 6 and 7 contain the results of among-team precision testing of HSI values for the geometric mean caribou model. Coniferous forest and low shrub yielded non-significant F-values for all tests (Appendix 6). In mat and cushion tundra the F-value for Winter Range Value was significant and the SNK indicated that the mean HSI value for team 2 differed significantly from those of the other teams. The multivariate F-value for this habitat was also significant. Also, the limiting factor was the same life requisite for all teams in the 3 habitat types.

All absolute mean differences between team HSI values were below the critical level of 0.100 for life requisites individually or averaged (Appendix 7). These results indicate that precision among teams was acceptable for the geometric mean caribou model.

Beaver

Multiplicative Mean - The results of precision testing of the multiplicative mean beaver model are presented in Appendices 8 and 9. Freshwater aquatic is the only habitat in which the beaver model was assessed. The univariate ANOVA of team HSI values yielded non-significant F-values for all life requisites and the multivariate F-value was also non-significant (Appendix 8) indicating that among-team precision was high. However, there was a considerable amount of variability among plots for the Lentic and Lotic Water Values as evidenced by the standard errors of the means in Appendix 8. It allowed some meaningful among-team differences to be statistically non-significant for these 2 parameters. Freshwater aquatic habitat was very diverse in our study area and included streams, lakes, ponds, and associated wetlands. This diversity undoubtedly led to the high level of variability among plots and indicates a need for a finer classification of habitat types than that currently used with this model.

The absolute mean differences between team HSI values (Appendix 9) indicated a lower level of precision than did the ANOVA (Appendix 8). The mean difference between team 1 and the other teams for both the Lentic Water Value and the Lotic Water Potential Value exceeded the acceptable level of 0.100. However, the large standard errors associated with the 2 values render these results questionable. Note that the mean difference averaged for all life requisites did not exceed the critical level for any of the team-to-team comparisons (with reasonable standard errors).

It appears that overall among-team precision was acceptable for this model in spite of the problems mentioned above. The limiting factor was the same life requisite for all teams and the mean differences averaged for all life requisites were within the acceptable range (Appendix 9). The problems associated with the Lentic Water Value and the Lotic Water Potential Value involved team 1 only and may have been due to high variability among plots. Teams 2 and 3 had acceptable mean differences between their respective HSI values (Appendix 9) for both of these life requisites.

Geometric Mean - Among-team precision was high for the geometric mean beaver model. All F-values from the one-way ANOVA and Discriminant Function Analysis were non-significant (Appendix 10). The mean differences between team HSI values were under the critical level in all but 1 case (between teams 1 and 3 for Lentic Water Value), and this difference exceeded the acceptable limit by only 0.010 (Appendix 11). The mean differences averaged for all variables were well below the critical level for all team comparisons.

Spruce Grouse

Multiplicative Mean - Appendices 12 and 13 contain the results of a one-way ANOVA and Discriminant Function Analysis and the absolute mean differences for among-team precision of the multiplicative mean spruce grouse model. The one-way ANOVA (Appendix 12) indicated that precision among team HSI values was high for all life requisites, except Reproductive Value in coniferous forest for which there was a highly significant ($p \leq .001$) F-value. The SNK revealed that the mean HSI value for team 2 differed significantly from those of the other teams. The multivariate F-value was significant in coniferous forest, undoubtedly because of the differences among teams in the Reproductive Value.

The absolute mean differences between team HSI values (Appendix 13) indicate that among-team precision was variable. Reproductive Value in coniferous forest was again a problem with mean differences greater than 0.100 for all team comparisons. In addition, in coniferous forest there were mean differences exceeding the acceptable limit for Food Value (Spring/Summer/Fall) with team 3's HSI values deviating from those of the other teams. The average for all life requisites in coniferous forest was below the critical level for each team-to-team comparison. In mixed forest among-team precision was low primarily because team 3 differed from the other teams. Only for the Reproductive Value did the mean differences exceed 0.100 for all team pairings. For Cover Value, Winter Range Value, and Average for All Life Requisites the mean difference between team HSI values exceeded the acceptable limit only in those pairings involving team 3.

Overall, among-team precision for this model was at an acceptable level, though not as high as for the models previously discussed. The major difficulties were with the life requisite Reproductive Value. An examination of the sample data reveals the cause for this. Of the 3 parameters involved in calculating the HSI for Reproductive Value, 2 (height of majority of trees and average height of ground vegetation) were estimated at significantly different levels by the 3 teams (Tables 1 and 3). Increased effort in accurately measuring these 2 variables would probably alleviate this problem. The other difficulties were primarily caused by deviations of team 3's HSI values from those of the other teams. The reason(s) for this disparity is not apparent.

Geometric Mean - Results of among-team precision testing for the geometric mean spruce grouse model appear in Appendices 14 and 15. The same problems that occurred with the multiplicative mean model were also found with this model. Again, the HSI values for Reproductive Value differed significantly among teams with team 2 deviating from the other teams (Appendix 14). Also, the multivariate F-value was significant for coniferous forest. Absolute mean differences (Appendix 15) indicate that the HSI values of team 3 deviated by greater than 0.100 from those of the other teams for Food Value Spring/Summer/Fall in coniferous forest and Winter Range Value in mixed forest. However, the averages for all life requisites were below the critical level in both habitat types for all team comparisons. Overall, among team precision was slightly higher for this model than for the multiplicative mean model.

Common Redpoll

Multiplicative Mean - The F-values in Appendix 16 indicate that among-team precision for the multiplicative mean common redpoll model was high for all habitat types except low shrub. All F-values (both univariate and multivariate) for tests among team HSI values were non-significant in coniferous, deciduous, and mixed forests. Dissimilarly, in low shrub the univariate F-values were highly significant ($p \leq .001$) for all life requisites except Cover Value. Also, the univariate F-value was highly significant ($p \leq .001$).

The mean differences between team HSI values in Appendix 17 were less than 0.100 in coniferous and deciduous forest habitats for all life requisites. In mixed forest there were differences exceeding the acceptable limit for all team pairings for Food Value Spring/Summer/Fall and Winter Range Value; these differences were not detected by the ANOVA or discriminant analysis. The average for all life requisites in mixed forest revealed a mean difference greater than 0.100 for the team 2 to 3 comparison. This difference exceeded the critical level by only 0.020, though, and the other team comparisons yielded acceptable mean differences. A similar pattern was found in low shrub where there were mean differences exceeding the critical level for Food Value Spring/Summer/Fall for all team comparisons. The averages for all life requisites yielded differences less than 0.100 for pairings between team 2 and the other teams. The team 1 to 3 comparison exceeded the acceptable mean difference by only 0.012.

Overall, it appears that among-team precision of HSI values for this model was at an acceptable level. The limiting factor was the same life requisite in all cases except in low shrub, where team 2 had a different life requisite for the limiting factor (Food Value Spring/Summer/Fall) than did teams 1 and 3 (Cover Value). As with the moose model, among-team precision was lower in low shrub habitat than in the other habitat types primarily because of high variability among teams in the shrub estimates (Tables 2 and 5). Shrub parameters in general appear to be inherently difficult to precisely estimate, and the shrub habitat in our study area was particularly difficult due to the extreme high density of shrubs. The problems in mixed forest with Food Value Spring/Summer/Fall and Winter Range Value were also related to difficulties in acquiring precise estimates of shrub-oriented parameters.

Geometric Mean - Results of among-team precision of HSI values for the geometric mean common redpoll model (Appendices 18 and 19) were similar to those for the multiplicative mean model (Appendices 16 and 17). Precision was high for coniferous and deciduous forest habitat types with all F-values non-significant (Appendix 18) and all mean differences within the acceptable limit (Appendix 19). The mean differences between team HSI values again exceeded 0.100 for Food Value Spring/Summer/Fall and Winter Range Value in mixed forest. However, these differences were lower than with the multiplicative means, and the averages for all life requisites were below the critical level for all team pairings. There were no significant F-values in mixed forest habitat. In low shrub habitat

F-values were significant for all life requisites except 1 (Cover Value) and the multivariate F-value was significant. The mean differences were greater than 0.100 for Food Value Spring/Summer/Fall, but to a lesser extent than for the multiplicative mean model. The mean differences averaged for all life requisites were less than 0.100 for all team comparisons in low shrub. Overall, among-team precision was acceptably high for this model.

Summary

Results of precision testing were similar for both the multiplicative and geometric mean models for a given species, team, and habitat type. This was not unexpected since the same sample data were inputted into both models in each situation; also the parameters and suitability curves are identical for both models. Only the calculation of the life requisite HSI values differ between the models, so the relative among-team variation should have been correspondent in most cases.

Precision among teams of the habitat quality estimates (HSI values) generated by the Alaska HEC Handbook was acceptably high for most models and habitat types assessed, based on the mean absolute differences between team's HSI values. In 83% (315 of 378) of between team comparisons made the mean absolute differences were less than or equal to 0.100. Precision was high for both the multiplicative and geometric mean caribou (Appendices 4, 5, 6 and 7) and beaver models (Appendices 8, 9, 10 and 11). Precision was acceptably high for both spruce grouse models, except for problems with team 3 (Appendices 12, 13, 14 and 15). The moose (Tables 8, 9, 10, and 11) and common redpoll (Appendices 16, 17, 18 and 19) models, both multiplicative and geometric means, showed acceptable levels of among-team precision except in low shrub habitat. As previously discussed, teams had considerable difficulties in obtaining similar estimates for shrub-type parameters in general, and in low shrub habitat in particular. Improved definition of the variables and practice by biologists in estimating these variables should reduce variability in these data.

These results support the notion that biologists are better able to produce repeatable (precise) habitat quality estimates when using written habitat criteria, as in the Alaska HEC Handbook, than when making strictly subjective appraisals of habitat suitability. Several other studies have substantiated this idea. Holmberg (1977) recommended the development of handbooks with established habitat criteria to reduce variability among habitat quality estimates. He found that subjective scoring of habitat quality by biologists using an early HEP System resulted in statistically significant among-group differences in average habitat unit values in 28% (10 of 36) of the comparisons made. Flood (1977) and Sparrowe and Sparrowe (1978) reported that the use of a handbook developed by Flood et al. (1977) containing standardized evaluation criteria compressed the range of habitat scores and lowered the variance when compared to subjective habitat ratings obtained for the same areas. They also found that groups or teams exhibited less variation in scores than did individuals. Ellis et al. (1978, 1979) also indicated that the use of standardized evaluation criteria, similar to that found in the HEC Handbooks, resulted in less variable estimates than did more subjective systems such as the early HEP schemes. Baskett et al. (1980) developed and tested a handbook that was a revised version of Flood's et al. (1977) handbook. Again, they found that the handbook approach with standardized evaluation criteria reduced variability in habitat quality scores. Byrne (1982) found similar results from tests of the Alaska HEC Handbook.

Thus, it appears that one of the primary reasons for development of the handbook approach versus the subjective scoring system is a valid one. The use of documented and standardized habitat evaluation criteria, as contained in the various HEC-type handbooks, does reduce variability (increases precision) in habitat quality estimates over those obtained from purely subjective assessments.

ACCURACY OF HANDBOOK MODEL HABITAT SCORES

Accuracy assessment of the HEC Handbook species-models was based on comparison of team Handbook habitat quality values with ratings given by species experts. For moose, caribou, spruce grouse, and common redpoll the experts gave, where appropriate, 2 habitat quality ratings for each site - a non-winter value and a winter value. These ratings were a combination of the various habitat components (food, cover, reproduction, etc.) important to each species. In these cases the expert winter range rating was compared with the winter range life requisite HSI value from the appropriate species-model and the expert non-winter rating was compared with each of the remaining life requisite HSI values. For beaver the expert gave 1 rating reflecting the year-round habitat quality of the site, and for green-winged teal the expert gave 1 rating per site as an indication of the quality of the site as breeding/summering habitat. In these 2 instances the single expert rating per plot was compared to each of the life requisite HSIs generated for the site. For mink the expert gave separate quality ratings for each of the habitat components deemed important to the species; each component rating, then, was compared to the corresponding life requisite HSI.

As stated earlier, the HEC models generally utilize the lowest HSI from among all the proper life requisite values as the overall

HSI value for a given site. However, in those cases where a Winter Range Value is calculated I have retained 2 values for each site - a Non-Winter Limiting Factor (NWLF) and a Winter Limiting Factor (WLF). The WLF is the HSI for the Winter Range Value life requisite and the NWLF is the lowest HSI from among the remaining life requisite HSI values. In those cases where there is no Winter Range Value calculated (the species does not utilize the habitat in winter) the overall HSI for the site is the lowest HSI from among all appropriate life requisites and is called the All Seasons Limiting Factor (ASLF).

Although all life requisite HSI values for each species and habitat type were compared to some appropriate expert rating, only the comparisons involving the NWLF, WLF,and ASLF are presented here to conserve space. It must be noted that accuracy was generally lower and certainly no higher with any of the other life requisite HSI values than with the NWLF, WLF, or ASLF.

Accuracy test results are presented in tables for the moose model and in appendices for the other species-models for reasons previously discussed.

Moose

Multiplicative Mean - The results of accuracy assessment for the multiplicative mean moose model are given in Table 12. In 1979 the moose models which appear in the current Terrestrial Habitat Evaluation Criteria Handbook - Alaska (Konkel 1980) (Appendix

Table 12. Mean team HSI values and species expert ratings, F-values from on-way ANOVA among team and expert scores, and mean absolute differences between team and expert scores for the multiplicative mean moose model by habitat type. The standard errors of the mean habitat scores and mean absolute differences are in parentheses. The ANOVA degrees of freedom are in brackets. Only the limiting factor life requisites are included. A dash indicates the limiting factor did not apply in that habitat type.

	NON-WINTER LIMITING FACTOR					WINTER LIMITING FACTOR				
HABITAT TYPE	GROUP	MEAN HABITAT SCORE	F-VALUE	TEAM COMPARED WITH EXPERT	MEAN ABSOLUTE DIFFERENCE	GROUP	MEAN HABITAT SCORE	F-VALUE	TEAM COMPARED WITH EXPERT	MEAN ABSOLUTE DIFFERENCE
CONIFEROUS FOREST (ORIGINAL MODEL 1979)	Team 1	.002(.002)		Team 1	.132*(.020)	Team 1	.002(.002)		Team 1	.115*(.015)
	Team 2	.002(.002)	27.8[a]	Team 2	.132*(.020)	Team 2	.000(.000)	41.0[a]	Team 2	.117*(.017)
	Team 3	.025(.010)	[4,25]	Team 3	.108*(.020)	Team 3	.008(.005)	[4,25]	Team 3	.108*(.019)
	Team Avg	.008(.004)		Team Avg	.125*(.022)	Team Avg	.003(.002)		Team Avg	.113*(.017)
	Expert	.133(.021)				Expert	.117(.017)			
DECIDUOUS FOREST (ORIGINAL MODEL 1979)	Team 1	.010(.003)		Team 1	.290*(.045)	Team 1	.006(.002)		Team 1	.260*(.035)
	Team 2	.007(.002)	42.8[a]	Team 2	.293*(.044)	Team 2	.000(.000)	61.4[a]	Team 2	.267*(.033)
	Team 3	.002(.002)	[4,25]	Team 3	.298*(.045)	Team 3	.003(.002)	[4,25]	Team 3	.263*(.035)
	Team Avg	.007(.002)		Team Avg	.293*(.044)	Team Avg	.005(.002)		Team Avg	.262*(.034)
	Expert	.300(.045)				Expert	.267(.033)			
MIXED FOREST (ORIGINAL MODEL 1979)	Team 1	.010(.003)		Team 1	.207*(.019)	Team 1	.010(.000)		Team 1	.273*(.017)
	Team 2	.010(.003)	143.[a]	Team 2	.207*(.017)	Team 2	.007(.002)	263.[a]	Team 2	.277*(.017)
	Team 3	.010(.003)	[4,25]	Team 3	.207*(.017)	Team 3	.008(.002)	[4,25]	Team 3	.275*(.017)
	Team Avg	.010(.000)		Team Avg	.207*(.017)	Team Avg	.008(.002)		Team Avg	.275*(.017)
	Expert	.217(.017)				Expert	.283(.017)			
LOW SHRUB (REVISED MODEL 1980)	Team	.729(.020)	1.82	Team	.084(.012)	Team	-		Team	-
	Expert	.788(.039)	[1,14]	Expert		Expert	-	-	Expert	-
HERBACEOUS SEDGE-GRASS (REVISED MODEL 1980)	Team	.816(.051)	166.[b]	Team	.691*(.055)	Team	-		Team	-
	Expert	.125(.016)	[1,14]	Expert		Expert	-	-	Expert	-
HERBACEOUS SEDGE-GRASS (ORIGINAL MODEL 1980)	Team	.326(.012)	96.2[b]	Team	.202*(.025)	Team	-		Team	-
	Expert	.125(.016)	[1,14]	Expert		Expert	-	-	Expert	-

* The mean absolute difference exceeded the .100 level of acceptability.

[a] The mean team HSI values differed significantly (p < .05) from the mean expert rating.

[b] The mean team HSI value differed significantly (p < .05) from the mean expert rating.

1) were used for the testing program. In 1980 revised models (Konkel, pers. comm.) (Appendix 2), which utilize a slightly different approach, were assessed in low shrub and herbaceous sedge-grass habitats on the CRD. The original model for herbaceous sedge-grass was also tested in 1980 for comparison with the new model. The life requisites which were the NWLF for this model are as follows: coniferous, deciduous, and mixed forest habitats - Food Value Spring/Summer/Fall; low shrub, revised model in 1980 - Food Value Spring/Early Summer; herbaceous sedge-grass, original model - Reproductive Value; herbaceous sedge-grass, revised model - Interspersion Value. The Winter Range Value was the WLF in all appropriate habitat types.

The F-values from a one-way ANOVA of team HSI values and expert ratings were highly significant ($p \leq .001$) in coniferous forest, deciduous forest, mixed forest, and herbaceous sedge-grass (original and revised models) for both the NWLF and the WLF where appropriate. The SNK procedure showed that the significant differences were between the mean HSI values for all teams and the mean expert ratings. Only in low shrub in 1980 with the revised model was the F-value (for the NWLF) non-significant. The mean absolute differences between team HSI values and expert ratings followed a similar pattern, as mean differences exceeded the acceptable 0.100 limit for all team-expert comparisons in all habitats except low shrub.

It is apparent from these results that accuracy of the model is low based on comparison to expert ratings. Only in low shrub habitat with the revised model in 1980 did the model yield habitat quality estimates (HSI values) which were in agreement with the expert ratings. In all other habitat types assessed in this study the HEC models yielded inaccurate estimates of the quality of the sites as moose habitat.

Geometric Mean - Table 13 contains the results of accuracy testing of the geometric mean moose model. The geometric means were not calculated for the revised moose model used in 1980 in low shrub and herbaceous sedge-grass. As with the multiplicative mean model, the NWLF for this model in coniferous, deciduous, and mixed forest habitats was Food Value Spring/Summer/Fall. For the original model in herbaceous sedge-grass the NWLF was again Reproductive Value. The Winter Range Value is the WLF in the appropriate habitat types.

Accuracy was also low for this model. All F-values were significant in coniferous forest, mixed forest, and herbaceous sedge-grass. The SNK revealed that all team mean HSI values differed significantly from the mean expert ratings. In these same habitats the mean absolute differences exceeded the acceptable level of 0.100 for all team-expert comparisons. In deciduous forest the F-value was non-significant for the NWLF, but significant for the WLF. The mean differences between team HSI values and expert ratings exceeded the acceptable limit for the NWLF for all team-expert comparisons except that involving team 3 (which was within the acceptable limit by only 0.005). For the WLF the mean absolute differences exceeded 0.100 for the team 1-expert

Table 13. Mean team HSI values and species expert ratings, F-values from one-way ANOVA among team and expert scores, and mean absolute differences between team and expert scores for the geometric mean moose model by habitat type. The standard errors of the mean habitat scores and mean absolute differences are in parentheses. The ANOVA degrees of freedom are in brackets. Only the limiting factor life requisites are included. A dash indicates the limiting factor did not apply in that habitat type.

	NON-WINTER LIMITING FACTOR					WINTER LIMITING FACTOR				
HABITAT TYPE	GROUP	MEAN HABITAT SCORE	F-VALUE	TEAM COMPARED WITH EXPERT	MEAN ABSOLUTE DIFFERENCE	GROUP	MEAN HABITAT SCORE	F-VALUE	TEAM COMPARED WITH EXPERT	MEAN ABSOLUTE DIFFERENCE
CONIFEROUS FOREST (ORIGINAL MODEL 1979)	Team 1	.315(.020)	19.2[a] [4,25]	Team 1	.182*(.017)	Team 1	.315(.014)	23.5[a] [4,25]	Team 1	.198*(.005)
	Team 2	.333(.006)		Team 2	.200*(.018)	Team 2	.303(.006)		Team 2	.187*(.011)
	Team 3	.403(.040)		Team 3	.270*(.052)	Team 3	.370(.037)		Team 3	.253*(.043)
	Team Avg	.348(.015)		Team Avg	.215*(.025)	Team Avg	.330(.014)		Team Avg	.213*(.018)
	Expert	.133(.021)				Expert	.117(.017)			
DECIDUOUS FOREST (ORIGINAL MODEL 1979)	Team 1	.392(.017)	2.30 [4,25]	Team 1	.125*(.025)	Team 1	.370(.010)	5.86[a] [4,25]	Team 1	.103*(.032)
	Team 2	.365(.013)		Team 2	.112*(.024)	Team 2	.335(.005)		Team 2	.088 (.023)
	Team 3	.345(.004)		Team 3	.095*(.025)	Team 3	.343(.006)		Team 3	.100 (.022)
	Team Avg	.367(.009)		Team Avg	.110*(.022)	Team Avg	.348(.005)		Team Avg	.102*(.024)
	Expert	.300(.045)				Expert	.267(.033)			
MIXED FOREST (ORIGINAL MODEL 1979)	Team 1	.450(.015)	54.3[a] [4,25]	Team 1	.233*(.028)	Team 1	.455(.013)	29.3[a] [4,25]	Team 1	.172*(.026)
	Team 2	.445(.014)		Team 2	.228*(.023)	Team 2	.430(.015)		Team 2	.147*(.024)
	Team 3	.463(.015)		Team 3	.247*(.023)	Team 3	.448(.010)		Team 3	.165*(.021)
	Team Avg	.453(.011)		Team Avg	.237*(.022)	Team Avg	.443(.010)		Team Avg	.160*(.022)
	Expert	.217(.017)				Expert	.283(.017)			
HERBACEOUS SEDGE-GRASS (ORIGINAL MODEL 1980)	Team	.689(.008)	942.[b] [1,14]	Team Expert	.564*(.022)	Team	-	-	Team Expert	-
	Expert	.125(.016)				Expert	-			-

*The mean absolute difference exceeded the .100 level of acceptability.

[a] The mean team HSI values differed significantly (p ≤ .05) from the mean expert rating.

[b] The mean team HSI value differed significantly (p ≤ .05) from the mean expert rating.

and team average-expert comparisons. Team 3 was within the acceptable limit by only 0.001 and team 2 by 0.012.

Caribou

The species experts agreed closely in their opinions of the value of the habitat as winter range, but disagreed regarding its importance for non-winter use. The was primarily because of disagreement over the quality of various sedge species used as forage by caribou. The disparity in their ratings, however, did not affect the overall evaluation of the model.

Multiplicative Mean - The results of accuracy testing of the multiplicative mean caribou model are presented in Appendix 20. In coniferous forest the only life requisite applicable was the Winter Range Value (the WLF); in mat and cushion tundra for both 1979 and 1980 there were only 2 appropriate life requisites, Food Value Spring/Summer/Fall (the NWLF) and the Winter Range Value (the WLF). The difference in team HSI values and species expert ratings were highly significant ($p \leq .001$) in all habitat types for both the NWLF and the WLF. Also, the mean absolute differences between teams and experts exceeded the acceptable limit of 0.100 for the NWLF and the WLF in all habitats and for all team-expert comparisons. In mat and cushion tundra in 1980 the SNK indicated that for the NWLF the mean team HSI value differed significantly from the mean of the ratings given by expert 1, but not from that of expert 2; the team mean value differed significantly from the mean of the 2 experts' ratings averaged. The mean absolute differences exceeded the 0.100 acceptable limit for all team-expert comparisons for the NWLF in this habitat type. For the WLF in mat and cushion tundra the SNK revealed that the mean team HSI value differed significantly from the means of both experts' ratings; also, the mean differences between teams and experts exceeded the acceptable level for all team-expert comparisons. These results indicate that accuracy of the multiplicative mean caribou model was low in all habitat types sampled in this study.

Geometric Mean - Appendix 21 lists the results of accuracy tests on the geometric mean caribou model. Again, only the Winter Range Value (the WLF) was appropriate in coniferous forest, and in mat and cushion tundra (both years) only the Food Value Spring/Summer/Fall (the NWLF) and the Winter Range Value (the WLF) were applicable. The team HSI values and expert ratings were significantly different in all habitats for both the NWLF and the WLF. In coniferous forest for the WLF and mat and cushion tundra (1979) for the NWLF the SNK indicated that the mean HSI values of all teams differed significantly from the mean expert ratings. For the WLF in mat and cushion tundra (1979) only the mean HSI of team 2 differed significantly from the mean expert rating. In mat and cushion tundra in 1980 for the NWLF the mean team HSI value differed significantly from the mean rating of expert 1 and the experts' average, but not from that of expert 2. For the WLF the mean team HSI value differed significantly from both experts' mean ratings.

The means of the absolute differences between team HSI values and expert ratings exceeded the acceptable limit of 0.100 for all team-expert pairings for the WLF in coniferous forest and for the NWLF in mat and cushion tundra in both 1979 and 1980. For the WLF in mat and cushion tundra in 1979 all team-expert comparisons yielded mean differences within the acceptable limit. For the WLF in mat and cushion tundra in 1980 the team-expert 2 and team-experts' average comparisons resulted in unacceptable mean differences; the team-expert 1 comparison was within the acceptable limit by only 0.006.

In general, accuracy for this model was low based on comparison to expert ratings. Only in mat and cushion tundra in 1979 for the WLF were the model HSI values in accord with the expert ratings. The model HSI values were inaccurate in most other situations in which the model was evaluated.

Beaver

Multiplicative and Geometric Means - Appendix 22 contains the results of accuracy testing of the multiplicative and geometric mean beaver models. The life requisite Behavioral Value was the ASLF for both models. The ASLF HSI values were identical for both models because estimates for only 1 parameter (Percent Shoreline Development) were involved in calculating the Behavioral Value;

thus, results of the analyses were the same for both the multiplicative and geometric models. The mean (for 6 plots) HSI value for the ASLF was 0.500 for each of the 3 teams.

The mean teams HSIs did not differ significantly from the mean expert rating (F=.063 at $p \leq .05$). However, the mean absolute differences greatly exceeded (by 0.417) the acceptable 0.100 limit for all team-expert comparisons. The non-significant F-value may have been caused by the high level of variability in the team HSIs among plots, as indicated by the standard errors of the means (0.224 for all teams). But this high variability cannot account for all of the apparent disparity in the results of the 2 analyses. The standard errors for the mean absolute differences are not great enough (0.135 for all) to invalidate the very large (on an HSI level) differences observed between teams and experts. The reason for this contradiction has to do with the nature of the 2 analyses. The one-way ANOVA tests only for differences among the group (teams and expert) mean HSI values for the 6 plots. The mean absolute difference is the absolute difference between team HSI values and expert ratings calculated for each plot and then averaged for all 6 plots. The means (for all plots) of the team HSI values and the expert ratings do not necessarily reflect differences that may occur on each of the plots separately. Thus, the ANOVA is not sensitive to actual differences on a plot-by-plot basis as is the mean of the absolute differences. In this case the difference between the mean team HSI values and the mean expert rating was small (as indicated by the ANOVA F-value), but the actual differences between teams and the expert on a plot-by-plot basis were quite consequential (as revealed by the mean absolute differences).

The model performed quite inaccurately when the team HSI values and the expert's ratings were compared directly for each plot with the mean absolute difference. It must by mentioned that the other life requisites (Food Value, Lentic Water Value, Lotic Water Value) for this model yielded HSI values that were slightly more accurate than those for Behavioral Value, but these were still unacceptably inaccurate by a large margin.

Mink

Multiplicative and Geometric Means - The results of accuracy assessment of the multiplicative and geometric mean mink models are presented in Appendix 23. Team HSI values were the same with both methods of calculation so the analyses yielded identical results for both models. The ASLF was Food Value in low shrub and Reproductive Value in herbaceous sedge-grass. The F-value in low shrub was highly significant ($p \leq .001$) and the mean absolute difference exceeded the acceptable limit by 0.461. In herbaceous sedge-grass the F-value was non-significant, but the mean absolute difference between the team and expert was greater by 0.237 than the acceptable limit. The F-value was non-significant despite the rather large difference between the mean team HSI value and the expert rating (0.375 and 0.088, respectively). This was most likely because of the high level of variability among the team HSI values (standard error of the mean = 0.183). The standard error of the mean absolute difference was not excessive enough (0.149) to affect the non-acceptance decision since the difference was so large (0.338). Overall, accuracy of the mink model with both the multiplicative and geometric means was very low based on comparison to expert ratings.

Spruce Grouse

Multiplicative Mean - Appendix 24 contains the results of an ANOVA, SNK, and mean absolute differences for the multiplicative mean spruce grouse model. The NWLFs were Food Value Spring/Summer/Fall in coniferous forest and Cover Value in mixed forest; Winter Range Value was the WLF in both habitat types. F-values were non-significant for both the NWLF and WLF in coniferous forest and for the NWLF in mixed forest. The F-value for the WLF in mixed forest was highly significant ($p \leq .001$), with the SNK indicating that all mean team HSI values differed significantly from the mean expert rating. The mean absolute differences of team HSI values from the expert ratings exceeded the acceptable 0.100 limit in both habitat types for the NWLF and the WLF for all team-expert comparisons, with acceptable standard errors. These results reveal the multiplicative mean spruce grouse model to be unacceptably inaccurate. The reasons for the apparent disparity in the results of the above 2 types of analyses have been discussed previously.

Geometric Mean - The geometric mean spruce grouse model yielded HSI values which were not within the acceptable limits of accuracy, as evidenced by the results in Appendix 25. These results were similar to that found for the multiplicative model (Appendix 24) with all mean absolute differences between team HSI values and expert ratings exceeding the 0.100 limit. In this instance, however, the ANOVA results were in agreement with the mean absolute differences; F-values were significant in all cases except for the NWLF in coniferous forest. Food Value Spring/Summer/Fall was the NWLF in both coniferous forest and mixed forest; the WLF was the Winter Range Value in both habitats. As with the previous model, this model yielded inaccurate habitat quality estimates when compared to ratings given by a species expert.

Common Redpoll

Multiplicative Mean - The results of accuracy testing of the multiplicative mean common redpoll model are presented in Appendix 26. These results indicate that accuracy of this model was variable depending on the habitat type and limiting factor (either NWLF or WLF) examined. The life requisites which were the NWLF in the various habitat types are as follows: coniferous forest - Food Value Spring/Summer/Fall; deciduous forest - Reproductive Value;

mixed forest - Reproductive Value; low shrub - Cover Value. The Winter Range Value was the WLF in all appropriate habitats.

In coniferous forest both the NWLF and the WLF had HSI values which were accurate, based on the non-significant F-values and the mean differences which were less than 0.100 in all cases except 1 (the mean difference for the team 3-expert comparison for the WLF exceeded the acceptable limit by 0.003). In deciduous forest the F-values for the NWLF and the WLF were non-significant, but the mean absolute differences for the NWLF exceeded 0.100 for all team-expert comparisons. For the WLF only the team 1-expert comparison resulted in an unacceptable mean absolute difference. In mixed forest the F-value for the NWLF was non-significant, but all mean differences exceeded the acceptable limit; for the WLF the F-value was significant (all mean team HSI values differed significantly from the mean expert rating), and all mean differences were greater than 0.100. The F-value for the NWLF in low shrub (there was no WLF) was significant, but the SNK revealed that only team 1 differed significantly from the expert. The mean absolute differences between team HSI values and the expert ratings in low shrub exceeded the acceptable limit for all team-expert comparisons. The standard errors of the team and expert scores and the absolute differences were very small throughout. Any disparities in the results of the 2 analyses were due to plot-by-plot differences between teams and the expert that were not apparent in the mean habitat scores.

It is difficult to generalize about this model. In some situations the model yielded HSI values which were in agreement with the expert ratings, but in other cases the model habitat quality estimates were inaccurate. However, such a high level of variability in the test results precludes acceptance of this model as adequate for assessing common redpoll habitat quality.

Geometric Mean - For the geometric mean common redpoll model the Food Value Spring/Summer/Fall was the NWLF in coniferous, deciduous, and mixed forests, while the NWLF was Cover Value in low shrub. The WLF, in the appropriate habitat types, was the Winter Range Value. This model generally yielded HSI values which were inaccurate when compared to expert ratings (Appendix 27). The mean absolute differences between team HSI values and expert ratings exceeded the 0.100 acceptable limit in all cases except for the WLF in mixed forest. In addition, F-values from the one-way ANOVA were significant in all instances except for the WLF in deciduous and mixed forests. The significant F-values resulted from (as indicated by the SNK) differences between the means of all teams' HSI values and the expert ratings, except in low shrub where only team 1 differed significantly from the expert.

Green-winged Teal

Multiplicative and Geometric Means - Appendix 28 contains the results of accuracy testing of the green-winged teal model with both the multiplicative and geometric mean approaches. The NWLF was Reproductive Value in both low shrub and herbaceous sedge-grass habitats. The Reproductive Value is the only life requisite modeled in the low shrub habitat type. The one-way ANOVA of team HSI values and expert ratings yielded non-significant F-values for both models in both habitat types. However, the differences between the means for both models in herbaceous sedge-grass were consequential from an HSI standpoint (0.350 and 0.356, respectively), and were statistically non-significant because of the high among-plot variability in the team scores (standard errors = 0.184 and 0.187, respectively).

For the geometric model the mean absolute differences between team HSI values and expert ratings were greater than 0.100 in both habitats with acceptable standard errors. For the multiplicative mean model the mean difference exceeded the acceptable 0.100 limit in herbaceous sedge-grass, but not in low shrub (both standard errors were reasonable). In low shrub with the multiplicative mean approach the model HSI values were quite close to the species expert ratings. However, this is probably because the plots sampled in this habitat were essentially unusable for breeding by green-winged teal, as the plots were too far from any suitable pond, lake, or other water body. The model easily detects this situation with a parameter called Distance to Eutrophic Water Body or Marsh. If this distance is great enough the overall HSI for the site becomes 0.000. Non-usable habitats for green-winged teal breeding were thus readily identified by both the model and the species expert. Habitats that are poor or better for green-winged teal reproduction may not be accurately rated by the model, as evidenced by the large mean difference (greater than 0.400) between the model HSI values and the expert ratings in herbaceous sedge-grass. The plots sampled in this habitat type were in general poor for green-winged teal breeding (mean expert rating of 0.138), yet the model rated the plots as fair (mean HSI values ≈ 0.488 and 0.494 for the multiplicative and geometric means, respectively).

Summary

The HEC species models assessed in this study generally yielded habitat quality estimates (HSI values) that were unacceptably inaccurate, based on comparison to expert ratings, in most of the habitat types sampled. Although the means of the team(s) HSI values and the expert(s) ratings for all plots in a habitat type may not have differed significantly (as indicated by the ANOVA F-values) to the same extent, the differences between the team(s) and expert(s) values on a plot-by-plot basis (as evidenced by the means of the absolute differences) generally were unacceptably high. The mean absolute differences between team HSI values and species expert ratings exceeded the 0.100 level 88% of the time (168 of 192 comparisons).

I feel that the plot-by-plot tests most effectively reflect the actual capability of the models to produce accurate estimates of habitat quality. The mean values for all plots in a habitat are useful, but should not be the primary criteria on which to assess model accuracy. Thus, for a particular model to be accepted as accurate both the ANOVA F-values and the mean absolute differences should be non-significant and acceptably low, respectively, with reasonable standard errors associated with the estimates.

The beaver model is a good example of the difficulties that may be encountered when only the mean values are examined. The ANOVA of the teams' HSI values and the expert's ratings accurately indicated that there was no significant difference among the mean values for the groups (Appendix 22). However, it is obvious from the mean absolute differences that the group means (for all 6 plots), because of the manner in which the teams' HSI values and the expert's ratings were ordered on a plot-by-plot basis, were not reliable indicators of the rather large (from an HSI standpoint) teams-expert differences actually present. This phenomenon may be associated with high within group variability, as shown by the large standard errors for the mean team HSI values and expert ratings. However, it did also occur in several other instances such as for the spruce grouse (Appendices 24 and 25) and common redpoll models (Appendices 26 and 27) for which the standard errors of the means were quite small.

For the mink and green-winged teal models in herbaceous sedge-grass the ANOVA F-values were non-significant, even though there were large differences between the team's HSI values and the expert's ratings for both the means for all plots and the values for plots separately (Appendices 23 and 28). The ANOVA, which is usually a very effective indicator of differences among group means, failed to detect the differences between these means because of the large variances associated with the estimates from both models. The mean absolute differences did reveal these disparities while having acceptable standard errors (condidering the magnitude of the differences observed).

The multiplicative mean approach generally resulted in more accurate HSI values than the geometric mean method, though neither yielded acceptably accurate estimates in most cases. The moose models, both multiplicative and geometric means, were unacceptably inaccurate in all habitat types sampled (Tables 12 and 13) except for low shrub with the revised model in 1980 (Table 12). The revised model (Appendix 2) seems to have some advantages over the original models (Appendix 1), though it did not perform acceptably in the other habitat sampled (herbaceous sedge-grass). Both the multiplicative and geometric mean caribou models were inaccurate in the habitats in which testing was conducted (Appendices 20 and 21). The beaver models, as already stated, were highly inaccurate in the freshwater aquatic habitat examined (Appendix 22). Both mink models were unacceptably inaccurate in either the low shrub or herbaceous sedge-grass habitats (Appendix 23). The multiplicative and geometric mean spruce grouse models were unacceptably inaccurate in both habitat types sampled (Appendices 24 and 25). Accuracy of the common redpoll model was quite variable. For the multiplicative mean model accuracy was high in coniferous forest for both the NWLF and WLF; in deciduous forest the NWLF was inaccurate, but accuracy of the WLF was acceptable; accuracy was unacceptably low in mixed forest and low shrub (Appendix 26). The geometric mean model was less accurate, as the model HSI values were unacceptably inaccurate in all cases except for the WLF in mixed forest (Appendix 27). The green-winged teal multiplicative mean model was highly accurate in low shrub, but highly inaccurate in herbaceous sedge-grass; the geometric mean model was unacceptably inaccurate in both habitat types (Appendix 28).

Byrne (1982) also found problems with inaccuracy of models in the Alaska HEC Handbook. He compared model HSI values (both multiplicative and geometric means) obtained by individual biologists to habitat ratings given by species experts during 3 field tests on the Bonanza Creek Experimental Forest near Fairbanks, Alaska. Models for the following species and habitat types were examined: moose in mixed forest and shrub; snowshoe hare (Lepus americanus), red squirrel (Tamiasciurus hudsonicus), and spruce grouse in mixed forest; willow ptarmigan (Lagopus lagopus) in shrub. Only the willow ptarmigan multiplicative mean model in shrub (WLF only) and the moose multiplicative model in mixed forest (both NWLF and WLF) yielded acceptably accurate (within ± 0.100 of the experts' ratings) estimates of habitat quality; the other models produced inaccurate HSI values in most cases. Byrne postulates that the moose model produced accurate HSI values in mixed forest primarily because the species experts' ratings were very low, and the nature of the multiplicative function results in low HSI vaues when there are a large number of Suitability Indices in the equation as in this model.

Participants' Handbook HSI values were generally more accurate and precise than their own subjective estimates of habitat quality. It should be emphasized, though, that these participants could not be considered experts on the habitat requirements of the species evaluated. Overall, Byrne (1982) expressed serious misgivings concerning the capability of most of the models he examined to produce accurate estimates of habitat quality.

Whelen et al. (1979), working in mixed-hardwood forest in Virginia, compared habitat quality ratings for white-tailed deer (Odocoileus virginianus), wild turkey (Meleagris gallopavo), and gray squirrel (Sciurus carolinensis) from 3 evaluation systems: DYNAST (Boyce 1977, 1978); an early version of the Missouri HEP Handbook (Flood et al. 1977); and the Information System for Wildlife Habitat Evaluation (Williamson et al. 1978). The hypothesis was that if each of the 3 systems had been developed independently and was providing an accurate evaluation, then each should yield similar habitat quality ratings for a given species and management mode (current stand conditions, a timber management practice, and a wilderness condition). The 3 systems produced very dissimilar habitat quality scores for all species within and among management modes. The question of which system was the most accurate was not tested. They concluded that each system should be validated for accuracy based on comparison of habitat quality scores with estimates of animal abundance.

Kling (1980) attempted to do what Whelen et al. (1979) suggested in their conclusions. On 3 study sites near Decker, Wyoming he compared estimates of animal abundance of habitat quality values generated from HEP models (USFWS 1979), Pattern Recognition or PATREC models (Kling 1980), and subjective opinions for 6 wildlife species (mule deer, *Odocoileus hemionus*; pronghorn, *Antilocapra americana*; sharp-tailed grouse, *Pediocetes phasianellus*; sage grouse, *Centrocercus urophasianus*; golden eagle, *Aquila chrysaetos*; and Brewer's sparrow, *Spizella breweri*). Several teams of biologists visited the sites and inventoried the parameters necessary for calculation of the habitat quality estimates for each system, as well as providing their own personal opinions of the habitat quality for each species. The model values and subjective opinions were converted to animals per unit area for comparison to actual density estimates for the areas obtained from various population inventories.

The performance of these models was extremely variable among areas, teams, and species. The density estimates from the HEP models, PATREC models, and subjective opinions were averaged for all teams for each species. The 3 sites were then ranked relative to these density estimates, and compared to the site rankings based on the inventory population estimates.

For mule deer both the HEP and PATREC models incorrectly ranked all sites; personal opinions resulted in correct ranking for 1 of the 3 sites. With pronghorn the areas were not ranked because the population estimates for all procedures were very close.

Pronghorn densities on the study area based on population inventories were very low (1.5 pronghorn per 2.6 km^2 on 2 of the sites and 0.0 on 1 of the sites). The PATREC model most closely mimicked the inventory population estimates on all sites, while personal opinions produced more accurate estimates than did the HEP model (which predicted densities that were too high). PATREC ranked all 3 sites correctly for sharp-tailed grouse; HEP incorrectly ranked all sites; personal opinions resulted in correct ranking of 1 site. For sage grouse both the PATREC and HEP models ranked all sites in the same order as for the inventory data, while personal opinions ranked only one of the sites correctly. PATREC, HEP, and personal opinions ranked each of the these sites in the correct order for Brewer's sparrow. For golden eagles personal opinions correctly predicted the presence or absence of eagle-occupied nest sites on all 3 areas; PATREC predictions were correct on 2 of the 3 areas, while HEP was correct on only 1 of the areas.

Because of the variability in the results of accuracy testing in the above study it is difficult to generalize. However, the highly variable results are an indication of major problems with model accuracy. The PATREC models generally produced more accurate estimates than the HEP models. However, for only 2 of the 6 wildlife species examined did the models, either PATREC or HEP, correctly rank all 3 sites. It is interesting that personal opinions produced as accurate, or more accurate, habitat quality estimates than the models, especially HEP.

Kling (1980) lists several reasons for the disparity observed among the model population estimates and the inventoried population information. The wrong combination of habitat attributes may have been used in the evaluation process, the level of the attribute may have been incorrect, the method used to interpret the combination of habitat attributes may have been inappropriate, the relative importance of the attributes assigned by the different methods may have been incorrect, or improper conversion of the model habitat quality estimates to animals per unit area may have been performed. He also implies that the inventoried population estimates could have been in error; even if accurate, population estimates may not be representative of true habitat quality because factors other than habitat may affect population levels at any one point in time.

Clawson (1980) also approached the question of model accuracy by comparing population estimates with habitat quality estimates from the Missouri Handbook (Baskett et al. 1980) and the draft HEP Handbook Ecoregion 2215 (USFWS 1979). The study was conducted on or near the Ashland Wildlife area in Missouri on 6 old field and 6 upland forest sites. She inventoried population levels of white-footed mice (Peromyscus leucopus), prairie voles (Microtus ochrogaster), and black rat snakes (Elaphe obsoleta obsoleta) on various of the sites. Scores from 0.0 to 10.0 were assigned to various population densities for each species based on information from the literature; the observed population densities on each site were then given the appropriate score. Since the model habitat quality values were on a scale from 0.0 to 10.0, a direct basis for comparison of model scores to the population density scores was possible.

For white-footed mice the Missouri Handbook slightly overestimated the habitat quality of all sites based on the population data, but the sites were ranked correctly. The HEP Handbook was completely inaccurate in its assessment of the habitat quality, with all sites rated much too low. Neither the Missouri Handbook nor the HEP Handbook produced habitat quality estimates in agreement with the population densities of prairie voles, with both handbooks overestimating the habitat quality. For the black rat snake only the HEP Handbook ratings were used in the comparison; the HEP estimates were totally incompatible with the habitat quality as determined by population densities.

It is apparent from these results that there are serious problems with accuracy of the Missouri Handbook models for all those examined except that for the white-footed mouse. Nonetheless, Clawson (1980) felt that the HEP Handbook model for the white-footed mouse could be improved with further field testing. The problem with overestimation of habitat quality by the prairie vole models may, according to the author, have been associated with the cyclic nature of prairie vole populations; the population estimates for the study were made during what may have been a low in the cycle that was not reflected in the habitat. She suggests that the black rat snake is simply a poor evaluation element because of its large home range and utilization of many different habitat types. To this I would add that the predatory nature of the animal may preclude accurate models based on habitat alone.

Darrow et al. (1981) attempted to determine if wildlife use of old field and forest sites near Ashland, Missouri were reflected in habitat quality estimates obtained using the Missouri Handbook (Baskett et al. 1980). Because of the low number of study sites it was not possible to run regressions of use data or trapping data on the habitat quality scores. However, non-statistical examination of the data revealed that estimates of site use by white-tailed deer and wild turkeys and trapping information for eastern cottontails (Sylvilagus floridanus) did not correspond at all with habitat quality scores produced by the HEP models.

The authors provided a number of explanations for the inadequate performances of the models in the above study. White-tailed deer and turkeys have home ranges much larger than the data inventory sites; while plots that encompass the animals' entire home range may not be necessary, habitat quality scores based on data collected from only a very small portion of the home range may be suspect. The plots were not diverse enough in habitat quality to allow for meaningful correlations of a wide range of habitat use data with model habitat quality scores. The number of plots was not adequate for a reasonable statistical test of the basic hypothesis. Some of the methods employed to estimate animal abundance or use of the habitats were unverified. Obvious flaws in the models were later discovered which may have adversely affected the results.

Lancia et al. (in press) studied habitat use of bobcats (Lynx rufus) in North Carolina through the use of radio-telemetry techniques. They developed and validated an HEP-like model based on radio-location information; if the model was accurate, bobcat use of an area as reflected in number of radio locations in that area should have correlated with habitat quality scores generated by the model. The model scores were expressed in terms of a Habitat Quality Index (HQI). Fifty-six percent of the time the HQI agreed with the habitat use data; 32% of the time the HQI indicated that habitat use should have been high, when it was actually low; 12% of the time the HQI predicted low use of an area when bobcat use was high.

The above study is an example of the most effective validation technique currently available. Comparison of actual habitat use data with model habitat quality estimates should provide a true test of model accuracy. Habitat use, as determined by radio-location information, is not subject to the problems (previously discussed) associated with the use of population estimates, expert opinion, or other habitat use estimators as the basis for accuracy assessment. Unfortunately, studies such as by Lancia et al. (1982) are very intensive, expensive, and generally long-term.

To summarize, the results from the present study indicate that the models we assessed from the Alaska HEC Handbook do not generate accurate estimates of habitat quality. The other studies discussed above reveal that model inaccuracy is a problem with most of the HEP Handbook models tested to date.

AN ATTEMPT AT CORRECTING FOR MODEL INACCURACIES

Because accuracy for most of the species models tested was not adequate, I explored the feasibility of developing a correction factor based on the expert ratings that could render the model HSI values as more realistic estimates of actual habitat quality. A correlation analysis was performed between the team HSI values and the expert ratings for the limiting factors in each habitat type. Significant correlations would indicate a systematic linear relationship that could be characterized by an equation. This equation could then be applied to the HSI values to correct for inaccuracies. Since both variables were random, a regression equation would not be appropriate for describing the relationship; that function delineating the principal axis would have been suitable in this case.

The results of the correlation analyses are given in Tables 14 and 15 for the multiplicative and geometric mean models, respectively. For 1979 data separate correlations were made between each team's and the average of the teams' HSI values and the expert's ratings. Only the team average-species expert correlations are presented; the individual team-expert correlations did not differ substantially from the team average-expert correlations. The comparisons for 1980 data for low shrub and herbaceous sedge-grass habitats were between the 1 set of team HSI values and the expert's

Table 14. Pearson's Product-moment Correlation Co-efficients (r-values) from correlation analysis between team HSI values and species expert ratings for multiplicative mean models by habitat type. Only the limiting factors are included. A dash indicates the limiting factor did not apply in that habitat type.

HABITAT TYPE	GROUPS COMPARED	MOOSE NWLF (ORIGINAL MODEL)	MOOSE WLF (ORIGINAL MODEL)	MOOSE NWLF (REVISED MODEL)	CARIBOU NWLF	CARIBOU WLF	BEAVER ASLF	MINK ASLF	SPRUCE GROUSE NWLF	SPRUCE GROUSE WLF	COMMON REDPOLL NWLF	COMMON REDPOLL WLF	GREEN-WINGED TEAL NWLF
CONIFEROUS FOREST (1979)	Team Avg. and Expert	-.263	-.316	-	.000	-	-	-	.789	-.620	-.129	.265	-
DECIDUOUS FOREST (1979)	Team Avg. and Expert	.354	-.447	-	-	-	-	-	-	-	-.322	.721	-
MIXED FOREST (1979)	Team Avg. and Expert	.000	-.200	-	-	-	-	-	.451	-.302	.000	-.133	-
LOW SHRUB (1979)	Team Avg. and Expert	-	-	-	-	-	-	-	-	-	-.404	-	-
LOW SHRUB (1980)	Team Avg. and Expert	-	-	.804*	-	-	-	-.338	-	-	-	-	.336
MAT AND CUSHION TUNDRA (1979)	Team Avg. and Expert	-	-	-	.000	-.591	-	-	-	-	-	-	-
MAT AND CUSHION TUNDRA (1980)	Team and Expert 1	-	-	-	.000	.494	-	-	-	-	-	-	-
	Team and Expert 2	-	-	-	.000	.473	-	-	-	-	-	-	-
	Team and Expert Avg.	-	-	-	.000	.516	-	-	-	-	-	-	-
HERBACEOUS SEDGE-GRASS (1980)	Team and Expert	-.463	-	-.123	-	-	-	.582	-	-	-	-	.698
FRESHWATER AQUATIC (1979)	Team and Expert	-	-	-	-	-	-.060	-	-	-	-	-	-

* The r-value was significant at $p < .05$.

Table 15. Pearson's Product-moment Correlation Co-efficients (r-values) from correlation analysis between team HSI values and species expert ratings for geometric mean models by habitat type. Only the limiting factors are included. A dash indicates the limiting factor did not apply in that habitat type.

HABITAT TYPE	GROUPS COMPARED	MOOSE NWLF (ORIGINAL MODEL)	MOOSE WLF (ORIGINAL MODEL)	CARIBOU NWLF	CARIBOU WLF	BEAVER ASLF	MINK ASLF	SPRUCE GROUSE NWLF	SPRUCE GROUSE WLF	COMMON REDPOLL NWLF	COMMON REDPOLL WLF	GREEN-WINGED TEAL NWLF
CONIFEROUS FOREST (1979)	Team Avg. and Expert	.035	.288	-	.000	-	-	.789	-.620	-.112	.176	-
DECIDUOUS FOREST (1979)	Team Avg. and Expert	.084	-.489	-	-	-	-	-	-	.581	.700	-
MIXED FOREST (1979)	Team Avg. and Expert	-.246	-.337	-	-	-	-	.471	-.323	.000	-.109	-
LOW SHRUB (1979)	Team Avg. and Expert	-	-	-	-	-	-	-	-	-.404	-	-
LOW SHRUB (1980)	Team Avg. and Expert	-	-	-	-	-	-.338	-	-	-	-	.345
MAT AND CUSHION TUNDRA (1979)	Team Avg. and Expert	-	-	.000	-.676	-	-	-	-	-	-	-
MAT AND CUSHION TUNDRA (1980)	Team and Expert 1	-	-	.000	.503	-	-	-	-	-	-	-
	Team and Expert 2	-	-	.000	.493	-	-	-	-	-	-	-
	Team and Expert Avg.	-	-	.000	.531	-	-	-	-	-	-	-
HERBACEOUS SEDGE-GRASS (1980)	Team and Expert	-.491	-	-	-	-	.582	-	-	-	-	.687
FRESHWATER AQUATIC (1979)	Team Avg. and Expert	-	-	-	-	-.060	-	-	-	-	-	-

ratings; for mat and cushion tundra separate correlations were made between the 1 set of team HSI values and the ratings from expert 1, expert 2, and experts averaged.

All correlation coefficients were non-significant, except for the moose NWLF with the revised model in low shrub in 1980 (Table 39). In this case, however, accuracy of the model was already acceptable as evidenced by the non-significant F-value (1.82, $p \leq .05$) and the low mean absolute difference (0.084) in Table 28. For all models in which the level of accuracy was unacceptable the correlations were not significant (Tables 39 and 40). Thus there was no reason to calculate correction factors, at least ones based on linear models, when these factors would not be reliable.

Bivariate scatter plots for the correlated variables were also made. These scatter plots are not presented here, but they indicated that correction factors based on some form of non-linear regression would also not have been feasible.

GENERAL DISCUSSION

Among-team precision of the sample data was highly variable. Estimates of parameters obtained on subplots consisting of ratio-type data showed low precision among teams. Percent cover or other ocular estimates showed lower levels of precision than those collected with measuring devices, such as tree diameters and distances between trees. Precision of the sample data could be improved by better definitions of the parameters being estimated, use of simple and accurate measuring devices where possible, and practice by team members with the instruments and techniques being implemented. Among-team precision was high for nominal-type estimates collected on subplots.

Ratio- and nominal-type estimates acquired at the plot level were precise among teams for the most part. The plot-level estimates derived from combined and/or averaging of the subplot data generally exhibited high levels of among-team precision except in low shrub habitat. Shrub parameters were difficult to precisely estimate in all habitats, but in low shrub especially because of the extreme high density of shrub plants in this habitat type. Much of the variability observed in the subplot data was obscured by the averaging process.

Precision among teams of the habitat quality estimates (HSI values) was acceptably high for most models and habitat types examined. The mean absolute differences between team HSI values were less than 0.100 in 83% (315 of 378) of the comparisons made. The only major problems were in the low shrub habitat where the moose and caribou models produced imprecise HSI values; the reasons for the difficulties in the low shrub type have been previously discussed.

The present study and other studies by Baskett et al. (1980), Byrne (1982), Ellis et al. (1978, 1979), Flood (1977), and Sparrowe and Sparrowe (1978) revealed that use of a handbook-type approach with written habitat criteria resulted in higher levels of precision, both within and among groups, in habitat quality scores compared to those obtained from purely subjective evaluations (personal opinions). Thus, it appears that 1 of the primary objectives in developing the handbook-type approach to habitat assessment, which is to reduce variability and increase repeatability of the estimates, has been attained.

Accuracy of the HEC models, based upon the mean absolute difference between team(s) HSI values and expert(s) rating, was unacceptably low for most models and habitat types assessed. Eighty-eight percent (168 of 192) of the team-expert comparisons yielded mean absolute differences greater than the 0.100 level of acceptability. Only the revised moose model in low shrub and the common redpoll models in coniferous forest (both the NWLF and the WLF) and deciduous forest (WLF only) produced habitat quality estimates in agreement with expert(s) opinions. An attempt to improve accuracy of the models through application of linear correction factors were unsuccessful, as the correlations between team HSI values and the expert ratings were non-significant ($p \leq .05$)in all cases.

Byrne (1982) found similar difficulties concerning accuracy of habitat quality scores generated by models in the Alaska HEC Handbook. Studies conducted by Clawson (1980), Darrow et al. (1981), Kling (1980), Lancia (in press), and Whelen et al. (1979) reveal accuracy problems with many other models in the HEP system. Whether the model habitat quality scores were compared to species expert ratings, population density estimates, habitat use information, or other model scores, most of the models tested to date do not perform at an acceptable level of accuracy.

What are the probable causes of inaccuracy in these models? The first consideration involves the basic approach to habitat assessment used by the models in the HEP system. Kling (1980) examined HEP Handbook models by Schamberger and Farmer (1978) and USFWS (1979) which are similar in format to those found in the Alaska HEC Handbook. He cautioned that the description of the procedures used in the models, such as the suitability index graphs, life requisite equations, and limiting factor concepts, did not provide an indication that the combination of relationships, equations, and limiting factors had been previously proven. He went on to state,

> "one can only assume the core concepts have not yet been proven and that literature on appropriate methods of developing the functional relationships and weighting schemes in the context of limiting factors is not available".

This point should be kept in mind throughout the discussion.

For certain wildlife species it appears that the approach used by the HEP models is reasonable in theory. These would be species that are habitat specialists and/or have fairly small home ranges. Populations of these species might be limited primarily by habitat; as such habitat quality may be an effective indicator of relative population levels over the long run. The habitat requirements of these species may also be simple enough to model with an HEP type of approach. The habitat specialists examined in this study include beaver, spruce grouse, and green-winged teal. Beaver and spruce grouse utilize fairly small home ranges throughout the year; green-winged teal may use widely separated habitats in Alaska for breeding, molting, or staging, but these habitats are specialized wetland types. Common redpolls can be regarded as habitat specialists in winter, being almost totally dependent on birch seeds as a food source; during other seasons redpolls are wide ranging habitat generalists with extremely unpredictable use of habitats (Spindler, pers. comm.). Thus, for the above species (common redpolls only in winter) and other such species the HEC Handbook type of approach seems feasible.

If it is possible to evaluate habitat for the above types of species with an HEP-like system, why have most of the models tested to date for these species performed inadequately in terms of accuracy? It is difficult to pinpoint the specific sources causing problems with accuracy in order to suggest corrective measures. A basic underlying problem is the general lack of the appropriate type of information needed to construct quantitative habitat models. The literature abounds with a seemingly infinite variety of wildlife studies, but relatively few deal directly with the quantification of animal-habitat interrelationships. This is the type of data required if realistic habitat models are to be developed. The situation is particularly acute in Alaska, where most of the models in the Alaska HEC Handbook were constructed from very inadequate data bases. For example, it was originally intended to regionalize the models in the handbook because of Alaska's large size and wide diversity of land forms and habitat types. Information concerning a species and its habitat requirements in one part of the state may not necessarily apply in other areas, even in similar habitat types. However, because of a lack of information concerning specific areas, the regional concept was disregarded and models developed for the state as a whole. For some species much of the data used in constructing the models came from studies conducted outside of the state, and may or may not have been representative of situations found in Alaska. Examination of the species narratives, literature sources, and models reveals this information deficiency to be a persistent problem throughout the handbook. If the relationships between wildlife species and their habitat requirements are to be effectively modeled in a quantitative fashion, then future research must be geared to answering the appropriate questions. There seems to be little value in developing models based on inadequate data just for the sake of having models, especially considering that the information generated by these models will be used in the decision-making process involving vital wildlife habitat issues.

Another point to consider is that the actual writing of the models (at least the Alaska models) was done primarily by biological technicians who reviewed the available literature. As stated above, the literature generally was inadequate in providing the information necessary to construct complete models. Even if the literature was adequate, it is questionable whether effective models can be developed solely from this source. Clawson (1980) pointed out the inadequacy of literature searching as the only means of determining habitat evaluation criteria. Also, the authors of the models were not species experts; since much of the information in the literature had to be converted to a format compatible with the model approach, a great deal of subjective interpretation was required. Whether these technicians were qualified to make such judgements is unknown. Of course, the project leader supervised all model development to eliminate any obvious errors in interpretation of the available data, but it must be noted that he too was not an expert on the species for which models were constructed.

I feel that for those species for which the HEP type of approach seems feasible, the actual model development should be conducted by species experts. If species experts cannot be found within the USFWS the endeavor should be contracted to qualified persons. These experts would be much more adept at interpreting the available literature while incorporating their own personal experience with the species into the models. They should know if it is possible to construct an accurate habitat model for a particular species with the current state of knowledge concerning its habitat requirements. Although several of the models in the Alaska HEC Handbook were reviewed by species experts, their input would be more effective if they had a part in actual model development. These experts would also be able to field test and fine tune the models until acceptably accurate versions were obtained. Models could be developed for more specific, localized areas instead of the broad regional system currently used. This approach would be much more expensive than the current one, but it appears to be a viable alternative to a system that has not produced satisfactory results.

For some wildlife species it appears that the HEP type of approach to evaluating habitat is simply not workable. One group of animals to which this applies are the large, mobile herbivores such as moose and caribou. These animals are habitat generalists that range over wide areas, utilize a variety of habitat types (often seasonally), and exhibit complex social and behavioral patterns. In addition to habitat, their populations in Alaska may be limited by non-human and human predation, weather, disease, parasites, or any number of other density dependent and density independent factors. Attempts to model habitat relationships for these and other such species are fraught with difficulties. The results from this and other studies (Darrow et al. 1981, Kling 1980) reveal the failure of models developed for herbivorous habitat generalists to accurately estimate habitat quality. Even with the wealth of information available on white-tailed deer, the Missouri Handbook (Baskett et al. 1980) model scores for this species were totally unrelated to estimates of habitat use (Darrow et al. 1981). The Alaska HEC models are written from a much less extensive data base.

I believe that attempting to estimate habitat quality for such species as discussed above, irrespective of their populations, is unwise. The population should be the basic biological unit of concern for these species, with limiting factors examined in terms of their impacts on the population; as such, habitat is only 1 of several possible limiting factors. The notion that habitat attributes such as food, cover, water, etc. may influence the potential of other controlling factors to limit populations is indeed true. However, because of the complex nature of these relationships it would be difficult, if not impossible, to incorporate them into simple HEP-type habitat models. Such interactions are more effectively addressed by examination of the populations involved.

I do not mean to imply that habitat is not vitally important to all wildlife populations; obviously, habitat is the ultimate long term limiting factor to any population. But from the standpoint of habitat and its immediate effect on animal numbers the population should be the starting point. Habitat assessment for these large herbivores would be more effective and meaningful if the populations were examined as the primary units of study.

Other groups of animals for which the HEP approach does not appear feasible are predators and omnivores. In this study I examined only 1 predator habitat model, that for mink. The results indicated that the mink model was highly inaccurate. This is not surprising considering the complex life requirements of mink and other predators. Attempting to model simplistically dynamic and intricate predator-prey interactions without regard to the actual populations involved seems unreasonable. This is not to intimate that other habitat attributes besides prey densities are not important, or even limiting for some species in certain instances. Certainly, denning and nesting sites, cover, or other life requirements besides food may limit predator populations. However, the presence of these habitat attributes in the absence of adequate prey densities does not constitute a situation favorable to supporting predator populations. Ultimately, populations of most predatory species are limited by the densities of their prey species. For any habitat assessment system to effectively evaluate habitat quality for predators, information on prey densities must be included along with the other habitat attributes.

There are some exceptions to the above generalization. Predators that utilize both terrestrial and aquatic ecosystems may generally be limited by habitat attributes other than food. The river otter (Lutra canadensis) in southeastern Alaska is an example of such a species. The aquatic portion of the habitat is the major source of food for these animals; food items may be considered as continuously distributed throughout this aquatic habitat in southeastern Alaska (Larsen, pers. comm.). In some areas there, otter occurence may be most closely linked to characteristics of the terrestrial environment not related to food availability, such as number of suitable denning sites. Models based on habitat characteristics other than food may be useful in these situations. Bald eagles (Haliaeetus leucocephalus) in southeastern Alaska are another example of a species that relies primarily on the aquatic portion of their habitat for food. Eagles in southeast are probably limited by the numbers of suitable nest trees rather than availability of prey.

Mink are also aquatic-terrestrial habitat users, though it is difficult to say which segment of their habitat provides the major portion of their various life requirements. It is apparent, though, that mink rely much more heavily on the terrestrial environment for food than do otters (Buskirk, pers. comm.). Thus, the non-aquatic food component is most likely an important factor in predicting mink distributions in the terrestrial-aquatic ecosystem. Prey species are not likely to be continuously distributed throughout terrestrial habitats, and any mink habitat assessment scheme should consider food as a primary component of the evaluation. This appears to be most effectively accomplished through population studies in conjunction with habitat investigations.

Some of the predator habitat models in the Alaska HEC Handbook (the mink model, for example) do incorporate prey population information into the assessment, either directly or indirectly. The direct approach has prey population density as a parameter with a corresponding suitability index curve. The problem is that the levels of the index are based on vague terminology such as "high", "medium", "low" or "abundant", "not abundant", "scarce".

Admittedly, this is primarily because of a lack of quantitative data regarding prey numbers and their importance to predator populations. However, I feel that if the available information is so inadequate as to preclude more exacting levels of the index, there seems to be little value in modeling the habitat relationships of these species until additional information is forthcoming. Another problem is that the estimates of prey densities are intended to come from sources other than site and time specific population studies, which may reduce the estimates to mere guesses.

The indirect approach is to relate prey densities to other more easily measurable habitat parameters, and then use those parameters as suitability indices in the predator model. Such an approach might be workable if the relationships between the habitat attributes and prey densities are accurate and quantifiable. An example of this is in the mink model for low shrub where the parameter Amount of Area in Shoreline is supposed to be representative of prey availability. Whether such an approach is valid remains unknown at this time.

Another indirect approach is to evaluate the quality of the habitat for the prey species, and then use that score as a parameter indicating availability of food for the predator. Other important habitat attributes are expressed in terms of other suitability indices and life requisites. Both the wolf (Canis lupus) and arctic fox (Alopex lagopus) habitat models utilize such a system. This approach seems to have some merit, at least in theory. However, it depends upon the assumption that the prey species habitat models are accurate which, for the models I examined, is apparently not the case.

Aside from difficulties in effectively dealing with predator-prey systems, the HEP type of approach also fails to address the problem of competitive interaction. It is widely known that inter- and intra-specific competition can and does limit wildlife populations under certain conditions; examples of this are too numerous to list here. It seems unreasonable to assume that competitive interaction can be adequately addressed through habitat studies alone. In those situations where competitive interactions are suspected to be limiting factors, intensive population investigations are needed if any habitat assessment scheme is to be effective in predicting present and future population trends.

Another major source of difficulty with the models involves the effects that adjacent habitat types have on one another in terms of habitat quality. For many wildlife species the type, size, shape, and juxtaposition of various habitats are important factors affecting the overall habitat suitability of an area. The HEC models are designed such that habitat types are evaluated as separate units with habitat quality scores produced for each type. With such a system the value of habitat mosaics is not taken into account; individual habitat types may be of low value to a particular species, but considered as parts of an overall whole they may have great value. Some habitats may not provide certain life requisites needed by a species at all times of the year, and thus would be rated as low in habitat quality. However, these same habitat types may provide other necessary habitat components and,if they are adjacent to other habitats containing the missing life requisites, may be of very high quality. Also, it is not only a question of whether a life requisite is simply present or absent, but rather the degree to which it occurs.

The models in the Alaska HEC Handbook attempt to incorporate this concept through 2 approaches. This first is by the *a priori* assumption that certain habitat types do not provide all of the life requisites needed by a particular species at all times of the year. Some habitats may be excellent summer range, but an absence of one or more attributes renders them as poor quality wintering habitat. In these situations the Winter Range Value is simply left out of the evaluation so that the HSIs generated for this life requisite do not affect the overall HSI, which may be high based on other life requisites.

The second approach is to include in the assessment a life requisite called the Interspersion Value. The HSI for the Interspersion Value increases for a particular habitat type if it is interspersed with, or adjacent to, certain other habitats. The so-called "edge effect" may also be incorporated into this value. These 2 approaches, either separately or in combination, may be effective in dealing with habitat interspersion in some situations.

However, there are problems with both of these approaches. The first concerns the assumption that it is known *a priori* which habitats do and which do not provide certain life requisites for a species during various times of the year. This assumption may not be valid considering what little is known about most wildlife species and their habitat requirements in Alaska. Also, the Interspersion Value is a separate life requisite; while this value may be high for a particular habitat, the overall HSI for the site might still be low because some other life requisite has a lower HSI and is assumed to be the limiting factor. Thus, the increase in availability or value of certain life requisites such as food and cover, because of the proximity of one habitat to another, is still not accounted for.

An example should help to clarify these points. The moose model for low and tall shrubs does not include the Winter Range Value as one of the life requisites. Because shrub habitats do not generally provide the thermal cover required by moose in winter, the inclusion of the Winter Range Value would result in a low overall HSI due to the limiting factor approach. Since certain shrublands such as willow and dwarf birch can provide excellent summer range for moose, the Winter Range Value is simply excluded from the assessment. The problem is that these shrublands may also be integral components of high quality moose wintering areas, providing the food resource with other nearby habitats (such as coniferous forest) contributing the necessary thermal cover. The moose model in the HEC Handbook is not designed to effectively deal with situations such as this. It appears that many of the models are incapable of handling animal-habitat interrelationships similar to that described above.

Any assessment of a wildlife habitat evaluation methodology would be incomplete without a discussion of exactly what such a system is supposed to be measuring. Are these models trying to evaluate habitat quality in terms of potential value irregardless of actual population levels, as estimates of habitat use, or as predictors of population densities? Unfortunately, there is a distinct lack of agreement among various authors concerning the meaning of habitat quality scores generated by the models in the HEP system.

Whelen et al. (1979) in a comparison of 3 habitat evaluation approaches implied that evaluation schemes should be assessing habitat potential:

> "The underlying question which arises from our comparison of forest habitat evaluation systems is: which system estimates most accurately the potential of a given habitat for meeting the life requirements of particular wildlife species?"

In my view habitat potential is an expression of carrying capacity as determined primarily by habitat limiting factors (food, cover, water, space, etc.) when negative effects of other regulating mechanisms (weather, predation, disease, parasites, emigration, etc.) are at a minimum. It is a measure of the number of animals a habitat <u>might</u> support under optimum conditions; this is a different gauge of habitat quality than the population densities that a habitat <u>actually</u> <u>does</u> sustain.

Lancia et al. (in press) tested the accuracy of a bobcat habitat model by comparing model Habitat Quality Index (HQI) values with habitat use information determined by radio-tracking of instrumented bobcats. They indicated in their introduction that habitat use was the true test of model accuracy. However, they supported the habitat potential notion by stating in their conclusions that:

> "...we attempted to predict potential habitat quality, not where individual animals located their home ranges. Predicting how individual animals distribute themselves within adequate habitat goes beyond the sophistication necessary to make management decisions."

The authors of a report by New England Research, Inc. (1980) criticized the habitat potential approach by stating that:

> "...many evaluations of habitat indicate, at best, only potential use of existing habitat. Projections of habitat value into an uncertain future therefore become increasingly abstract..."

Baskett et al. (1980) evaluated variation in scores generated from the Missouri HEP Handbook (Baskett et al. 1980), and concluded in their closing remarks, "Finally, the real test of a handbook of this sort is whether the scores reflect animal abundance or wildlife usage of the habitat."

Darrow et al. (1981) commented that during the seminar in 1978 entitled "Habitat Evaluation Scoring, Can We Be Consistent?", many biologists indicated that habitat scores should be validated by comparison to animal abundance data. They attempted to determine if the level of wildlife use of areas was reflected in habitat quality scores generated by HEP models for the same areas. In their conclusions they warned that although corroborative animal population data have some possible value, temporal changes in wildlife population densities may occur even in good habitat.

Finally, Kling (1980) strongly supported the idea that habitat quality estimates should ultimately reflect population densities. He stated:

> "I believe that habitat quality must be related in some way to population level and, therefore, expressed in terms of population. Habitat is merely a means to an end; wildlife produced by habitat is the important thing. For example, the fact that a strip mine or reservoir destroys a hectare of habitat is important, not because the hectare of habitat is lost but because the habitat cannot produce wildlife. We try to replace that lost production by improving habitat elsewhere to produce more wildlife. It would seem logical then to have the information used as the basis for decisions and ultimate evaluation of the project in terms of population."

I support Kling's (1980) contention that for most species managers should be concerned primarily with populations when mitigating wildlife habitat losses. Unfortunately, it appears that the majority of models developed for the HEP system are not capable of accurately predicting population densities for reasons previously discussed. It appears that the best most of the present models can do is to estimate the potential of habitats to support wildlife populations; for some species this may be adequate. It is disconcerting, though, that most of the models examined by us and other researchers are apparently not very effective in even estimating habitat potential.

Studies involving wildlife habitat and mitigation procedures should center on habitat as 1 of several factors that may limit animal populations. Considering habitat as the only limiting factor is just too simplistic of an approach to be realistic for most species, especially in Alaska. Any effort to model the importance of habitat should involve an attempt to model the populations of these species. I realize that population studies are much more time consuming and expensive than the HEP type of approach, but such investigations would yield much more meaningful information to the manager attempting to mitigate habitat losses. If the appropriate population data are not available and if population studies cannot be funded, then I suggest for Alaska at the present time that species expert opinions be used as the best estimates of habitat quality. I believe that expert habitat quality ratings will be more accurate and reliable than the habitat scores generated by the models currently in the Alaska HEC Handbook. I must emphasize that these ratings should not be considered predictions of actual animal abundance, unless the expert has intimate knowledge of the species' population densities in the area being evaluated. Otherwise, the species expert ratings can be viewed only as indicators of habitat potential.

The models in the Alaska HEC Handbook and other HEP Handbooks do have value to wildlife managers and researchers. The species narratives in the Alaska Handbook are excellent in compiling most of the available information dealing with selected wildlife species and their habitat requirements. The modeling effort was also very effective in exposing information gaps concerning species-habitat interrelationships. By documenting these deficiences the authors of the models provided a valuable service in indicating where future research should be directed; for this they should be commended. For certain species discussed previously they may provide a useful framework for future modeling attempts. While the models may be somewhat crude and oversimplified at the present time because of an inadequate data base, researchers willing to expend the time and energy required to gather the necessary information could use the Alaska HEC models as the basis for their modeling efforts. I can recommend using the models only under such conditions; the models should not be used for assessing habitat quality unless they are modified for specific localities and validated for accuracy by field testing. Ideally, accuracy validation would involve techniques similar to that employed by Lancia et al. (in press).

The guilding technique proposed by Short and Burnham (1982) may be an alternative to the HEC model approach for assessing wildlife habitat quality. The technique is based on the assumption that a wildlife species can be described as occupying a discrete area within a two-dimensional "species-habitat" matrix. The axes of this matrix are food sources (x-axis) and breeding requirements (y-axis), with the categories of each based on vertical stratification of the habitat. Those habitat attributes delineated by the intersection of the x and y coordinates in this matrix are known as "guild blocks".

Various wildlife species occupying similar guild blocks are grouped into aggregations called "guilds". The number of vertical strata in a habitat determines how many guild blocks are present, which in turn ascertains the potential number of guilds that can occur in that habitat. Thus, increasing habitat complexity in terms of more vertical strata corresponds to greater numbers of potential guilds.

The guilding technique has application in a variety of management applications (Short and Burnham 1982). A community rather than single-species approach to habitat management is possible. The impact of various management practices on the wildlife community can be predicted based on the known changes that will occur to the habitat strata. Proposed land use changes can be evaluated by comparing the products of multiplying the present potential guilds by the present hectares of the habitat type to the future potential guilds by the future hectares. The difference in the two products represents the effect that a proposed project will have on the wildlife community.

Short and Burnham (1982) state that this technique can also be incorporated into the existing HEP system (USFWS 1980). A measure of habitat quality can be achieved by comparing the actual number of guilds present in a habitat type to the number of guilds that would be present if all potential guild blocks were occupied. The ratio of present guilds divided by potential guilds is substituted for the Habitat Suitability Index in the calculation of the Habitat Units. The Habitat Units can then be used according to the standard HEP methodology.

It is acknowledged by Short and Burnham (1982) that there are problems with such a system. Difficulties arise in developing the data base needed to drive the guild analyses because wildlife have not normally been associated with vertical strata in habitat. There is no provision for assessing how adequate a habitat is for a particular species. It also does not determine whether factors other than habitat are responsible for the absence of a species from an area. Finally, they state that the proposed applications of the technique are assumed and not proven, and must await completion of an applications study presently in progress.

To Short and Burnham's (1982) comments I would add the following. The assumption that species and their niches can be described in terms of their position along the continuums of food and breeding requirements is vital to the guilding process. This assumption may hold true for some species, but it cannot be stated with certainty that it is true for all species. Some species may be limited in their distributions by habitat parameters that do not relate directly to food or breeding requirements. In addition, the multivariate statistical techniques involved in developing guild blocks and guilds would be extremely difficult to implement without a sophisticated computer and the necessary programs. If this technique is to be widely used in habitat evaluation projects, then some provisions must be made to aid biologists in the process.

As mentioned above, this technique does not consider factors other than habitat in determining whether or not a species is found in a particular area. In this sense it shares many of the difficulties associated with the HEC models. For reasons already discussed, such an approach does not appear feasible for many wildlife species in Alaska.

CONCLUSIONS AND RECOMMENDATIONS

The accuracy and precision of habitat quality scores (HSI values) generated by selected species-models from the Alaska HEC Handbook were evaluated. Precision was assessed by comparison of sample data and the HSIs calculated from those data among 3 teams that used the models to estimate habitat quality at various sites. Accuracy appraisal was based on comparison of the model HSI values with species expert habitat quality ratings.

Among-team precision of the sample data was highly variable. Estimates of parameters obtained on subplots consisting of ratio-type data generally exhibited low precision among teams. Precision was higher for percent cover and other ocular estimates than for those sampled with measuring devices. Some parameters were inherently difficult to precisely estimate such as tree height, number of plant species, and those involving shrubs. Low shrub habitat was particularly difficult to sample with precision among teams because of the extreme high density of shrubs in this habitat type.

The averaged and/or combined ratio-type data that were originally acquired from subplots showed high levels of among team precision except in low shrub habitat. Thus, it is apparent that the averaging and/or combining process obscured some of the among team variability found in the subsample data. However, if these variables had been originally sampled at the plot level, it is likely that the data inputted into the HEC models would not have been as accurate.

For those parameters which subsampling was not deemed necessary and both ratio- and nominal-type data were collected only at the plot level, precision among teams of the estimates was high in most cases. Of 6 parameters estimated with ratio-type data for beaver only 1, Percent Cover of Aquatic Forage, yielded imprecise estimates among teams. Again, a percent cover estimate was difficult to obtain precisely. Two nominal-type parameters, Sedge Grass Competition in low shrub and Edaphic Mixture in Stand in deciduous forest, showed high variability in the estimates among teams. Parameters for which nominal-type data were collected on subplots (tree species in the point-center-quarter sampling scheme) exhibited high levels of among-team precision in the estimates.

Concerning the actual habitat scores, precision among teams was acceptably high for most models and habitat types assessed based on the mean absolute differences between team HSI values. Results were similar for both the multiplicative and geometric mean models. The only problems were with the spruce grouse and common redpoll models. For the spruce grouse model the HSI values from team 3 consistently differed at an unacceptable level from those of the other teams; no explanation for this is apparent. The common redpoll model yielded unacceptable mean differences among all the teams for most life requisites in low shrub habitat. The limiting factors were the same life requisites for the 3 teams in all but 2 instances. The absolute mean differences between team HSIs exceeded 0.100 in only 63 of 378 comparisons, indicating that the models were acceptably precise 83% of the time. Overall, it is evident from the results of this and other studies that the use of documented and standardized habitat evaluation criteria, as found in the various HEC-like handbooks, does reduce variability and increase repeatability in habitat quality scores compared to those obtained from strictly subjective assessments.

In general, accuracy of the models examined was unacceptable, based on the mean differences between team HSI values and species expert ratings. The multiplicative mean HSIs were usually more accurate than the geometric means, though still not acceptably so. Of all the models and habitat types assessed only the following generated acceptably accurate habitat quality scores for all team expert comparisons: the revised multiplicative moose model in low shrub for the NWLF; the multiplicative common redpoll models in coniferous forest for both the NWLF and WLF and in deciduous forest for the WLF; the green-winged teal multiplicative model in low shrub for the NWLF. In total, only 24 of 192 comparisons between model HSI values and species expert ratings resulted in absolute mean differences less than or equal to 0.100; thus, the models yielded acceptably accurate habitat quality scores at the rate of only 12%. It is apparent from these results that the models examined from the Alaska HEC Handbook did not generate accurate estimates of habitat quality in most cases. Other studies revealed that most of the HEP models tested to date have not produced accurate habitat quality scores, whether these scores were compared to animal abundance estimates or habitat use data. There are numerous possible explanations for the accuracy problem and these have been discussed previously.

Based on these findings I make the following recommendations which are directed primarily to the situation in Alaska, but may also apply to other areas where HEP might be utilized:

1) The models that have been examined in this study from the Alaska HEC Handbook should not be used in their current form for wildlife habitat assessments; other models in this handbook also are suspected to produce inaccurate habitat quality estimates.

2) None of the models in any HEP Handbook should be employed unless validated for accuracy through field testing; the approach of Lancia et al. (in press) appears to be the most effective method of model validation.

3) Models should not be developed when the necessary information is grossly inadequate; once in print these models might be used without further modification, possibly resulting in major errors in habitat quality assessment.

4) For certain species such as resident, close-ranging, or habitat specialist types the HEP approach may be useful; however, researchers must be willing to modify and validate models before utilizing them in the decision making process.

5) For the wide-ranging, herbivorous, habitat generalist types and most predatory species the HEP approach does not

appear feasible for Alaska; population studies which include habitat as one of several possible limiting factors are more useful for mitigating habitat losses for these species.

6) If population studies cannot be conducted, then in lieu of the current models in the Alaska HEC Handbook species expert opinions should be accepted as the best estimates of habitat quality; preferably, at least 2 experts should be involved in the assessment.

7) It should be remembered that for most wildlife species the habitat quality scores produced by the various HEC models are at best estimates of habitat potential; habitat quality, even if accurately assessed, may not be a reliable indcator of actual level of animal abundance or habitat use.

8) A recent approach that might have future applications for some areas in certain situations is the guilding approach (Short and Burnham 1982) previously discussed; however, this technique has not yet been validated through field testing.

I do not wish to leave the reader with the impression that development of the Alaska HEC Handbook models was not a worthwhile endeavor. As stated above, for some species the models might be useable if modified and validated for specific localities; the models may also provide a framework for future modeling attempts. In those situations where the approach does not appear to be feasible, at least it is evident which avenues should not receive further exploration. Finally, the gathering of all available data concerning species and their habitat requirements has been invaluable in identifying information gaps, and should assist in directing future research in Alaska.

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APPENDICES

Appendix 1. Habitat evaluation model from Terrestrial Habitat Evaluation Criteria Handbook - Alaska (Konkel 1980) for moose in mixed coniferous-deciduous forest.

HABITAT SUITABILITY INDEX

Moose in Mixed Coniferous-Deciduous Forest

Food Value (Spring/Summer/Fall) (X_1) = $I_1 \times I_2 \times I_3 \times I_4 \times I_5 \times I_6$

Where: I_1 = Suitability Index of dominant forest type

I_2 = SI of dominant deciduous browse species in forests

I_3 = SI of % shrub and deciduous sapling crown cover under 10 feet (or DBH <1.6 inches)

I_4 = SI of average shrub and deciduous sapling height (not including decumbent sp.) (feet)

I_5 = SI of herbaceous ground cover in summer

I_6 = SI of interspersion with moose feeding habitats (wetland, grassland, tundra, or seral deciduous forest)

Winter Range Value (X_2) = $I_1 \times I_2 \times I_3 \times I_4 \times I_7 \times I_8$

Where: I_1 = SI of dominant forest type

I_2 = SI of dominant deciduous browse species in forests

I_3 = SI of % shrub and deciduous sapling crown cover under 10 feet (or DBH <1.6 inches)

I_4 = SI of average shrub and deciduous sapling height (not including decumbent sp.) (feet)

I_7 = SI of % ground cover of low-growing winter forage (foliose lichens, *Vaccinium* sp. and *Carex* sp.)

I_8 = SI of maximum snow depth (highest monthly reading for average year)

Cover Value (Spring/Summer/Fall) (X_3) = $I_9 \times I_{10} \times I_{11}$

Where: I_9 = SI of tree canopy closure

I_{10} = SI of height of majority of trees (feet)

I_{11} = SI of % shrub and sapling crown cover

Cover Value (Winter) (X_4) = $I_{12} \times I_9$

Where: I_{12} = SI of dominant forest type

I_9 = SI of tree canopy closure

Reproductive Value (X_5) = $I_9 \times I_{10} \times I_{11} \times I_{13}$

Where: I_9 = SI of tree canopy closure

I_{10} = SI of height of majority of trees (feet)

I_{11} = SI of % shrub and sapling crown cover

I_{13} = SI of interspersion with wetlands (marsh, shallow lentic or slow lotic water)

Note: This life requisite requires that adequate food be present, therefore, the lowest of either the Food Value (Spring/Summer/Fall) or the Reproductive Value should be used for the final Reproductive Value.

Interspersion Value (X_6) = $I_{14} \times I_{15} \times I_{16}$

Where: I_{14} = SI of plant species diversity within stand

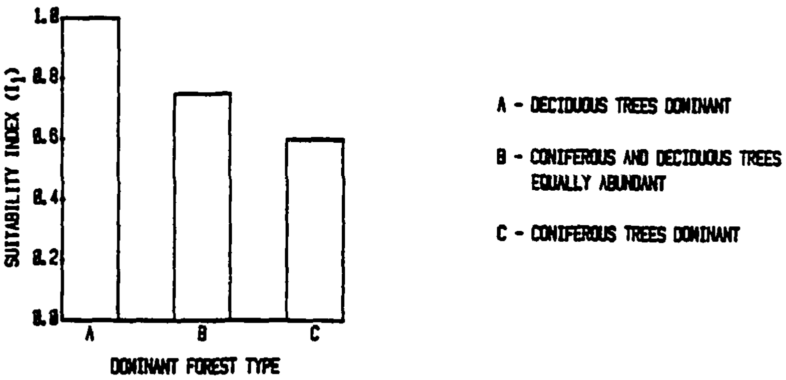
I_{15} = SI of edaphic mixture within stand

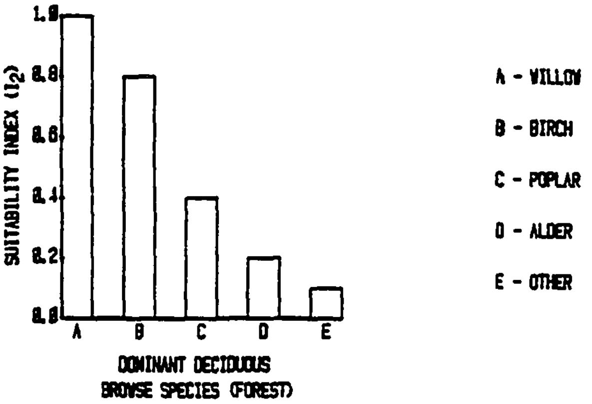
I_{16} = SI of external edge of stand

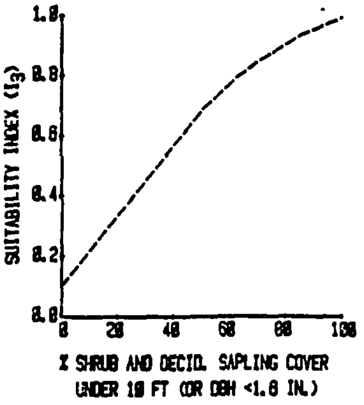
The Habitat Suitability Index is the lowest X_n value.

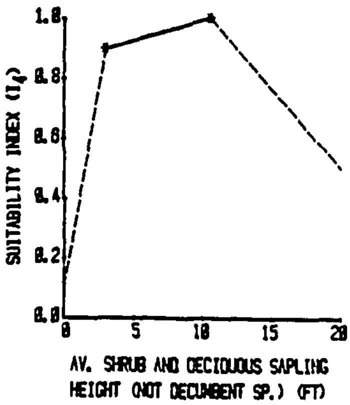
MOOSE

MIXED CONIFEROUS-DECIDUOUS FOREST



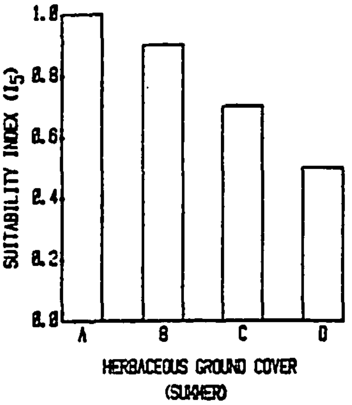




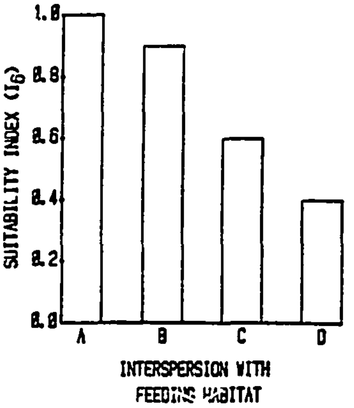


MOOSE

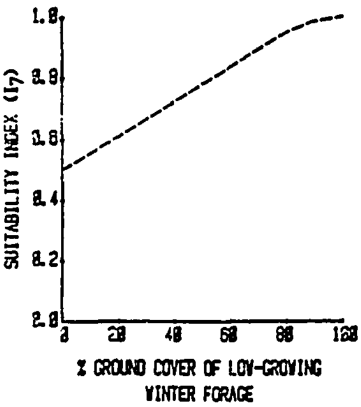
MIXED CONIFEROUS-DECIDUOUS FOREST



A-DENSE, LUSH HERBACEOUS FORAGE (75-100% GROUND COVER) — OR WILLOW-DOMINATED SHRUB COVER (GREATER THAN 80% CROWN COVER) AND THEREFORE HIGH QUALITY FORAGE PRESENT DESPITE LACK OF HERBS
B-MODERATELY DENSE HERBACEOUS FORAGE (50-75% GROUND COVER)
C-SPARSE TO MODERATE HERBACEOUS FORAGE (25-50% GROUND COVER)
D-SPARSE HERBACEOUS FORAGE (LESS THAN 25% GROUND COVER

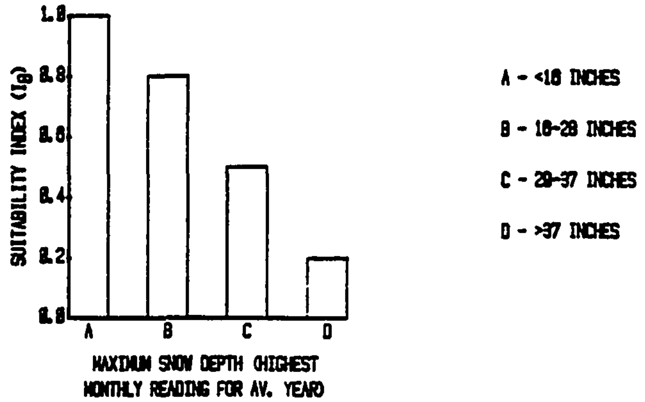


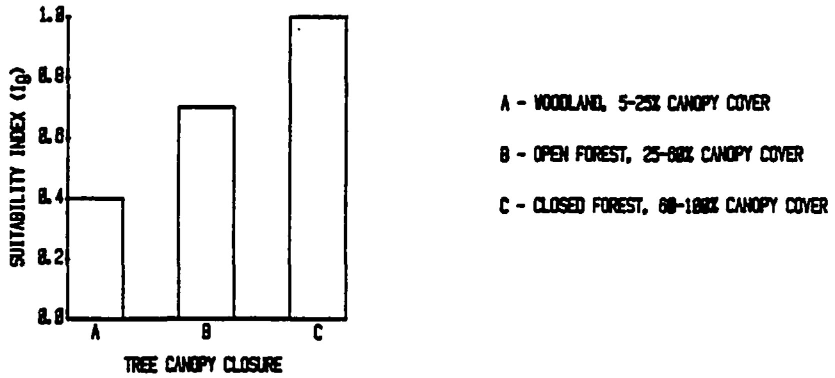
A - FEEDING HABITAT (WETLAND, GRASSLAND, TUNDRA OR SERAL DECIDUOUS FOREST) ABUNDANT WITHIN ONE MILE
B - FEEDING HABITAT COMMON WITHIN ONE MILE
C - FEEDING HABITAT UNCOMMON WITHIN ONE MILE BUT SUBSTANTIAL WITHIN TWO MILES
D - NO SIGNIFICANT FEEDING HABITAT WITHIN TWO MILES

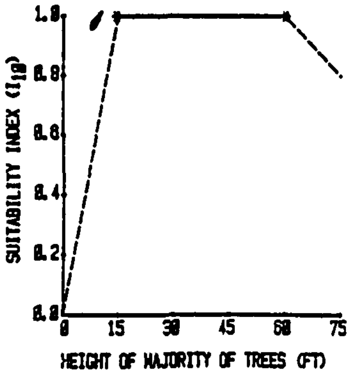


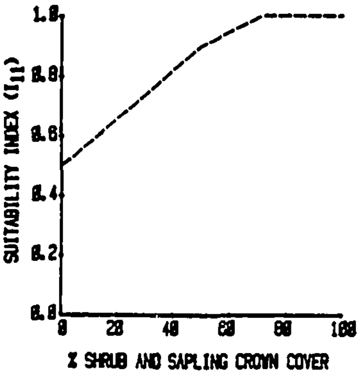
MOOSE

MIXED CONIFEROUS-DECIDUOUS FOREST



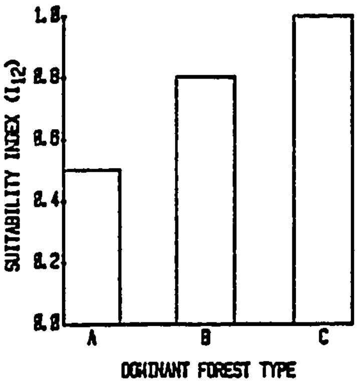






MOOSE

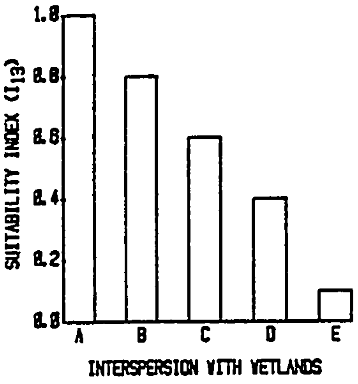
MIXED CONIFEROUS-DECIDUOUS FOREST



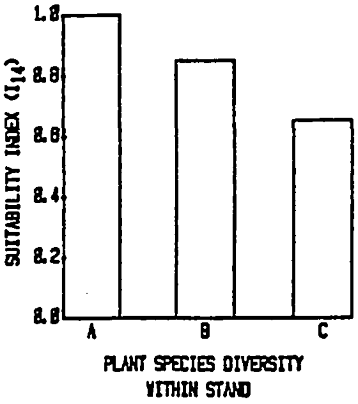
A - DECIDUOUS TREES DOMINANT

B - CONIFEROUS AND DECIDUOUS TREES EQUALLY DOMINANT

C - CONIFEROUS TREES DOMINANT



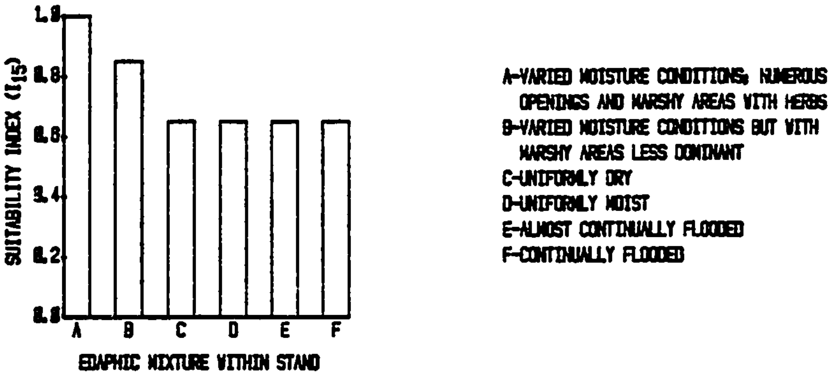
A-HIGHLY INTERSPERSED WITH WETLAND POCKETS; NUMEROUS BOGS, MARSHES, PONDS, SHALLOW LAKES OR SLOUGHS
B-MODERATELY INTERSPERSED - WETLAND POCKETS COMMON BUT NOT ABUNDANT
C-FEW OR NO SIGNIFICANT WETLAND POCKETS, BUT HOMOGENEOUS COVER TYPE IS BORDERED BY AREAS OF WETLAND HABITAT
D-FEW OR NO SIGNIFICANT WETLAND POCKETS; BORDERED BY A SMALL AMOUNT OF WETLANDS
E-NO SIGNIFICANT WETLAND HABITAT WITHIN ANY REASONABLE DISTANCE

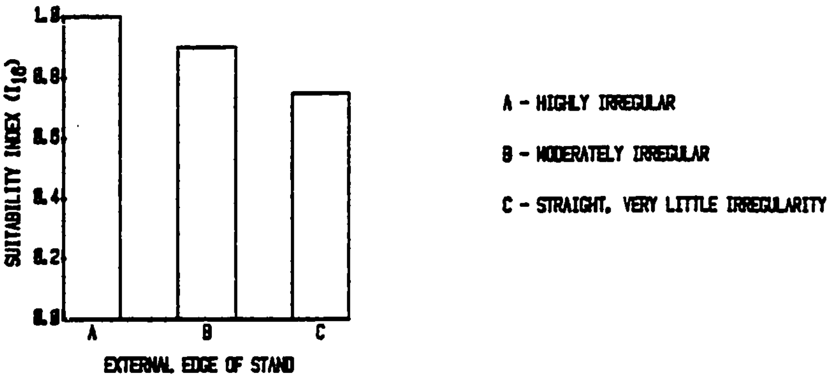


A-HIGH PLANT SPECIES DIVERSITY; VARIETY OF FORAGE AND COVER TYPES; STAGGERED MATURATION RATES
B-MEDIUM PLANT SPECIES DIVERSITY; FORAGE AND COVER TYPES FEW IN NUMBER; MATURATION RATES TENDING TO BE WEIGHTED IN ONE DIRECTION
C-LOW PLANT SPECIES DIVERSITY; HOMOGENEOUS FORAGE AND COVER; UNIFORM MATURATION RATES

MOOSE

MIXED CONIFEROUS-DECIDUOUS FOREST





Appendix 2. Revised habitat evaluation model (Konkel, pers. comm.) for moose in all habitat types.

HABITAT SUITABILITY INDEX MODEL
for
Moose (Alces Alces)
on the
KENAI PENINSULA

I. GENERAL INFORMATION ABOUT THE MODEL

This descriptive model applies only to moose on the Kenai Peninsula and was specifically developed for use in the evaluation of potential impacts on moose resulting from a proposed dam and power facility in the Bradley Lake area. The primary sources of information for this model were the Terrestrial Habitat Evaluation Criteria Handbook for Alaska (Konkel and Shea 1980) and consultations with Dr. Wayne Regelin (U.S. Fish and Wildlife Service, Moose Research Center) and Bill Gasaway (Game Biologist, Alaska Department of Fish and Game).

The general assumptions in the model include:

1. The quality of moose habitat can be described and rated as the Habitat Suitability Index (HSI) on a scale of 0.0 to 1.0;

2. The quality of moose habitat (HSI) is a function of the quality of individual life requisites, such as food, cover, reproduction, etc., which can each be described and rated as a Life Requisite Index (LRI) on a scale of 0.0 to 1.0;

3. The quality of each Life Requisite can be described in Suitability Index (SI) variables, which are measureable parameters rated on a scale 0.0 to 1.0;

4. The values given to HSI, LRI and SI correspond to vernacular ratings of habitat quality as follows:

   0.9 - 1.0 = excellent
   0.7 - 0.8 = above average; good
   0.4 - 0.6 = average
   0.2 - 0.3✓ = fair to poor
   0.0 - 0.1 = unsuitable;

5. theoretical models are useful in the analysis of complex systems in that they isolate and document generally accepted assumptions about the nature of the system (in this case the habitat requirements of moose) and thereby help to increase the knowledge of the system by encouraging further discussion of the assumptions; and

6. theoretical models must be tested in the best way possible and subsequently refined.

Information on the *threshold range size* for moose in Alaska is insufficient to estimate the minimum area of suitable habitat necessary to support a viable population. Information on the *optimum and required compositions of moose habitat,* in terms of the proportionate areas of each vegetation cover type, is also insufficient to allow any meaningful estimate. Research into both these factors would help in future assessments of the impacts of development upon moose.

The model refers to the vegetation cover types classified by Dyrness and Viereck (1979) using the following abbreviations:

Coniferous Forest = CF
Deciduous Forest = DF
Mixed Forest = MF
Tall Shrubland = TS
Low Shrubland = LS
Shrub Tundra = ST
Tall Grassland = TG
Mid Grassland = MG
Herbaceous Sedge-Grass = HSG

II. Spring - Early Summer Food Value (X_1)

CF, DF,	V_1 = SI of dominant deciduous moose browse species	
MF, TS,	a) *Salix* sp. + *Populus* sp. + *Betula papyrifera*	1.0
LS, ST	b) *Salix* sp. + *Betula papyrifora*	1.0
	c) *Salix* sp. + *Populus* sp.	0.9
	d) *Salix* sp. + *Alnus* sp.	0.8
	e) *Salix* sp. + *Betula glandulosa* or *Betula nana*	0.7
	f) *Salix* sp.	0.9
	g) *Betula papyrifera*	0.8
	h) *Populus* sp.	0.4
	i) *Alnus* sp.	0.2
	j) other combination of species to be evaluated on ground	0.0 - 0.5
CF, DF,	V_2 = SI of % horizontal foliar cover of moose browse species < 10 feet tall (or with DBH < 1.6 inches)	
MF, TS,	a) 75 - 100%	1.0
LS, ST	b) 51 - 75%	0.7 - 0.9
	c) 26 - 50%	0.4 - 0.6
	d) 6 - 25%	0.1 - 0.3
	e) 0 - 5%	0.0
CF, DF,	V_3 = SI of the average vertical extent of the foliage	
MF, TS,	of moose browse species within 10 feet of the ground	
LS, ST	a) 8 - 10 feet	1.0
	b) 5 - 7 feet	0.7 - 0.9
	c) 2 - 4 feet	0.4 - 0.6
	d) $\leq$ 1.9 feet	0.0 - 0.3

CF, DF,	V_4 = SI of % horizontal forb cover	
MF, TS,	a) 75 - 100%	1.0
LS, ST,	b) 51 - 75%	0.9
TG, MG	c) 25 - 50%	0.6 - 0.8
	d) 5 - 25%	0.3 - 0.5
	e) 0 - 5%	0.0 - 0.2

Spring-Early Summer Food Value for coniferous, deciduous and mixed forests, tall and low shrublands and shrub tundra is a function of V_1, V_2, V_3 and V_4. The suggested function is:

$$[2V_1 + (V_2 \times V_3)^{1/2} + V_4] / 4$$

Spring-Early Summer Food Value for tall and mid grasslands is the Suitability Index value of V_4.

The rationale behind the Spring-Early Summer Food Value model is based upon two factors:

1. most moose biologists recognize the significance of the identified browse species and new-growth forbs in the diet of moose, and
2. the horizontal and vertical measurements of cover of the browse species within the foraging capabilities of moose (i.e. within 10 feet of the ground or spindly enough to be bent over) are an indication of the biomass of potential moose food.

III. Late Summer - Fall Food Value (X_2)

CF, DF,	V_1 = SI of dominant deciduous moose browse species	
MF, TS,	a) *Salix* sp. + *Populus* sp. + *Betula papyrifera*	1.0
LS, ST	b) *Salix* sp. + *Betula papyrifora*	1.0
	c) *Salix* sp. + *Populus* sp.	0.9
	d) *Salix* sp. + *Alnus* sp.	0.8
	e) *Salix* sp. + *Betula glandulosa* or *Betula nana*	0.7
	f) *Salix* sp.	0.9
	g) *Betula* papyrifera	0.8
	h) *Populus* sp.	0.4
	i) *Alnus* sp.	0.2
	j) Other combination of species to be evaluated on ground	0.0 - 0.5

CF, DF	V_2 = SI of % horizontal foliar cover of moose browse species < 10 feet tall (or with DBH < 1.6 inches)	
MF, TS,	a) 75 - 100%	1.0
LS, ST	b) 51 - 75%	0.7 - 0.9
	c) 26 - 50%	0.4 - 0.6
	d) 6 - 25%	0.1 - 0.3
	e) 0 - 5%	0.0

CF, DF, MF, TS, LS, ST

V_3 = SI of the average vertical extent of the foliage of moose browse species within 10 feet of the ground

a) 8 - 10 feet	1.0
b) 5 - 7 feet	0.7 - 0.9
c) 2 - 4 feet	0.4 - 0.6
d) $\leq$ 1.9 feet	0.0 - 0.3

Late Summer-Fall Food Value for coniferous, deciduous and mixed forests, tall and low shrublands and shrub tundra is a function of V_1, V_2 and V_3. The suggested function is:

$$[\ 2\ V_1 + (V_2 \times V_3)^{1/2}\ ]\ /\ 3$$

The rationale behind the Late Summer-Fall Food Value model is based upon two factors:

1. most moose biologists recognize the significance of the identified browse species, and
2. the horizontal and vertical measurements of cover of the browse species within the foraging capabilities of moose are an indication of the biomass of potential moose food.

IV. Winter Range Value (X_3)

CF, DF, MF, TS

V_1 = SI of dominant deciduous moose browse species

a) *Salix* sp. + *Populus* sp. + *Betula papyrifera*	1.0
b) *Salix* sp. + *Betula papyrifera*	1.0
c) *Salix* sp. and *Populus* sp.	0.9
d) *Salix* sp. and *Alnus* sp.	0.8
e) *Salix* sp. and *Betula glandulosa* or *B. nana*	0.7
f) *Salix* sp.	0.9
g) *Betula papyrifera*	0.8
h) *Populus* sp.	0.4
i) *Alnus* sp.	0.2
j) other combination of species to be evaluated on ground	0.0 - 0.5

CF, DF, MF, TS

V_3 = SI of the average vertical extent of the foliage of moose browse species within 10 feet of the ground

a) 8 - 10 feet	1.0
b) 5 - 7 feet	0.7 - 0.9
c) 2 - 4 feet	0.4 - 0.6
d) $\leq$ 1.9 feet	0.0 - 0.3

CF, DF, MF, TS

V_5 = SI of % horizontal foliar cover of moose browse species < 10 feet (or DBH < 1.6 inches) and > 16 inches above the ground

a) 75 - 100%	1.0
b) 51 - 75%	0.7 - 0.9
c) 26 - 50%	0.4 - 0.6
d) 6 - 25%	0.1 - 0.3
e) 0 - 5%	0.0

CF, DF, MF, TS — V_6 = SI of % coniferous tree canopy cover

a) 76 - 100%	1.0
b) 51 - 75%	0.7 - 0.9
c) 26 - 50%	0.4 - 0.6
d) 0 - 25%	0.0 - 0.3

CF, DF, MF, TS — V_7 = SI of % ground cover of foliose lichens (*Peltigera* sp.) and *Vaccinium vitis-idaea* (as well as other species that appear to be used as winter forage in a study area)

a) 76 - 100%	1.0
b) 51 - 75%	0.8 - 0.9
c) 26 - 50%	0.5 - 0.7
d) 6 - 25%	0.1 - 0.4
e) 0 - 5%	0.0

Note: This parameter may be omitted if deep snow conditions limit the availability of this food source.

CF, DF, MF, TS — V_8 = SI of average maximum snow depth (e.g. highest monthly snow depth for average year)

a) < 16 inches	0.9 - 1.0
b) 116 - 28 inches	0.6 - 0.8
c) 29 - 37 inches	0.3 - 0.5
d) > 37 inches	0.0 - 0.2

Note: Heavier snow is more difficult for moose to travel through and, therefore, areas that generally have wetter snow should be rated lower than those areas with drier snow.

The Winter Range Value for coniferous, deciduous and mixed forests and tall shrublands is a function of V_1, V_3, V_5, V_6, V_7 and V_8. The suggested function is:

$$[2\,V_1 + (V_3 \times V_5)^{1/2} + V_6 + V_7 + V_8] \,/\, 6$$

The rationale behind the Winter Range Value model is based upon the same two factors discussed under the Late Summer-Fall Food model as well as the following three factors:

1. The degree of snow cover determines the availability of forage species. Therefore, the greater the coniferous tree canopy that intercepts falling snow, the less the accumulation of snow on the ground and therefore the greater the potential forage. Regelin (pers. comm. May 1980) advised that "winter forage" was generally considered to be the preferred plant species that occur between 16 inches and 10 feet above the ground.

2. The significance of average snow depth is based upon studies by Coady (1973).

3. The availability of low-growing foliose lichens and lowbush cranberry may not be as important as the availability of browse (Regelin, pers. comm. May 27, 1980) but may serve as important alternate food sources (LeResche et al. 1974).

V. Spring - Summer - Fall Cover Value (providing concealment and thermal protection) (X_4)

CF, DF,	V_9 = SI of tree canopy closure	
MF, TS	a) closed forest, with 60 - 100% cover	0.8 - 1.0
	b) open forest, with 25 - 60% cover	0.5 - 0.7
	c) woodland, with 5 - 25% cover	0.0 - 0.4

CD, DF,	V_{10} = SI of tall shrub and sapling crown cover	
MF, TS	a) 76 - 100%	1.0
	b) 51 - 75%	0.8 - 0.9
	c) 26 - 50%	0.5 - 0.7
	d) 6 - 25%	0.1 - 0.4
	e) 0 - 5%	0.0

Spring-Summer-Fall Cover Value for coniferous, deciduous and mixed forests and tall shrublands is a function of V_9 and V_{10}. The suggested function is:

$$(V_9 + V_{10}) / 2$$

The rationale behind the Spring-Summer-Fall Cover Value model is that both tree canopy and tall understory crown cover provide moose with thermal shelter and concealment from predators.

VI. Reproductive Value (X_5)

CF, DF,	V_9 = SI of % tree canopy closure	
MF	a) woodland, 5 - 25% cover	1.0
	b) open forest, 25 - 60% cover	0.5 - 0.9
	c) closed forest, 60 - 100% cover	0.0 - 0.4

CF, DF,	V_{10} = SI of proximity to freshwater (suitable for drinking)	
MF, TS,	a) freshwater is < 100 m from plot	0.9 - 1.0
LS, ST,	b) " is < 200 m " "	0.5 - 0.8
TG, MG,	c) " is < 400 m " "	0.1 - 0.4
HSG	d) " is > 400 m " "	0.0

CF, DF, MF, TS, LS, ST, TG, MG, HSG	V_{11} = SI of proximity to spring-early summer feeding habitat (considering the suitability of the quantity and quality of food for cow with calves)	
	a) < 100 m from plot	0.9 - 1.0
	b) < 200 m " "	0.5 - 0.8
	c) < 400 m " "	0.1 - 0.4
	d) > 400 m " "	0.0

Reproductive Value for coniferous, deciduous and mixed forests is a function of V_9, V_{10} and V_{11}. The suggested function is:

$$(V_9 \times V_{10} \times V_{11})^{1/3}$$

Reproductive Value for tall and low shrublands, shrub tundra, tall and mid-grasslands, and herbaceous sedge-grass is a function of V_{10} and V_{11}. The suggested function is:

$$(V_{10} \times V_{11})^{1/2}$$

The rationale behind the Reproductive Value model is that moose prefer to calve in relatively open areas, so that they can see predators coming from quite a distance, and that food and water need to be within close proximity so that the cow need not wander far from her calf which is bedded down in cover (Regelin, pers. comm. May 1980). Variable 11 requires consideration of distance to and quality of food (i.e. low quality food within 100 meters would receive a lower rating than high quality food within 100 meters).

VII. Interspersion Value (I_6)

All Types	V_{12} = SI of the proximity of Spring-Early Summer Food and Spring-Summer-Fall Cover	
	a) < 110 yards if terrain is flat; or < 1/4 mile if terrain is undulating;	0.8 - 1.0
	b) 110 - 215 yards (1/8 mile) if flat; 1/4 to 1/2 mile if undulating;	0.4 - 0.7
	c) > 1/8 mile if flat; or > 1/2 mile if undulating	0.0 - 0.3
All Types	V_{13} = SI of the proximity of Summer-Fall Food and Spring-Summer-Fall Cover	
	a) < 110 yards of terrain is flat; or < 1/4 mile if terrain is undulating;	0.8 - 1.0
	b) 110-215 yards (1/8 mile) if flat; or 1/4 to 1/2 mile if undulating;	0.4 - 0.7
	c) > 1/8 mile if flat; or > 1/2 mile if undulating	0.0 - 0.3

All Types	V_{14}	SI of the availability of all seasonal food, cover and reproductive life requisites of moose (i.e. X_1, X_2, X_3, X_4 and X_5) within the watershed or within adjacent watersheds that are joined by low mountain passes negotiable by moose or separated only by gentle hills	
		a) all life requisites are provided	1.0
		b) all life requisites are not provided	0.0

The Interspersion Value of potential moose habitat is a function of V_{12}, V_{13} and V_{14}. The suggested function is:

$$(V_{12} \times V_{13} \times V_{14})^{1/3}$$

The rationale behind the Interspersion Value model is based on two principles:

1. that moose will not utilize feeding areas if they are too far away from cover; and
2. all life requisites must be available within an area over which a moose can and does move throughout a normal year. The distances used in this model are based upon <u>estimates</u> of Regelin and Gasaway provided in discussions during May 1980.

VIII. The Habitat Suitability Index (HSI) of a watershed is a function of X_1, X_2, X_3, X_4, X_5 and X_6 where:

X_1 = Spring-Early Summer Food Value
X_2 = Summer-Fall Food Value
X_3 = Winter Range Value
X_4 = Spring-Summer-Fall Cover Value
X_5 = Reproductive Value
X_6 = Interspersiion Value.

The suggested function is:

$$(X_1 \times X_2 \times X_3 \times X_4 \times X_5 \times X_6)^{1/6}$$

The rationale behind the HSI model is that moose will move up and down a valley and over hills and low mountain passes to find seasonal ranges, but if any life requisite is not adequately provided within the potential home range of moose, then the entire watershed will not provide moose habitat. Therefore, the absence or low value of any one life requisite seriously limits the overall habitat suitability.

Appendix 3. Species narrative for moose from Terrestrial Habitat Evaluation Criteria Handbook - Alaska (Konkel 1980).

MOOSE

General

The moose (Alces alces) in Alaska is primarily associated with the upland shrub and lowland bog climax communities, and seral communities created by fire and glacial or fluvial action (LeResche et al. 1974a). The upland shrub communities, usually composed of willow along streamsides and birch in the drier sites, are most important in summer and autumn, although in some areas of light snow accumulation they may be used all year. The lowland bogs, important summer range, are frequently "... an intricate mosaic of black spruce forests, bogs, shrubs, and subclimax hardwood communities as well as numerous intermediate stages" (LeResche et al. 1974a). The glacial and riparian communities, predominately willow, provide key winter range in much of Alaska and are the only consistently occupied habitat on the North Slope and Arctic coastal plain. Fire-created seral range, the most temporary of habitats supporting the greatest population explosions, is usually dominated by birch, willow, aspen, or a combination of these. Although resident populations exist, the moose is predominately migratory, utilizing a combination of these habitats (which may occur distinctly or integrated) depending upon climate, availability, tradition, and seasonal needs. (Habitats used by moose are classified here as freshwater aquatic, herbaceous sedge-grass, tundra, low shrub, tall shrub, grassland, deciduous forest, coniferous forest, and mixed coniferous-deciduous forest).

Food Requirements

Quality and distribution of forage are of primary importance in providing the moose with its nutritional requirements and maintaining the variety that is desirable in the ruminant diet (Sigman and Franzmann 1977, LeResche and Davis 1973). Browse, an important winter staple comprising 75 to 80 percent of the diet on normal winter range, is eaten year-round, although its use declines as herbaceous vegetation becomes more available (LeResche et al. 1974b). Leaves, twigs, and bark are consumed. Moose can browse to a height of 9.8 feet (3 m)., and taller stems may be broken if the DBH is less than 1.6 inches (4 cm) (Wolff 1976).

The most preferred browse species, willow (Salix spp.), is usually eaten out of proportion to its density (Scott et al. 1958, LeResche and Davis 1971). Birch (Betula spp.), apparently the second most palatable species, is utilized heavily in areas where willow is scarce or absent (LeResche et al. 1974b). Aspen (Populus tremuloides), cottonwood (Populus spp.), alder (Alnus spp.), and rarely, spruce (Picea spp.) are selected in varying small amounts (Scott 1958, LeResche 1970). Some low growing species, particularly lowbush cranberry (Vaccinium vitis-idaea) and, in late winter, foliose lichens (Peltegera spp.), may serve as important alternate winter food sources on both normal and depleted range, and are selected even when adequate browse is available (LeResch et al. 1974b). Areas in which deep and persistent snow cover does not limit availability of lowbush cranberry and lichens can support high densities of moose (LeResch and Davis 1973). In early winter when snow depths are less than about 11.8 inches (30 cm), sedges (Carex spp.) are sought out in boggy areas (LeResch et al. 1973).

The highest moose densities in Alaska occur on the northern Kenai Peninsula where fire has created seral range of predominantly paper birch with some willow and aspen and an abundance of available low growing forage in winter (LeResche et al. 1974a). However, there are indications that "... more moose exist on the northern Kenai moose ranges than can be supported in winter by the traditional browse available, and that the balance is easily upset by small variations in other ecological factors such as snow conditions" (Bishop and Rausch 1974). Fair to moderate calf production and apparently slow growth of cows on the Kenai Peninsula as opposed to the Tanana Flats suggest that the security of large moose numbers on birch-dominated seral range is tenuous (Bishop and Rausch 1974).

Summer diet, in addition to the previously mentioned browse species, consists of a variety of terrestrial and aquatic herbaceous plants. Beginning around late May, the newly emergent aquatic and marsh growing plants such as sedges, horsetail (Equisetum spp.), and pondweed (Potomogeton spp.) are consumed in the boggy areas and lakes and ponds in water depths up to shoulder height and sometimes deeper (LeResche and Davis 1973, LeResche 1966). Ritcey and Verbeak (1969) observed two feeding methods in Bowron Lake Park, British Columbia: "Usually moose walked or swam about picking up mouthfuls of floating leaves. Alternately, the head was submerged to just below eye level with leaves, stems, and sometimes roots being eaten." Diving was also observed. Aquatic plants are eaten with decreasing frequency throughout the summer as palatability decreases (Peterson 1955). In midsummer, forbs such as fireweed (Epilobium spp.) and lupine (Lupinus spp.) in the prefloral stage are heavily utilized, and mushrooms are eaten when encountered (LeResche and Davis 1973). The use of browse increases as fall approaches and herbaceous vegetation becomes unpalatable.

Density, height, and relative distribution of forage species affect the intensity with which moose will utilize a particular species and vegetative type. LeResche (1966) observed that moose selected for areas of abundant aquatic vegetation. Milke (1969) concluded that moderately preferred browse species were used more when occurring with highly preferred species than when occurring in pure stands, that tall shrubs seemed to be browsed to a greater degree than short plants, and that individual plant species were usually browsed more intensely where total plant density was highest than where plant density was lowest. Apparently when available browse is reduced below a critical density, moose will move on to a different area (Wolff 1976). Spencer and Hakala (1964) felt that a mixed type of browse stand was of much greater forage value than a pure stand of a moderately palatable species. In summer, the forbs which are most heavily utilized are also the most abundant (LeResche et al. 1973).

Water Requirements

Marshy areas are necessary for production of aquatic vegetation and are a key component of high quality calving habitat. Deep water can also provide relief from annoying insects.

Cover Requirements

Cover is used by moose for resting, traveling, and hiding, and varies seasonally in relation to feeding habitat, snow cover, and reproduction. In summer, moose frequently feed in open areas and utilize the bordering shrub and forest areas for cover. LeResche (1966) observed that moose bedded down within 3.3 feet (1 m) of the edge of willow or spruce islands, seeking out drier areas between hummocks, and only occasionally bedding in the open meadows. Calves frequently remained bedded down in brush or high grass while cows usually fed within a 32.8 to 43.7 yard (30-40 m) radius. LeResche (1966) observed that traveling moose made maximum use of concealing timber fingers and also moved along the edge of spruce and willow islands and fingers where the vegetation provided cover and disruptive background coloration. Deciduous stands were used more heavily by males while cows with calves preferred the areas of dense shrub growth. Stringham (1974), noting a tendency of young to avoid open areas, reported "... although it may normally accompany its mother when she is browsing and grazing, an infant typically remains on shore in cover while she is feeding in a lake."

Winter cover needs are generally determined by the influence of climate on food availability and mobility. Mature forest stands with dense canopy provide cover for escape and from deep snow, especially in late winter (LeResche et al. 1973, Coady 1976).

Reproductive Requirements

Wet, marshy lowlands consisting of open areas interspersed with dense stands of shrubs and trees are usually used as calving grounds by moose. Rausch (1967) summarized "... concentrations of parturient cows have been found only in association with wet marshy areas representing tidal flats, bogs created by fire and subsequent slumping and thawing of permafrost areas, flooding by beavers, lowland areas associated with major rivers, and shallow partially filled lakes. All of the calving centers examined to date can be characterized as having openings with abundant early spring forage including horsetail (Equisetum spp.) sedges (Carex spp.), and aquatic vegetation. Almost without exception, the areas are interspersed with 'islands', elevated areas with better drainage that have a dense cover of trees or shrubs 10 to 60 feet (3 - 18.3 m) tall. Most cows give birth on these 'islands'." Scott et al. (1958) noted that these marshy areas were frequently covered with 8 to 20 inches (19.5 - 48.8 cm) of water in the spring and that births occasionally occurred on drier sites in adjacent hillsides. Calves are usually kept in the seclusion of dense cover for a short period after birth (Peterson 1955).

The small amount of information found on breeding habitat indicates that, during the rut, a wide variety of habitats may be used. On the northern Kenai Peninsula, breeding groups of moose may concentrate in the riparian habitats of specific drainages (Didrickson et al. 1977, LeResche and Davis 1971). Lent (1974) reported observations of groups in or on the fringes of small clearings or bogs on the Kenai and frequently at or above timberline in the Alaska Range.

Special Habitat Requirements

Winter range is a critical habitat for moose and is often limited by snowfall, which can decrease food availability and restrict mobility. Coady (1973) found that snow depths of up to 16.4 inches (40 cm) (carpus or tarsus height) causes little or no hindrance to movement; movement becomes slightly restricted at snow depths of 16.4 to 28.7 inches (40 - 70 cm) (2/3 chest height), movement is definitely impeded at depths greater than 28.7 inches (70 cm), and, at depths greater than 36.9 inches (90 cm) (equal to or less than chest height), movement is restricted to where adequate food intake may be impossible. Mortality of calves is known to increase substantially with increasing snow depth

(Sigman and Franzmann 1977, Johnson et al. 1973). Highway and railroad mortality also increase in winter when moose are attracted to the plowed openings (Atwell et al. 1963, Coady 1973).

Moose generally prefer the more open shrub-dominated areas and sedge meadows in early winter when snow depth is minimal, shifting in late winter to closed canopy coniferous and deciduous habitats where snow accumulation is less, and ground vegetation more visible than in the shrub and open meadow habitats (Coady 1976, Gassaway 1977, LeResche et al. 1973). Kelsall and Telfer (1974) reported: "Moose can occupy regions having deep snow if there is also abundant food, but they cannot if food is so scattered that the laborious process of wading through snow to get to it results in deficit energy balance." Downed trees and dense lower branches of new growth conifers shield the understory foods from deep snow (LeResche et al. 1973).

Interspersion Requirements

Moose habitat consisting of a mixture of vegetative types can provide cover habitat close to feeding habitat, a variety of alternate food species, and staggered maturation rates of individual stands (LeResche et al. 1973). Optimally interspersed habitat will supply all requirements within a minimum area. Frequently the value of a habitat depends on the proximity to other habitat types. The taiga, normally supporting only low densities of moose, is important when bordering riparian or upland shrub habitats or interspersed with seral fire-created communities, providing cover and some food for moose utilizing more preferred habitats (LeResche et al. 1974a). Apparently, mature forest edge will hasten establishment of moose in a new burn (LeResche et al. 1974a). LeResche et al. (1973) found that total edge in a 635 acre (254 ha) area supporting high densities of moose was 70 miles (112 km). The majority of stands were 1.25 acres (0.5 ha). Optimum calving habitat is highly interspersed with cover areas.

Home range size for moose is variable. LeResche (1974) summarized: "Seasonal home ranges are consistently small throughout North America. Casual observations and formal studies all have concluded that regardless of how far moose habitually move between seasons, home range during a given season seldom exceeds 5 - 10 km^2. This is true in areas where moose migrate and where they are primarily sedentary; and in all habitats studied."

Special Considerations

The majority of moose are migratory and show traditional preferences for migratory routes and winter and summer ranges. Barriers or elimination of traditional ranges could be disastrous to moose (LeResche and Davis 1971). "When lands are designated for special uses ... it is essential to understand seasonal movement patterns of all segments of the group in question. Without such understanding, critical (e.g. winter range, calving areas) outside the designated area might be destroyed, thereby affecting any moose from the 'protected' area that might use them seasonally .... Misuse of a very small critical seasonal range for only a month each year could result in serious interference in the life cycle of thousands of moose over a vast area .... Where migrations do occur, managers must realize that free movement is of major importance to healthy moose populations." (LeResche et al. 1974a).

Moose often serve as prey to carnivorous mammals, particularly wolves and brown bear. This can be a limiting factor in some areas. Coady (1976) noted that a ratio of one wolf to 15 moose was higher than a moose population could handle.

Fire can improve moose habitat by retarding succession and increasing the degree of interspersion (Spencer and Hakala 1964, LeResche et al. 1973). "The optimum amount of edge and/or the optimum size and shape of individual burned stands in Alaska is difficult to determine because moose densities depend upon so many variables" (LeResche et al. 1974a). Maximum benefits to moose are produced by successional courses involving birch-willow-aspen shrub thickets with a high proportion of willow (LeResche et al. 1973).

Discussion

The majority of moose studies have been conducted in southcentral and interior Alaska, while the southeastern portion, the Alaska Peninsula, and the area north of the Arctic Circle have been dealt with very little. Although considerable information was available, much of it could not be translated into quantitative habitat evaluation criteria. It was also difficult to apply these criteria to individual habitat types in view of the numerous and highly interspersed habitats used by moose and the inconsistencies in habitat classification by various authors. Many histograms in this species analysis are labeled in considerable detail in an attempt to adequately evaluate the interspersion relationships. The Interspersion Value should reflect the capability of a highly mixed habitat to provide all requirements. Thus a habitat with a high Interspersion Value providing a good mixture of both food and cover may have moderate individual Food and Cover Values; an area with a high Cover

Value might not provide adequate food and vice versa, but the mixture of vegetative types providing both food and cover results in more suitable habitat than a uniform type providing only one life requisite. In cases such as this, it may not be desirable to designate the lowest X_n value as the Habitat Suitability Index. It is not meant to imply here that a uniform habitat cannot provide both good food and cover or that only highly interspersed habitats should have a high Habitat Suitability Index; rather it is hoped that the means is provided to realistically evaluate two different situations (uniform and interspersed habitats) which in their best conditions, may both fulfill the habitat requirements of moose. It is felt that this approach allows the flexibility to determine which situation is applicable and to select the appropriate X_n value as the Habitat Suitability Index.

In some cases, the inter-relationship between the parameters presented a problem. For example, Cover Value in grasslands is derived from height of grass and interspersion with cover areas. In areas highly interspersed with cover, it may make little difference how tall the grass is; however, as the amount of interspersed cover decreases, the importance of tall grass as cover would probably increase. Thus, there is a possibility that, in some situations when conditions are optimum, a specific parameter may not be a limiting factor while, in other cases when conditions are marginal, that same parameter may become a limiting factor. In this particular instance regarding grassland habitats, it was decided that short grass should be given a fairly high value and the interspersion factor should be considered the main influence in deriving cover suitability. In cases where the Suitability Index of amount of interspersed cover is greater than 0.8, only this parameter should be used to determine Cover Value. It is felt that this will prevent the grass height parameter from unrealistically lowering the Cover Value when highly interspersed cover is present.

Although the literature indicated that tundra habitats are used by moose, either little information was found on use of specific types or it could not be determined how the types that were mentioned fit in with the habitat classification scheme adopted for HEP; therefore, curves for tundra were difficult to develop. Criteria for evaluating shrub tundra are nearly identical to those used for shrublands; since the separation between habitats is often difficult to define other than by geographic differences, this approach seems valid. Mat and cushion tundra is evaluated on the basis of occurrence of willow for food. The value of the remaining tundra habitats - sedge-grass, herbaceous, and tussock - is determined by considering the availability of willow stands utilized by moose for most of the year in the tundra areas; apparently open tundras which occur far from the sustaining willow habitat are rarely if ever used. No tundra, even in its best condition, is considered optimum habitat.

Overall, a fair amount of information exists on preferred browse species, general characteristics of calving areas, and effects of snow depth. There is also much information to support the high value of interspersed habitats. However, the value that should be placed on preferred habitats when stability is considered remains uncertain; i.e., should small communities capable of supporting high densities of moose for only a limited period of time be considered high quality habitat as opposed to stable climax shrub communities which support lower densities?

KEB

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Appendix 4. Mean team HSI values and F-values from one-way ANOVA and Discriminant Function Analysis among team HSIs for the multiplicative mean caribou model by habitat type. The standard errors of the mean HSIs are in parentheses. The degrees of freedom for the ANOVA and discriminant analysis are 2,15. All life requisites are included. A dash indicates the life requisite did not apply in that habitat type.

		ONE-WAY ANOVA				DISCRIMINANT ANALYSIS
		FOOD VALUE (SPRING/ SUMMER/FALL)		WINTER RANGE VALUE		ALL LIFE REQUISITES
HABITAT TYPE	TEAM	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MULTIVARIATE F-VALUE
CONIFEROUS FOREST	1	-		.000(.000)		
	2	-	-	.000(.000)	.000	test not possible
	3	-		.000(.000)		
LOW SHRUB	1	1.00(.000)		.000(.000)		
	2	1.00(.000)	.000	.000(.000)	.000	.000
	3	1.00(.000)		.000(.000)		
MAT AND CUSHION TUNDRA	1	.200(.000)		.233(.059)		
	2	.200(.000)	.000	.183(.002)	1.32	1.32
	3	.200(.000)		.267(.023)		

Appendix 5. Mean absolute differences between team HSI values for the multiplicative mean caribou model by habitat type. The standard errors of the mean differences are in parentheses. All life requisites are included. A dash indicates the life requisite did not apply in that habitat type.

HABITAT TYPE	TEAMS COMPARED	FOOD VALUE (SPRING/ SUMMER/FALL)	WINTER RANGE VALUE	AVERAGE FOR ALL LIFE REQUISITES
CONIFEROUS FOREST	1 and 2	-	.000(.000)	.000(.000)
	1 and 3	-	.000(.000)	.000(.000)
	2 and 3	-	.000(.000)	.000(.000)
LOW SHRUB	1 and 2	.000(.000)	.000(.000)	.000(.000)
	1 and 3	.000(.000)	.000(.000)	.000(.000)
	2 and 3	.000(.000)	.000(.000)	.000(.000)
MAT AND CUSHION TUNDRA	1 and 2	.000(.000)	.110*(.039)	.055(.020)
	1 and 3	.000(.000)	.110*(.039)	.055(.020)
	2 and 3	.000(.000)	.083(.022)	.042(.011)

* The mean absolute difference exceeded the .100 level of acceptability.

Appendix 6. Mean team HSI values and F-values from one-way ANOVA and Discriminant Function Analysis among team HSIs for the geometric mean caribou model by habitat type. The standard errors of the mean HSIs are in parentheses. The degrees of freedom for the ANOVA and discriminant analysis are 2,15. All life requisites are included. A dash indicates the life requisite did not apply in that habitat type.

		ONE-WAY ANOVA				DISCRIMINANT ANALYSIS
		FOOD VALUE (SPRING/ SUMMER/FALL)		WINTER RANGE VALUE		ALL LIFE REQUISITES
HABITAT TYPE	TEAM	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MULTIVARIATE F-VALUE
CONIFEROUS FOREST	1	-	-	.000(.000)	.000	test not possible
	2	-		.000(.000)		
	3	-		.000(.000)		
LOW SHRUB	1	1.00(.000)	.000	.000(.000)	.000	.000
	2	1.00(.000)		.000(.000)		
	3	1.00(.000)		.000(.000)		
MAT AND CUSHION TUNDRA	1	.200(.000)	.000	.772(.020)	5.37[a]	5.37*
	2	.200(.000)		.712(.002)		
	3	.200(.000)		.763(.014)		

* The F-value exceeded the critical value at $p \leq .05$.

[a] Mean HSI of team two differed significantly ($p \leq .05$) from mean HSIs of teams one and three.

Appendix 7. Mean absolute differences between team HSI values for the geometric mean caribou model by habitat type. The standard errors of the mean differences are in parentheses. All life requisites are included. A dash indicates the life requisite did not apply in that habitat type.

HABITAT TYPE	TEAMS COMPARED	FOOD VALUE (SPRING/ SUMMER/FALL)	WINTER RANGE VALUE	AVERAGE FOR ALL LIFE REQUISITES
CONIFEROUS FOREST	1 and 2	-	.000(.000)	.000(.000)
	1 and 3	-	.000(.000)	.000(.000)
	2 and 3	-	.000(.000)	.000(.000)
LOW SHRUB	1 and 2	.000(.000)	.000(.000)	.000(.000)
	1 and 3	.000(.000)	.000(.000)	.000(.000)
	2 and 3	.000(.000)	.000(.000)	.000(.000)
MAT AND CUSHION TUNDRA	1 and 2	.000(.000)	.060(.020)	.030(.010)
	1 and 3	.000(.000)	.055(.019)	.028(.010)
	2 and 3	.000(.000)	.052(.013)	.026(.006)

Appendix 8. Mean team HSI values and F-values from one-way ANOVA and Discriminant Function Analysis among team HSIs for the multiplicative mean beaver model by habitat type. The standard errors of the mean HSIs are in parentheses. The degrees of freedom for the ANOVA and discriminant analysis are 2,15. All life requisites are included.

		ONE-WAY ANOVA								DISCRIMINANT ANALYSIS
		FOOD VALUE		LENTIC WATER VALUE		LOTIC WATER POTENTIAL VALUE		BEHAVIORAL VALUE		ALL LIFE REQUISITES
HABITAT TYPE	TEAM	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MULTIVARIATE F-VALUE
FRESHWATER AQUATIC	1	.535(.081)		.700(.190)		.450(.136)		.500(.224)		
	2	.560(.063)	.055	.550(.201)	.203	.297(.091)	.881	.500(.224)	.000	1.31
	3	.527(.076)		.540(.206)		.260(.088)		.500(.224)		

Appendix 9. Mean absolute differences between team HSI values for the multiplicative mean beaver model by habitat type. The standard errors of the mean differences are in parentheses. All life requisites are included.

HABITAT TYPE	TEAMS COMPARED	FOOD VALUE	LENTIC WATER VALUE	LOTIC WATER POTENTIAL VALUE	BEHAVIORAL VALUE	AVERAGE FOR ALL LIFE REQUISITES
FRESHWATER AQUATIC	1 and 2	.042(.012)	.150*(.149)	.153*(.149)	.000(.000)	.086(.078)
	1 and 3	.008(.005)	.160*(.148)	.190*(.148)	.000(.000)	.090(.075)
	2 and 3	.033(.015)	.010(.010)	.040(.024)	.000(.000)	.021(.012)

* The mean absolute difference exceeded the .100 level of acceptability.

Appendix 10. Mean team HSI values and F-values from one-way ANOVA and Discriminant Function Analysis among team HSIs for the geometric mean beaver model by habitat type. The standard errors of the mean HSIs are in parentheses. The degrees of freedom for the ANOVA and discriminant analysis are 2,15. All life requisites are included.

		ONE-WAY ANOVA								DISCRIMINANT ANALYSIS
		FOOD VALUE		LENTIC WATER VALUE		LOTIC WATER POTENTIAL VALUE		BEHAVIORAL VALUE		ALL LIFE REQUISITES
HABITAT TYPE	TEAM	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MULTIVARIATE F-VALUE
FRESHWATER AQUATIC	1	.798(.043)	.112	.820(.114)	.231	.877(.042)	.675	.500(.224)	.000	2.08
	2	.820(.031)		.730(.121)		.832(.040)		.500(.224)		
	3	.797(.042)		.710(.131)		.807(.048)		.500(.224)		

Appendix 11. Mean absolute differences between team HSI values for the geometric mean beaver model by habitat type. The standard errors of the mean differences are in parentheses. All life requisites are included.

HABITAT TYPE	TEAMS COMPARED	FOOD VALUE	LENTIC WATER VALUE	LOTIC WATER POTENTIAL VALUE	BEHAVIORAL VALUE	AVERAGE FOR ALL LIFE REQUISITES
FRESHWATER AQUATIC	1 and 2	.025(.010)	.090(.090)	.045(.041)	.000(.000)	.040(.035)
	1 and 3	.002(.002)	.110*(.088)	.070(.044)	.000(.000)	.046(.034)
	2 and 3	.023(.011)	.020(.020)	.028(.016)	.000(.000)	.018(.012)

* The mean absolute difference exceeded the .100 level of acceptability.

Appendix 12. Mean team HSI values and F-values from one-way ANOVA and Discriminant Function Analysis among team HSIs for the multiplicative mean spruce grouse model by habitat type. The standard errors of the mean HSIs are in parentheses. The degrees of freedom for the ANOVA are 2,15 and for the discriminant analysis are 8,24. All life requisites are included.

		ONE-WAY ANOVA								DISCRIMINANT ANALYSIS
		FOOD VALUE (SPRING/ SUMMER/FALL)		COVER VALUE		REPRODUCTIVE VALUE		WINTER RANGE VALUE		ALL LIFE REQUISITES
HABITAT TYPE	TEAM	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MULTIVARIATE F-VALUE
CONIFEROUS FOREST	1	.095(.048)		.252(.029)		.548(.024)		.497(.059)		
	2	.142(.085)	.754	.243(.024)	.085	.773(.038)	11.4[a]	.475(.052)	.053	2.58*
	3	.268(.150)		.233(.039)		.600(.041)		.497(.051)		
MIXED FOREST	1	.698(.025)		.628(.034)		.893(.017)		.993(.005)		
	2	.672(.022)	.497	.655(.075)	1.90	.772(.067)	1.22	.907(.091)	1.17	1.17
	3	.675(.013)		.493(.071)		.860(.070)		.812(.113)		

* The F-value exceeded the critical value at $p \leq .05$.

[a] Mean HSI of team two differed significantly ($p \leq .05$) from mean HSIs of teams one and three.

Appendix 13. Mean absolute differences between team HSI values for the multiplicative mean spruce grouse model by habitat type. The standard errors of the mean differences are in parentheses. All life requisites are included.

HABITAT TYPE	TEAMS COMPARED	FOOD VALUE (SPRING/ SUMMER/FALL)	COVER VALUE	REPRODUCTIVE VALUE	WINTER RANGE VALUE	AVERAGE FOR ALL LIFE REQUISITES
CONIFEROUS FOREST	1 and 2	.063(.035)	.012(.005)	.225*(.045)	.028(.008)	.082(.023)
	1 and 3	.173*(.104)	.032(.021)	.125*(.027)	.017(.005)	.087(.039)
	2 and 3	.127*(.068)	.033(.018)	.183*(.035)	.022(.007)	.091(.032)
MIXED FOREST	1 and 2	.033(.009)	.083(.034)	.152*(.064)	.090(.086)	.090(.048)
	1 and 3	.030(.017)	.152*(.061)	.127*(.038)	.182*(.112)	.123*(.057)
	2 and 3	.023(.007)	.182*(.067)	.175*(.046)	.165*(.108)	.136*(.057)

* The mean absolute difference exceeded the .100 level of acceptability.

Appendix 14. Mean team HSI values and F-values from one-way ANOVA and Discriminant Function Anlysis among team HSIs for the geometric mean spruce grouse model by habitat type. The standard errors of the mean HSIs are in parentheses. The degrees of freedom for the ANOVA are 2,15 and for the discriminant analysis are 8,24. All life requisites are included.

		ONE-WAY ANOVA								DISCRIMINANT ANALYSIS
		FOOD VALUE (SPRING/ SUMMER/FALL)		COVER VALUE		REPRODUCTIVE VALUE		WINTER RANGE VALUE		ALL LIFE REQUISITES
HABITAT TYPE	TEAM	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MULTIVARIATE F-VALUE
CONIFEROUS FOREST	1	.095(.048)		.757(.016)		.818(.011)		.787(.031)		
	2	.142(.085)	.717	.752(.014)	.198	.915(.014)	10.9[a]	.777(.027)	.043	2.55*
	3	.265(.151)		.738(.030)		.842(.019)		.787(.026)		
MIXED FOREST	1	.698(.025)		.927(.007)		.963(.006)		.995(.003)		
	2	.672(.022)	.497	.928(.018)	2.09	.913(.028)	1.20	.945(.055)	1.10	1.56
	3	.675(.013)		.880(.027)		.945(.028)		.887(.071)		

* The F-value exceeded the critical value at $p \leq .05$.

[a] Mean HSI of team two differed significantly ($p \leq .05$) from the mean HSIs of teams one and three.

Appendix 15. Mean absolute differences between team HSI values for the geometric mean spruce grouse model by habitat type. The standard errors of the mean differences are in parentheses. All life requisites are included.

HABITAT TYPE	TEAMS COMPARED	FOOD VALUE SPRING/ SUMMER/FALL)	COVER VALUE	REPRODUCTIVE VALUE	WINTER RANGE VALUE	AVERAGE FOR ALL LIFE REQUISITES
CONIFEROUS FOREST	1 and 2	.063(.035)	.005(.002)	.097(.019)	.013(.004)	.044(.015)
	1 and 3	.177*(.102)	.028(.021)	.060(.012)	.010(.003)	.069(.034)
	2 and 3	.123*(.069)	.027(.019)	.077(.016)	.010(.004)	.059(.027)
MIXED FOREST	1 and 2	.033(.009)	.022(.010)	.060(.028)	.053(.051)	.042(.024)
	1 and 3	.030(.017)	.050(.024)	.048(.017)	.108*(.070)	.059(.032)
	2 and 3	.023(.007)	.052(.024)	.065(.021)	.102*(.069)	.060(.030)

* The mean absolute difference exceeded the .100 level of acceptability.

Appendix 16. Mean team HSI values and F-values from one-way ANOVA and Discriminant Function Analysis among team HSIs for the multiplicative mean common redpoll model by habitat type. The standard errors of the mean HSIs are in parentheses. The degrees of freedom for the ANOVA are 2,15 and for the discriminant analysis are 8,24. All life requisites are included. A dash indicates the life requisite did not apply in that habitat type.

		ONE-WAY ANOVA										DISCRIMINANT ANALYSIS
		FOOD VALUE		FOOD VALUE (SPRING/ SUMMER/FALL)		COVER VALUE		REPRODUCTIVE VALUE		WINTER RANGE VALUE		ALL LIFE REQUISITES
HABITAT TYPE	TEAM	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MULTIVARIATE F-VALUE
CONIFEROUS FOREST	1	-		.173(.020)		1.00(.000)		.230(.028)		.223(.026)		
	2	-	-	.180(.025)	.102	.995(.003)	.682	.220(.032)	1.62	.233(.031)	.110	.791
	3	-		.188(.025)		.995(.005)		.297(.038)		.243(.034)		
DECIDUOUS FOREST	1	-		.448(.072)		.873(.018)		.275(.004)		.477(.076)		
	2	-	-	.528(.043)	.478	.907(.024)	1.45	.273(.005)	2.57	.552(.024)	.454	.827
	3	-		.512 (.064)		.922(.018)		.288(.006)		.525(.057)		
MIXED FOREST	1	-		.497(.034)		.955(.014)		.335(.038)		.545(.048)		
	2	-	-	.435(.074)	.923	.910(.037)	2.30	.362(.018)	1.01	.487(.072)	1.52	1.11
	3	-		.378(.069)		.982(.012)		.407(.069)		.390(.068)		
LOW SHRUB	1	1.00(.000)		.855(.066)		.765(.025)		.973(.014)		-		
	2	.937(.022)	8.06[a]	.590(.014)	9.35[a]	.685(.016)	2.93	.935(.023)	9.83[b]	-	-	12.3*
	3	1.00(.000)		.717(.033)		.695(.032)		.865(.014)		-		

* The F-value exceeded the critical value at $p \leq .05$.

[a] The mean HSI of team two differed significantly ($p \leq .05$) from the mean HSIs of teams one and three.

[b] The mean HSI of team three differed significantly ($p \leq .05$) from the mean HSIs of teams one and two.

Appendix 17. Mean absolute differences between team HSI values for the multiplicative mean common redpoll model by habitat type. The standard errors of the mean differences are in parentheses. All life requisites are included. A dash indicates the life requisite did not apply in that habitat type.

HABITAT TYPE	TEAMS COMPARED	FOOD VALUE	FOOD VALUE (SPRING/ SUMMER/FALL)	COVER VALUE	REPRODUCTIVE VALUE	WINTER RANGE VALUE	AVERAGE FOR ALL LIFE REQUISITES
CONIFEROUS FOREST	1 and 2	-	.023(.011)	.005(.003)	.040(.018)	.037(.014)	.026(.012)
	1 and 3	-	.065(.024)	.005(.005)	.067(.013)	.090(.027)	.057(.017)
	2 and 3	-	.065(.021)	.010(.005)	.077(.031)	.090(.026)	.060(.021)
DECIDUOUS FOREST	1 and 2	-	.087(.053)	.077(.014)	.002(.002)	.122*(.045)	.072(.028)
	1 and 3	-	.077(.063)	.048(.009)	.013(.004)	.085(.059)	.056(.034)
	2 and 3	-	.040(.018)	.058(.018)	.015(.003)	.063(.024)	.044(.016)
MIXED FOREST	1 and 2	-	.132*(.040)	.065(.026)	.045(.074)	.158*(.041)	.064(.045)
	1 and 3	-	.135*(.032)	.027(.007)	.031(.062)	.155*(.026)	.087(.032)
	2 and 3	-	.160*(.056)	.075(.035)	.081(.057)	.163*(.071)	.120*(.055)
LOW SHRUB	1 and 2	.063(.022)	.265*(.063)	.080(.019)	.042(.019)	-	.112*(.031)
	1 and 3	.000(.000)	.195*(.043)	.070(.024)	.108*(.013)	-	.093(.020)
	2 and 3	.063(.022)	.127*(.029)	.067(.021)	.070(.020)	-	.082(.023)

* The mean absolute difference exceeded the .100 level of acceptability.

Appendix 18. Mean team HSI values and F-values from one-way ANOVA and Discriminant Function Analysis among team HSIs for the geometric mean common redpoll model by habitat type. The standard errors of the mean HSIs are in parentheses. The degrees of freedom for the ANOVA are 2,15 and for the discriminant analysis are 8,24. All life requisites are included. A dash indicates the life requisite did not apply in that habitat type.

		ONE-WAY ANOVA										DISCRIMINANT ANALYSIS
		FOOD VALUE		FOOD VALUE (SPRING/ SUMMER/FALL)		COVER VALUE		REPRODUCTIVE VALUE		WINTER RANGE VALUE		ALL LIFE REQUISITES
HABITAT TYPE	TEAM	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MEAN HSI	F-VALUE	MULTIVARIATE P-VALUE
CONIFEROUS FOREST	1	-		.415(.025)		1.00(.000)		.688(.023)		.468(.026)		
	2	-	-	.418(.028)	.083	.995(.003)	.682	.682(.022)	1.48	.478(.030)	.108	.716
	3	-		.430(.029)		.995(.005)		.733(.025)		.488(.034)		
DECIDUOUS FOREST	1	-		.660(.057)		.873(.018)		.727(.003)		.678(.057)		
	2	-	-	.723(.032)	.498	.907(.024)	1.45	.727(.003)	1.11	.742(.017)	.580	1.15
	3	-		.708(.049)		.922(.018)		.733(.004)		.720(.043)		
MIXED FOREST	1	-		.703(.023)		.955(.014)		.762(.008)		.733(.032)		
	2	-	-	.652(.055)	1.12	.910(.037)	2.30	.775(.011)	.554	.692(.050)	1.80	1.21
	3	-		.605(.054)		.982(.012)		.790(.030)		.612(.054)		
LOW SHRUB	1	1.00(.000)		.920(.036)		.765(.025)		.985(.008)		-		
	2	.937(.022)	8.06[a]	.768(.009)	9.99[b]	.685(.016)	2.90	.967(.012)	9.19[c]	-	-	11.9*
	3	1.00(.000)		.845(.018)		.697(.032)		.930(.007)		-		

* The F-value exceeded the critical value at $p \leq .05$.

[a] The mean HSI of team two differed significantly ($p \leq .05$) from the mean HSIs of teams one and three.

[b] The mean HSIs of all teams differed significantly ($p \leq .05$).

[c] The mean HSI of team three differed significantly ($p \leq .05$) from the mean HSIs of teams one and two.

Appendix 19. Mean absolute differences between team HSI values for the geometric mean common redpoll model by habitat type. The standard errors of the mean differences are in parentheses. All life requisites are included. A dash indicates the life requisite did not apply in that habitat type.

HABITAT TYPE	TEAMS COMPARED	FOOD VALUE	FOOD VALUE (SPRING/ SUMMER/FALL)	COVER VALUE	REPRODUCTIVE VALUE	WINTER RANGE VALUE	AVERAGE FOR ALL LIFE REQUISITES
CONIFEROUS FOREST	1 and 2	-	.023(.011)	.005(.003)	.027(.011)	.030(.012)	.021(.009)
	1 and 3	-	.078(.027)	.005(.005)	.045(.006)	.093(.028)	.055(.016)
	2 and 3	-	.075(.024)	.010(.005)	.052(.020)	.090(.027)	.057(.019)
DECIDUOUS FOREST	1 and 2	-	.070(.042)	.077(.014)	.000(.000)	.090(.037)	.059(.023)
	1 and 3	-	.065(.049)	.048(.009)	.007(.003)	.062(.048)	.046(.027)
	2 and 3	-	.032(.016)	.058).018)	.007(.003)	.048(.019)	.036(.014)
MIXED FOREST	1 and 2	-	.102*(.030)	.065(.026)	.020(.007)	.108*(.027)	.074(.022)
	1 and 3	-	.112*(.028)	.027(.007)	.035(.029)	.122*(.025)	.074(.022)
	2 and 3	-	.130*(.042)	.075(.035)	.035(.022)	.127*(.052)	.092(.038)
LOW SHRUB	1 and 2	.063(.022)	.152*(.035)	.080(.019)	.022(.010)	-	.079(.022)
	1 and 3	.000(.000)	.105*(.024)	.068(.024)	.055(.007)	-	.057(.014)
	2 and 3	.063(.022)	.077(.016)	.068(.020)	.037(.010)	-	.061(.017)

* The mean absolute difference exceeded the .100 level of acceptability.

Appendix 20. Mean team HSI values and species expert ratings, F-values from one-way ANOVA among team and expert scores, and mean absolute differences between team and expert scores for the multiplicative mean caribou model by habitat type. The standard errors of the mean habitat scores and mean absolute differences are in parentheses. The ANOVA degrees of freedom are in brackets. Only the limiting factor life requisites are included. A dash indicates the limiting factor did not apply in that habitat type.

	NON-WINTER LIMITING FACTOR					WINTER LIMITING FACTOR				
HABITAT TYPE	GROUP	MEAN HABITAT SCORE	F-VALUE	GROUPS COMPARED	MEAN ABSOLUTE DIFFERENCE	GROUP	MEAN HABITAT SCORE	F-VALUE	GROUPS COMPARED	MEAN ABSOLUTE DIFFERENCE
CONIFEROUS FOREST (1979)	Team 1	-	-	Team 1 and Expert	-	Team 1	.000(.000)	30.0[a] 4,25	Team 1 and Expert	.200*(.037)
	Team 2	-		Team 2 and Expert	-	Team 2	.000(.000)		Team 2 and Expert	.200*(.037)
	Team 3	-		Team 3 and Expert	-	Team 3	.000(.000)		Team 3 and Expert	.200*(.037)
	Team Avg	-		Team Avg and Expert	-	Team Avg	.000(.000)		Team Avg and Expert	.200*(.037)
	Expert	-			-	Expert	.200(.037)			
MAT AND CUSHION TUNDRA (1979)	Team 1	.200(.000)	405.[a] [4,25]	Team 1 and Expert	.450*(.022)	Team 1	.233(.059)	70.9[a] [4,25]	Team 1 and Expert	.550*(.065)
	Team 2	.200(.000)		Team 2 and Expert	.450*(.022)	Team 2	.183(.002)		Team 2 and Expert	.600*(.018)
	Team 3	.200(.000)		Team 3 and Expert	.450*(.022)	Team 3	.267(.023)		Team 3 and Expert	.516*(.033)
	Team Avg	.200(.000)		Team Avg and Expert	.450*(.022)	Team Avg	.245(.008)		Team Avg and Expert	.538*(.023)
	Expert	.650(.022)				Expert	.783(.017)			
MAT AND CUSHION TUNDRA (1980)	Team	.200(.000)	21.9[b] [3,28]	Team and Expert 1	.412*(.040)	Team	.279(.015)	50.0[c] [3,28]	Team and Expert 1	.396*(.027)
	Expert 1	.612(.040)		Team and Expert 2	.106*(.050)	Expert 1	.675(.031)		Team and Expert 2	.359*(.025)
	Expert 2	.306(.050)		Team and Expert Avg	.259*(.042)	Expert 2	.637(.028)		Team and Expert Avg	.402*(.030)
	Expert Avg	.459(.042)				Expert Avg	.681(.089)			

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[*] The mean absolute difference exceeded the .100 level of acceptability.

[a] All mean team HSI values differed significantly ($p \leq .05$) from the mean expert rating.

[b] The mean team HSI value differed significantly ($p \leq .05$) from the mean ratings of Expert 1 and Expert Avg.

[c] The mean team HSI value differed significantly ($p \leq .05$) from all mean expert ratings.

Appendix 21. Mean team HSI values and species expert ratings, F-values from one-way ANOVA among team and expert scores, and mean absolute differences between team and expert scores for the geometric mean caribou model by habitat type. The standard errors of the mean habitat scores and mean absolute differences are in parentheses. The ANOVA degrees of freedom are in brackets. Only the limiting factor life requisites are included. A dash indicates the limiting factor did not apply in that habitat type.

	NON-WINTER LIMITING FACTOR					WINTER LIMITING FACTOR				
HABITAT TYPE	GROUP	MEAN HABITAT SCORE	F-VALUE	GROUPS COMPARED	MEAN ABSOLUTE DIFFERENCE	GROUP	MEAN HABITAT SCORE	F-VALUE	GROUPS COMPARED	MEAN ABSOLUTE DIFFERENCE
CONIFEROUS FOREST (1979)	Team 1	-	-	Team 1 and Expert	-	Team 1	.000(.000)	30.0[a] [4,25]	Team 1 and Expert	.200*(.037)
	Team 2	-		Team 2 and Expert	-	Team 2	.000(.000)		Team 2 and Expert	.200*(.037)
	Team 3	-		Team 3 and Expert	-	Team 3	.000(.000)		Team 3 and Expert	.200*(.037)
	Team Avg	-		Team Avg and Expert	-	Team Avg	.000(.000)		Team Avg and Expert	.200*(.037)
	Expert	-			-	Expert	.200(.037)			
MAT AND CUSHION TUNDRA (1979)	Team 1	.200(.000)	405.[a] [4,25]	Team 1 and Expert	.450*(.022)	Team 1	.772(.020)	4.22[b] [4,25]	Team 1 and Expert	.055 (.015)
	Team 2	.200(.000)		Team 2 and Expert	.450*(.022)	Team 2	.712(.002)		Team 2 and Expert	.078 (.017)
	Team 3	.200(.000)		Team 3 and Expert	.450*(.022)	Team 3	.763(.014)		Team 3 and Expert	.050 (.015)
	Team Avg	.200(.000)		Team Avg and Expert	.450*(.022)	Team Avg	.752(.005)		Team Avg and Expert	.055 (.005)
	Expert	.650(.022)				Expert	.783(.017)			
MAT AND CUSHION TUNDRA (1980)	Team	.200(.000)	21.9[c] [3,28]	Team and Expert 1	.412*(.040)	Team	.770(.009)	4.39[d] [3,28]	Team and Expert 1	.095 (.030)
	Expert 1	.612(.040)		Team and Expert 2	.106*(.050)	Expert 1	.675(.031)		Team and Expert 2	.132*(.025)
	Expert 2	.306(.050)		Team and Expert Avg	.259*(.042)	Expert 2	.637(.028)		Team and Expert Avg	.114*(.029)
	Expert Avg	.459(.042)				Expert Avg	.681(.089)			

[*] The mean absolute difference exceeded the .100 level of acceptability.

[a] All mean team HSI values differed significantly ($p < .05$) from the mean expert rating.

[b] The mean HSI value of team two differed significantly ($p < .05$) from the mean rating.

[c] The mean team HSI value differed significantly ($p < .05$) from the mean ratings of Expert 1 and Expert Avg.

[d] The mean team HSI value differed significantly ($p < .05$) from all mean expert ratings.

Appendix 22. Mean team HSI values and species expert ratings, F-values from one-way ANOVA among team and expert scores, and mean absolute differences between team and expert scores for the multiplicative and geometric mean beaver models by habitat type. The standard errors of the mean habitat scores and mean absolute differences are in parentheses. The ANOVA degrees of freedom are in brackets. Only the limiting factor life requisites are included.

	MULTIPLICATIVE MEAN ALL SEASONS LIMITING FACTOR					GEOMETRIC MEAN ALL SEASONS LIMITING FACTOR				
HABITAT TYPE	GROUP	MEAN HABITAT SCORE	F-VALUE	TEAM COMPARED WITH EXPERT	MEAN ABSOLUTE DIFFERENCE	GROUP	MEAN HABITAT SCORE	F-VALUE	TEAM COMPARED WITH EXPERT	MEAN ABSOLUTE DIFFERENCE
FRESHWATER AQUATIC	Team 1	.500(.224)		Team 1	.517*(.135)	Team 1	.500(.224)		Team 1	.517*(.135)
	Team 2	.500(.224)	.063	Team 2	.517*(.135)	Team 2	.500(.224)	.063	Team 2	.517*(.135)
	Team 3	.500(.224)	[4,25]	Team 3	.517*(.135)	Team 3	.500(.224)	[4,25]	Team 3	.517*(.135)
	Team Avg	.500(.224)		Team Avg	.517*(.135)	Team Avg	.500(.224)		Team Avg	.517*(.135)
	Expert	.617(.125)				Expert	.617(.125)			

*The mean absolute difference exceeded the .100 level of acceptability.

Appendix 23. Mean team HSI values and species expert ratings, F-values from one-way ANOVA among team and expert scores, and mean absolute differences between team and expert scores for the multiplicative and geometric mean mink models by habitat type. The standard errors of the mean habitat scores and mean absolute differences are in parentheses. The ANOVA degrees of freedom are in brackets. Only the limiting factor life requisites are included.

HABITAT TYPE	MULTIPLICATIVE MEAN ALL SEASONS LIMITING FACTOR				GEOMETRIC MEAN ALL SEASONS LIMITING FACTOR			
	GROUP	MEAN HABITAT SCORE	F-VALUE	MEAN ABSOLUTE DIFFERENCE	GROUP	MEAN HABITAT SCORE	F-VALUE	MEAN ABSOLUTE DIFFERENCE
LOW SHRUB	Team	.800(.076)	42.3*	.562$^+$(.098)	Team	.800(.076)	42.3*	.562$^+$(.098)
	Expert	.238(.042)	[1,14]		Expert	.238(.042)	[1,14]	
HERBACEOUS SEDGE-GRASS	Team	.375(.183)	2.36	.338$^+$(.149)	Team	.375(.183)	2.36	.338$^+$(.149)
	Expert	.088(.040)	[1,14]		Expert	.088(.040)	[1,14]	

*The F-value exceeded the critical value at $p \leq .05$.

$^+$The mean absolute difference exceeded the .100 level of acceptability.

Appendix 24. Mean team HSI values and species expert ratings, F-values from one-way ANOVA among team and expert scores, and mean absolute differences between team and expert scores for the multiplicative mean spruce grouse model by habitat type. The standard errors of the mean habitat scores and mean absolute differences are in parentheses. The ANOVA degrees of freedom are in brackets. Only the limiting factor life requisites are included.

	NON-WINTER LIMITING FACTOR					WINTER LIMITING FACTOR				
HABITAT TYPE	GROUP	MEAN HABITAT SCORE	F-VALUE	TEAM COMPARED WITH EXPERT	MEAN ABSOLUTE DIFFERENCE	GROUP	MEAN HABITAT SCORE	F-VALUE	TEAM COMPARED WITH EXPERT	MEAN ABSOLUTE DIFFERENCE
	Team 1	.095(.048)		Team 1	.105*(.033)	Team 1	.497(.059)		Team 1	.257*(.064)
CONIFEROUS	Team 2	.142(.085)	.469	Team 2	.115*(.037)	Team 2	.475(.052)	.671	Team 2	.245*(.054)
	Team 3	.268(.150)	[4,25]	Team 3	.192*(.070)	Team 3	.497(.051)	[4,25]	Team 3	.243*(.061)
FOREST	Team Avg	.168(.095)		Team Avg	.108*(.037)	Team Avg	.488(.053)		Team Avg	.245*(.059)
	Expert	.200(.063)				Expert	.383(.075)			
	Team 1	.628(.034)		Team 1	.078(.029)	Team 1	.993(.005)		Team 1	.543*(.033)
MIXED	Team 2	.655(.075)	1.26	Team 2	.135*(.049)	Team 2	.907(.091)	8.91[a]	Team 2	.457*(.088)
	Team 3	.493(.071)	[4,25]	Team 3	.150*(.053)	Team 3	.812(.113)	[4,25]	Team 3	.455*(.063)
FOREST	Team Avg	.592(.051)		Team Avg	.102*(.027)	Team Avg	.905(.057)		Team Avg	.455*(.074)
	Expert	.550(.043)				Expert	.450(.034)			

*The mean absolute difference exceeded the .100 level of acceptability.

[a] All mean team HSI values differed significantly ($p \leq .05$) from the mean expert rating.

Appendix 25. Mean team HSI values and species expert ratings, F-values from one-way ANOVA among team and expert scores, and mean absolute differences between team and expert scores for the geometric mean spruce grouse model by habitat type. The standard errors of the mean habitat scores and mean absolute differences are in parentheses. The ANOVA degrees of freedom are in brackets. Only the limiting factor life requisites are included.

	NON-WINTER LIMITING FACTOR					WINTER LIMITING FACTOR				
HABITAT TYPE	GROUP	MEAN HABITAT SCORE	F-VALUE	TEAM COMPARED WITH EXPERT	MEAN ABSOLUTE DIFFERENCE	GROUP	MEAN HABITAT SCORE	F-VALUE	TEAM COMPARED WITH EXPERT	MEAN ABSOLUTE DIFFERENCE
	Team 1	.095(.048)		Team 1	.105*(.033)	Team 1	.787(.031)		Team 1	.403*(.097)
CONIFEROUS	Team 2	.142(.085)	.449	Team 2	.115*(.037)	Team 2	.777(.027)	18.4[a]	Team 2	.393*(.094)
	Team 3	.265(.151)	[4,25]	Team 3	.195*(.071)	Team 3	.787(.026)	[4,25]	Team 3	.403*(.093)
FOREST	Team Avg	.168(.095)		Team Avg	.108*(.037)	Team Avg	.783(.027)		Team Avg	.400*(.094)
	Expert	.200(.063)				Expert	.383(.075)			
	Team 1	.698(.025)		Team 1	.148*(.043)	Team 1	.995(.003)		Team 1	.545*(.033)
MIXED	Team 2	.672(.022)	5.22[a]	Team 2	.122*(.038)	Team 2	.945(.055)	24.2[a]	Team 2	.495*(.056)
	Team 3	.675(.013)	[4,25]	Team 3	.125*(.034)	Team 3	.887(.071)	[4,25]	Team 3	.447*(.089)
FOREST	Team Avg	.683(.018)		Team Avg	.133*(.038)	Team Avg	.943(.033)		Team Avg	.493*(.055)
	Expert	.550(.043)				Expert	.450(.034)			

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*The mean absolute difference exceeded the .100 level of acceptability.

[a] All mean team HSI values differed significantly ($p \leq .05$) from the mean expert rating.

Appendix 26. Mean team HSI values and species expert ratings, F-values from one-way ANOVA among team and expert scores, and mean absolute differences between team and expert scores for the multiplicative mean common redpoll model by habitat type. The standard errors of the mean habitat scores and mean absolute differences are in parentheses. The ANOVA degrees of freedom are in brackets. Only the limiting factor life requisites are included. A dash indicates the limiting factor did not apply in that habitat type.

	NON-WINTER LIMITING FACTOR					WINTER LIMITING FACTOR				
HABITAT TYPE	GROUP	MEAN HABITAT SCORE	F-VALUE	TEAM COMPARED WITH EXPERT	MEAN ABSOLUTE DIFFERENCE	GROUP	MEAN HABITAT SCORE	F-VALUE	TEAM COMPARED WITH EXPERT	MEAN ABSOLUTE DIFFERENCE
CONIFEROUS FOREST	Team 1	.173(.020)		Team 1	.083(.017)	Team 1	.223(.026)		Team 1	.060(.019)
	Team 2	.180(.025)	1.92	Team 2	.087(.023)	Team 2	.233(.031)	.136	Team 2	.073(.019)
	Team 3	.188(.025)	[4,25]	Team 3	.072(.019)	Team 3	.243(.034)	[4,25]	Team 3	.103*(.019)
	Team Avg	.180(.015)		Team Avg	.073(.018)	Team Avg	.235(.018)		Team Avg	.058(.019)
	Expert	.116(.017)				Expert	.217(.031)			
DECIDUOUS FOREST	Team 1	.275(.004)		Team 1	.168*(.056)	Team 1	.477(.076)		Team 1	.123*(.069)
	Team 2	.273(.005)	.113	Team 2	.170*(.058)	Team 2	.552(.024)	.564	Team 2	.052(.022)
	Team 3	.288(.006)	[4,25]	Team 3	.182*(.054)	Team 3	.525(.057)	[4,25]	Team 3	.058(.023)
	Team Avg	.277(.006)		Team Avg	.173*(.057)	Team Avg	.520(.046)		Team Avg	.067(.034)
	Expert	.250(.092)				Expert	.583(.048)			
MIXED FOREST	Team 1	.335(.038)		Team 1	.132*(.031)	Team 1	.545(.048)		Team 1	.158*(.055)
	Team 2	.362(.018)	1.01	Team 2	.162*(.018)	Team 2	.487(.072)	4.39[a]	Team 2	.237*(.059)
	Team 3	.407(.069)	[4,25]	Team 3	.207*(.069)	Team 3	.390(.068)	[4,25]	Team 3	.310*(.079)
	Team Avg	.368(.027)		Team Avg	.168*(.027)	Team Avg	.475(.048)		Team Avg	.225*(.058)
	Expert	.200(.000)				Expert	.700(.026)			
LOW SHRUB	Team 1	.765(.025)		Team 1	.182*(.052)	Team 1	-		Team 1	-
	Team 2	.685(.016)	3.58[b]	Team 2	.135*(.026)	Team 2	-		Team 2	-
	Team 3	.695(.032)	[4,25]	Team 3	.182*(.033)	Team 3	-	-	Team 3	-
	Team Avg	.717(.021)		Team Avg	.167*(.034)	Team Avg	-		Team Avg	-
	Expert	.600(.052)				Expert	-			

*The mean absolute difference exceeded the .100 level of acceptability.

[a] All mean team HSI values differed significantly ($p \leq .05$) from the mean expert rating.

[b] The mean HSI value of team one differed significantly ($p \leq .05$) from the mean expert rating.

Appendix 27. Mean team HSI values and species expert ratings, F-values from one-way ANOVA among team and expert scores, and mean absolute differences between team and expert scores for the geometric mean common redpoll model by habitat type. The standard errors of the mean habitat scores and mean absolute differences are in parentheses. The ANOVA degrees of freedom are in brackets. Only the limiting factor life requisites are included. A dash indicates the limiting factor did not apply in that habitat type.

	NON-WINTER LIMITING FACTOR					WINTER LIMITING FACTOR				
HABITAT TYPE	GROUP	MEAN HABITAT SCORE	F-VALUE	TEAM COMPARED WITH EXPERT	MEAN ABSOLUTE DIFFERENCE	GROUP	MEAN HABITAT SCORE	F-VALUE	TEAM COMPARED WITH EXPERT	MEAN ABSOLUTE DIFFERENCE
CONIFEROUS FOREST	Team 1	.415(.025)		Team 1	.298*(.036)	Team 1	.468(.026)		Team 1	.252*(.033)
	Team 2	.418(.028)	32.5^a	Team 2	.302*(.038)	Team 2	.478(.030)	16.9^a	Team 2	.262*(.037)
	Team 3	.430(.029)	[4,25]	Team 3	.313*(.023)	Team 3	.488(.034)	[4,25]	Team 3	.272*(.049)
	Team Avg	.420(.018)		Team Avg	.303*(.026)	Team Avg	.480(.018)		Team Avg	.263*(.033)
	Expert	.117(.017)				Expert	.217(.031)			
DECIDUOUS FOREST	Team 1	.660(.057)		Team 1	.477*(.093)	Team 1	.678(.057)		Team 1	.165*(.017)
	Team 2	.723(.032)	12.1^a	Team 2	.477*(.093)	Team 2	.742(.017)	2.24	Team 2	.158*(.034)
	Team 3	.708(.047)	[4,25]	Team 3	.483*(.095)	Team 3	.720(.043)	[4,25]	Team 3	.137*(.019)
	Team Avg	.697(.040)		Team Avg	.478*(.094)	Team Avg	.715(.033)		Team Avg	.138*(.028)
	Expert	.250(.092)				Expert	.583(.048)			
MIXED FOREST	Team 1	.703(.023)		Team 1	.503*(.023)	Team 1	.733(.032)		Team 1	.093(.019)
	Team 2	.652(.055)	27.4^a	Team 2	.452*(.055)	Team 2	.692(.050)	1.21	Team 2	.095(.033)
	Team 3	.605(.054)	[4,25]	Team 3	.405*(.054)	Team 3	.612(.054)	[4,25]	Team 3	.142*(.043)
	Team Avg	.653(.035)		Team Avg	.453*(.035)	Team Avg	.677(.035)		Team Avg	.083*(.029)
	Expert	.200(.000)				Expert	.700(.026)			
LOW SHRUB	Team 1	.765(.025)		Team 1	.182*(.052)	Team 1	-		Team 1	-
	Team 2	.685(.016)	3.59^b	Team 2	.135*(.026)	Team 2	-		Team 2	-
	Team 3	.697(.032)	[4,25]	Team 3	.183*(.033)	Team 3	-	-	Team 3	-
	Team Avg	.717(.021)		Team Avg	.167*(.034)	Team Avg	-		Team Avg	-
	Expert	.600(.052)				Expert	-	-		

*The mean absolute difference exceeded the .100 level of acceptability.

[a] All mean team HSI values differed significantly ($p \leq .05$) from the mean expert rating.

[b] The mean HSI value of team one differed significantly ($p \leq .05$) from the mean expert rating.

Appendix 28. Mean team HSI values and species expert ratings, F-values from one-way ANOVA among team and expert scores, and mean absolute differences between team and expert scores for the multiplicative and geometric mean green-winged teal models by habitat type. The standard errors of the mean habitat scores and mean absolute differences are in parentheses. The ANOVA degrees of freedom are in brackets. Only the limiting factor life requisites are included.

	MULTIPLICATIVE MEAN NON-WINTER LIMITING FACTOR				GEOMETRIC MEAN NON-WINTER LIMITING FACTOR			
HABITAT TYPE	GROUP	MEAN HABITAT SCORE	F-VALUE	MEAN ABSOLUTE DIFFERENCE	GROUP	MEAN HABITAT SCORE	F-VALUE	MEAN ABSOLUTE DIFFERENCE
LOW SHRUB (YEAR 2)	Team Expert	.012(.010) .025(.013)	.563 [1,14]	.020(.012)	Team Expert	.155(.120) .025(.013)	1.16 [1,14]	.155*(.112)
HERBACEOUS SEDGE-GRASS	Team Expert	.488(.184) .138(.042)	3.42 [1,14]	.412*(.135)	Team Expert	.494(.187) .138(.042)	3.47 [1,14]	.419*(.138)

*The mean absolute difference exceeded the .100 level of acceptability.