AN OVERVIEW OF A HABITAT SUITABILITY INDEX MODEL FOR MOOSE: LAKE SUPERIOR REGION

Arthur W. Allen,[1] James W. Terrell,[2] Peter A. Jordan ,[3]
[1]U.S. Fish and Wildlife Service, 2627 Redwing Road, Fort Collins, CO 80526-2899; [2]U.S. Fish and Wildlife Service, 2627 Redwing Road, Fort Collins, CO 80526-2899; [3]University of Minnesota, Department of Fisheries and Wildlife, St. Paul, MN 55108

ABSTRACT: A three-day workshop was held to develop a model for evaluation of moose habitat in the Lake Superior Region. The ultimate goal of the workshop was to provide planning tools to enhance habitat management for moose and maximize the integration of those management objectives with silvicultural goals. An abstract of the models resulting from the workshop is presented and model validation concepts are discussed.

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Resource management problems often occur at the interface between disciplines. Identification of habitat management priorities and communication of those objectives to resource managers with divergent priorities can assist biologists in accomplishing long-term managment goals. Integration of silvicultural and wildlife management objectives to address habitat management on a landscape scale can be facilitated through development and use of models based on the habitat requirements of selected wildlife species.

METHODS

Immediately following the 23rd North American Moose Conference in Duluth, Minnesota, a three-day workshop was held to develop a Habitat Suitability Index (HSI) model for evaluation of moose (*Alces alces*) habitat in the Lake Superior Region (Figure 1). Participants in the workshop were invited on the basis of their knowledge of moose ecology or their familiarity with forest wildlife and silvicultural management in the region. The concepts discussed at the workshop were used as a foundation for written documentation of habitat characteristics and relationships believed important to moose in the region. The initial model was sent to all workshop participants to insure that the model correctly represented the habitat relationships and assumptions discussed at the workshop. Subsequent to revisions based on these reviews and a follow-up meeting in Duluth, the models were reviewed by additional moose authorities in the Lake Superior region who had not participated in the workshop, and then published. We believe testing of model assumptions and refinement of model relationships will result in eventual development of models that will more accurately simulate the effects of silviculture and wildlife management practices and provide a focal point for improved coordination of those practices.

Our objective was to develop a habitat-based model that would assist in: (1) identification of components that define moose habitat quality on both a landscape and individual stand scale, (2) identification of habitat management opportunities, (3) clarification of strategies to maximize compatability between moose habitat and silvicultural goals, and (4) priorizing research efforts to increase knowledge on the relationships of moose habitat use and forest management. The models have been designed to facilitate their application where timber and wildlife management are being coordinated in integrated resource planning.

RESULTS

Two models (Allen *et al.* 1988) were de-

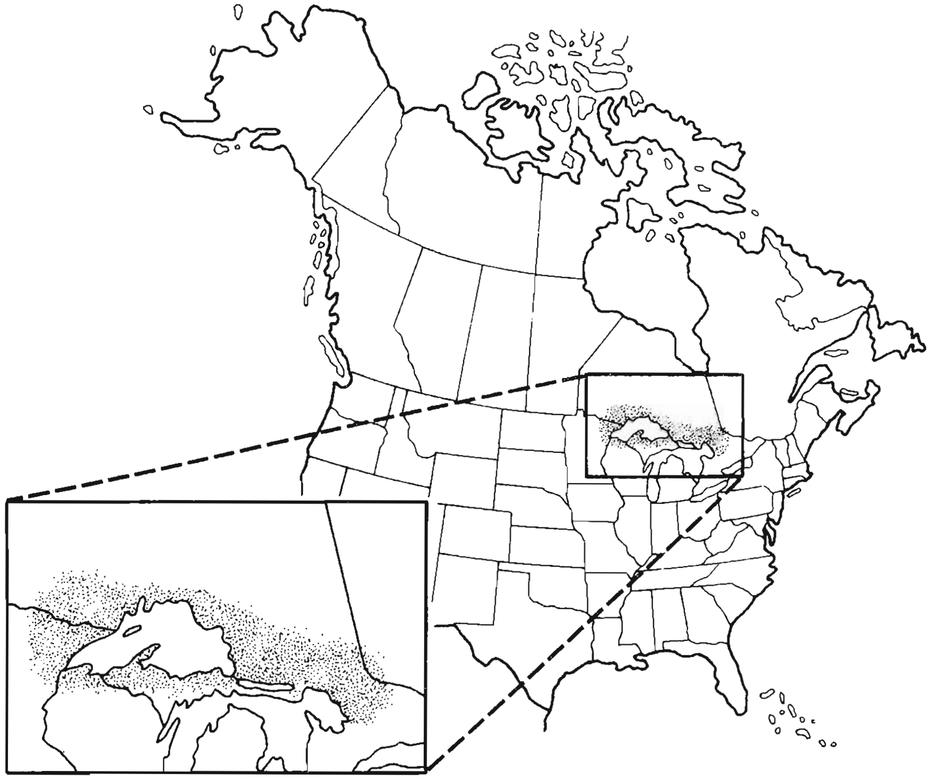

Figure 1. Approximate area of applicability (shaded) of the HSI model for moose in the Lake Superior region.

veloped based on workshop discussions and subsequent reviews. Model I evaluates abundance and quality of growing-season (mid-May to mid-September) and dormant-season (mid-September to mid-May) food and cover. The majority of data required for the model can be obtained from existing data sources however,portions of the model related to browse abundance and quality require on-site data collection. Model I evaluates individual 600-ha (6 km^2) evaluation units which are assumed to be roughly equal to the annual home range of cow moose in the Lake Superior region. Model II defines an assumed relationship of cover type composition to moose habitat quality in the Lake Superior region. The model is recommended for rapid evaluation of large areas (e.g., townships) and is based solely on data that can be obtained from aerial photography or cover type maps.

Both models are based on the assumption that habitats with food of sufficient quality interspersed with a suitable amount and quality of cover have the potential to support moose populations that will increase at faster rates and stabilize at higher densities (in the absence of non-habitat factors that contribute to mortality) than habitats without these features. Although it is recognized that mortality factors (eg., predation, disease, parasitism, harvest and competition) influence population growth where habitat is favorable, the models do not include these factors in formulations of habitat suitability (U.S. Fish and Wildlife Service 1980, 1981). The models quantify the potential of food and cover resources to support moose and are designed for habitat management. Management of the

Table 1. Model life requisites, data requirements, and outputs for HSI Models I and II for moose in the Lake Superior region.

HSI model	Life requisite	Data requirements	Output
	Growing-season browse	Annual browse production, diversity, and quality	Potential number of moose/km^2 that can be supported by growing-season browse
	Aquatic forage	Area of nonforested, nonacidic wetlands	Potential number of moose/km^2 that can be supported by aquatic forage
I	Growing-season cover	Area and species composition of forest cover	Potential number of moose/km^2 that can be supported by growing-season cover
	Dormant-season browse	Annual browse production, diversity, quality, and distance to dormant-season cover	Potential number of moose/km^2 that can be supported by dormant-season browse
	Dormant-season cover	Height, density, and species composition of forest cover	Potential number of moose/km^2 that can be supported by dormant-season cover
II	Cover type composition in relation to overall habitat quality	Percent of area in the following cover types: shrub and forested <20 years old, spruce/fir forest ≥20 years old, deciduous or mixed forest ≥20 years old, and nonforested wetlands	Index of habitat quality ranging from 0.0 to 1.0, where 0.0 = unsuitable 1.0 = optimum

other mortality factors would likely be necessary for moose populations to actually reach the potential levels described by the models. Table 1 provides an overview of the data requirements and output for both models. This presentation provides a brief discussion and overview of the models. A complete description of model assumptions and limitations is provided in Allen *et al.* (1987).

Model I.

Model I is based on separate evaluations of abundance, distribution, and quality of growing- and dormant-season food and cover. The growing- and dormant-season food components are based on the assumption that stands providing a diversity of browse species are of higher value to moose than are equally sized areas that provide little forage diversity. Common browse species in the area of model applicability were identified and weighted to reflect their assumed relative values as moose forage during both seasons. It is believed that moose in the Lake Superior region require aquatic vegetation as a result of low sodium concentration in terrestrial forage. Therefore, the availability of aquatic forage has been incorporated into the growing season model. The model does not recommend detailed evaluation of the abundance or diversity of aquatic forage. Rather, it is assumed that if sufficient area of suitable wetlands are present within an evaluation area an ample amount of aquatic vegetation will be available.

It is assumed that browse availability is influenced by the distribution of cover within both the growing and dormant seasons. The growing season cover component is based on the assumption that moose easily heat stress and that habitat devoid of mature, closed canopy forest will provide less than optimum habitat. During the dormant season (late-winter) it is assumed that only browse resources near suitable conifer-dominated cover are useful when deep snow and inclement weather reduce mobility and browse availability.

Model variables are assumed to define browse abundance, browse species diversity, the values of various forest types as both growing-and dormant-season cover, and the distribution of cover stands in relation to browse resources. Estimates of these vegetative and spatial variables are incorporated into simple equations that are assumed to estimate the density of moose (moose/km^2) that potentially can be supported within the evaluation area. Estimated potential density is converted to a Habitat Suitability Index (HSI) by dividing it by the assumed optimum density. The potential density of moose under optimum conditions in the Lake Superior region was defined as 2 moose/km^2. This density is believed to be conservative and is used as a standard of comparison to describe potential density estimates based on habitat conditions on a 0.0 to 1.0 scale. Therefore, the HSI within an evaluation area is defined as:

$$HSI = \frac{\text{potential density of moose}}{DM}$$

where: DM = the standard of comparison for maximum potential density of moose in the Lake Superior region, 2 moose/km^2.

Model II

Model II requires less intense sampling and is designed to be applied to township size (or larger) areas. It is based on the assumption that four key habitat components must be present within an evaluation area: (1) cut-over areas <20 years old; (2) mature spruce-fir forest; (3) mature aspen-paper birch forest; and (4) wetlands. The model is based on the assumption that ideal availability of forage will be provided when 40 to 50% of the township (or larger area) is composed of stands with > = 50% aerial coverage by shrub or forested cover types <20years old (regeneration). Cover types in this age class may be the result of direct forest management, wildfire, or defoliation by forest insects (e.g., spruce budworm [*Choristoneura fumiferana*]). Winter cover is assumed to be provided when 5 to 15% of the area is dominated by spruce/fir stands >20 years old. Upland deciduous forests, or mixed stands, are assumed to provide food as well as cover. Optimum conditions are assumed to be present when 35 to 55% of the evaluation area is composed of such cover types. Five to 10% of the evaluation area in wetlands is assumed to reflect optimum availability of aquatic forage.

Model II is based on the assumption that all four habitat components must be present for optimum year-round habitat. Low HSI values are calculated when one or more of the major cover types are present at less than, or greater than, assumed optimum composition. If any one of the cover types, with the exception of wetlands, is completely absent from the evaluation area it is assumed to provide unsuitable year-round habitat.

DISCUSSION

Obviously, the models are simplifications of moose habitat requirements and the animals' relations to those resources. The process of modeling is normally initiated with development of an inferential model formulated on existing knowledge and experience. Seldom are empirical data on all aspects of the system being modeled available. We intentionally strived to maintain simplicity in the models. Inclusion of variables believed possibly important but vaguely defined, too difficult to measure, or simply poorly understood were omitted. Model variables have been constrained to those: assumed to be important to moose in the Lake Superior region, can be routinely obtained or measured, are influenced during forest management and for which future conditions can be projected. Expert opinion and judgement were used to bridge data gaps whenever possible. We believe that many aspects of the models are educated guesses, they are presented to potential users as an initial step in defining practical, operational planning tools to assess affects of forest management practices on moose habitat. The models are meant to assist experienced biologists in clarification of concept and assumptions important for moose habitat management. They should be viewed as guides to decision making, not substitutions for experience or critical thought.

While it must be stressed that models are abstractions and are not intended, nor can they be, exact duplications of the real system, they can be viewed as a guide that can be used to more clearly identify management objectives. Models permit the examination of functions and relationships that we can visualize individually but cannot be comprehended collectively. Not all areas can be managed to maximize either timber or wildlife resources yet timber management can be an effective wildlife management tool if specific objectives can be identified and incorporated into long-range forest planning. The use of desk-top microcomputers and Geographic Information Systems (GIS) to establish data bases of habitat model variables will permit the examination and evaluation of changes in habitat resulting from actual or proposed management scenarios. Frequently it is not the quantity or quality of any one component that limits the numbers or distribution of animals within a given area but rather the degree of interspersion of required resources. Computerized data bases in conjunction with habitat models permit development of management plans that can address interspersion, habitat composition, the quality of individual sites, and the influence of other land use on habitat quality in large areas rather than on a stand by stand or compartment basis.

While it is often stated that habitat models cannot be developed because we do not know enough, biologists must make judgements on the effect of management actions despite uncertainty and are expected to produce practical solutions to management problems. We believe that the major benefit stemming from the described models is that the standardized, quantitative description of moose habitat quality can be used to help formulate those judgements. An acceptable description of habitat quality combined with the biologists' knowledge of local conditions can permit explicit description and justification of management recommendations beneficial to moose. These models, however ,will be of value only if they are perceived as useful and defendable by managers responsible for making those recommendations.

Development and refinement of any model is an integrative process,the influence of experimentation and additional research directed toward greater understanding of model assumptions and performance is mandatory if increased precision and dependability are desired (Bunnell 1974;Tipton 1980). Confidence in model performance can be increased through investigation of relationships between model output and a standard of comparison that reflects a measure of habitat quality (Farmer *et al.*1982). The moose HSI models are based on the key assumptions that moose select and use areas that are most capable of satisfying their needs and that greater use occurs in habitats of higher quality than those of poor quality. The models are not intended to mimic dynamics of moose populations since they do not explicitly incorporate temporal and population variables (e.g., natality, mortality). However, they are assumed to define long-term upper limits to population density, and should be tested to determine if they meet this this supposition. Validation objectives of the moose models would be similar to that described for other models: (1) to determine model reliability under a particular set of circumstances; and (2) to improve model performance (Terrell and Nickum 1984; Schamberger and O'Neil 1986). The intent of habitat model validation is to determine not only if the model works, or does not work, but also how well it performs under a given set of circumstances. Validation of model performance can be accomplished by comparing model output to species responses (e.g., production, condition, home range size, survival) in the area of model applicability. However, unless individual model assumptions are tested first, the reason for model success (or failure) in predicting species responses will be difficult to determine (Blenden *et al.* 1986). A desirable long-term strategy for model improvement is to implement validation studies that address individual model assumptions prior to testing of the entire model. Initial evaluations should be orientated toward analysis of the most elementary model assumptions such as the effects of browse diversity or quality and interspersion between forage and cover resources on habitat quality. Although such an approach will not immediately address overall model performance it will provide the foundation for evaluation of higher levels in the model that combine individual assumptions and suitability indices.

The most frequent approach toward validation of HSI models has been to compare final model output (HSI) with estimates of animal density (Cole and Smith 1983; Hammill and Moran 1984; Cook and Irwin 1985; Irwin and Cook 1985). Although frequently the most accessible data, animal density may not accurately describe habitat quality because: (1) animal density might not be a function of habitat quality in the evaluation area, (2) animal density is difficult to measure precisely, (3) density data are frequently available for only certain periods of the year, and (4) not all factors influencing population numbers are incorporated to the HSI model. Evaluations of habitat model performance using density data are most likely to provide useful information when: (1) a large number of sample sites and corresponding density data are available,(2) when the entire spectrum of habitat conditions are included in the sample, (3) long-term (e.g., >than the mean life span of the individual animals) density data are available for all sites, and (4) when inventory techniques and observers are consistent. Validation efforts must be conducted in relation to the geographic and seasonal constraints specified in the model.

Measures of well-being or condition factors, such as age at first reproduction (Schwartz *et al.* 1982), twinning rates (Franzmann and Schwartz 1985), blood assay (Franzmann and LaResche 1978), and fat content (Verme and Ullery 1984) have been related to the health of cervids. Measures of well-being used in conjunction with density data might provide the best means to validate the moose HSI model in the Lake Superior region.

Ideally, validation of the moose models will include study sites where forest management is planned and past population or habitat use data are available. Alterations in habitat quality resulting from forest management could then be predicted and compared to changes in animal use yielding an indication of model reliability. This approach to validation usually requires a long-term commitment of resources in order to obtain base-line habitat data and monitoring of animal response to changes in habitat conditions.

Validation and refinement of several fundamental assumptions should substantially improve model performance in the Lake Superior region. Development of regionally accurate estimates of daily browse consumption rates should enhance the ability of Model I to predict potential density of moose based on estimates of available browse. Quantitative descriptions of habitat composition, and interspersion between cover and forage resources in areas that appear to consistently support high numbers of moose on a long-term basis will permit refinement of spatial and composition components in both models. Descriptions of density of preferred forage provided by specific wetland classes will permit refinement of the aquatic habitat requirements. Predictive models of browse biomass and diversity based on existing data or vegetation classification systems already in use by resource agencies [e.g.,Ecological Land Types (U.S. Department of Agriculture 1986)] should improve the efficiency of estimating browse availability and define data requirements for GIS applications. Perhaps the most basic question to be addressed is the size of the area the model should be applied to. Is 600 ha a reasonable minimum area upon which to base detailed evaluation and management of moose habitat in the region? Is this area compatible with forest management prescriptions, and coordination of moose habitat management?

Model validation involves rejection and reformulation of model assumptions and relationships between variables as knowledge is obtained through testing. Attaining the goal of precisely defining the causal factors that influence moose abundance in relation to habitat conditions and model refinement will require a long-term study involving habitat manipulation. Model testing should result in a more precise and practical model upon which to base management decisions. Ideally, the HSI models will be useful decision making aids early in the forest planning process and can provide a focal point for research that will serve to improve our understanding of the effects of forest management on moose habitat quality. A fundamental benefit of the models might be their usefulness to those responsible for habitat management in formalization of objectives and assistance in effective communication of those goals to managers and decision makers with differing priorities. Use and improvement of these models should promote more effective, integrated, moose and forest management in the Lake Superior region .

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