# Forest Wildlife Habitat Description and Data for Minnesota Species

by

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## Abstract

Forest wildlife habit relationships are important to a wide range of forest management decisions. This report describes the development and improvement of a forest wildlife habitat model format for use by natural resource professionals in silvicultural decision making and forest planning. Specifically, this paper describes rationale, data, and models assembled for describing habitat suitability indices (HSI) plus guidance for their application. Importantly, this work has also provided an update of habitat relationship data and model forms for many of the bird, mammal and amphibian species common to Minnesota. In total, data and models are provided for nearly 200 wildlife species.

HSI are a coarse filter method for considering the impact of forest management on wildlife species habitats. They are best described as a hypothesis regarding species-habitat relationships. In this usage, the premise is that there is a functional relationship between habitat suitability and habitat features that are widely observed at the forest stand level, such as the forest covertype and stand age class or size class—information which is widely available from systematic forest inventory data.

The modeling format is intended to allow rapid and straightforward analyses of potential changes in wildlife habitat for (1) long-term forest-wide planning efforts such as those by large landowners (forest-based industry, federal, state, and county managed lands), (2) rapid site-specific on-the-ground assessment of habitat conditions and considerations in timber sale or other project considerations, and (3) input to environmental review of large forestry-related project proposals.

Sequel papers are under development to describe a PC-based model implementation package and trials to aid user interpretation of model outputs.

## Introduction

The overall objectives of this report are twofold: (1) to describe the rationale for the use of habitat suitability indexes (HSI) to model the impacts of forest change on habitat for forest-dependent wildlife species in Minnesota; (2) to update and improve the models developed and used for the generic environmental impact statement (GEIS) on timber harvesting and forest management in Minnesota (Jaakko Pöyry Consulting, Inc. 1994), and the ten-year assessment of the accuracy of the GEIS projections (Kilgore et al. 2005).

The explicit motivation for this effort was a charge from the Minnesota Legislature to the Interagency Information Cooperative (IIC)[1] to develop a "forest wildlife habitat model framework." Implied in this directive is both the model framework and the database to make it fully operational. Importantly, increasingly detailed environmental review of forestry projects since the GEIS and expanding forest planning needs have further indicated a need for this work.

HSI are a coarse filter method for considering the impact of forest management on wildlife species habitat. They are best described as a hypothesis regarding species-habitat relationships. In this case the premise is that there is a functional relationship between habitat suitability and habitat features that are widely measured, such as forest stand covertype and stand age class or stand size class, information which is widely available from systematic forest inventory data (Bender et al. 1996). Changes in forest covertype and age or size class distributions, and thus habitat via HSI, can be summarized at stand, forest, landscape, regional, and statewide scales, for the past, present, and future projections based on a number of scenarios of change. Typically instructive scenarios are:

- Changes in levels of harvesting
- Changes in forest management practices (e.g., silvicultural methods, rotation age)
- Changes caused by forest growth and succession in forests reserved from harvesting
- Environmental impact statements including various harvesting scenarios
- Climate change scenarios

A HSI does indicate whether more or less suitable habitat will be available as time passes. However, a number of other factors such as climate fluctuations and climate change, unusual weather events, hunting, diseases, and invasive species can have a large effect on wildlife populations. Populations commonly fluctuate widely in response to these factors, even in cases where the amount of suitable habitat does not change. Therefore, a high HSI for a given species does not guarantee a high population; it merely indicates that habitat is available, not the degree to which that habitat is used and occupied. Describing populations of wildlife and how and why they fluctuate is typically the domain of wildlife ecologists and population biologists, and not the objective here. Here we show how to model the abundance of potentially suitable habitat at a

[1] See Minnesota Statutes Revised 2004, Chapter 89A.09 Interagency Information Cooperative. The Cooperative is administered through the University of Minnesota's Department of Forest Resources.

variety of spatial scales, and how various forest management scenarios would affect those habitat abundances. Details are discussed in the following sections.

## Methodology

### Principles for Use of HSI in Minnesota

#### *Species Considered*

The species considered for Minnesota are those that were determined to be forest dependent in the GEIS wildlife background paper (Jaakko Pöyry Consulting, Inc. 1992, Appendix I). This list could grow or shrink with a changing climate or other factors that may influence forest ecosystem structure and function.

#### *Speed and Flexibility*

The framework used in the GEIS was not developed for repeated use with diverse scenarios and situations. However, environmental review and planning applications since have stressed the need for rapid compilations of alternative scenarios and updating. The latter is essential to allow the database (matrices of forest wildlife relationships for each species) and associated HSI models and specific formulae to be updated when new information on wildlife/habitat relationships for one or more species becomes available. In particular, it is anticipated that more detailed and more accurate information will become available in the future for individual species, depending on various studies that may be conducted for this or related purposes. A framework in which species can be added or subtracted depending on future changes is also desirable.

### Documenting Changes to Database and HSI

This paper is intended as a reference document for the overall database and HSI. However, the data that describe wildlife and habitat relationships may change with new survey or research efforts. Additionally, the HSI models and associated formulas may also change when new information is available. Below are suggested standards for making and documenting such changes.

1. Archive previous versions of data matrixes and associated HSI for future comparison of the 1992 GEIS wildlife background paper to present and future analyses.

2. When filing a list of changes made, indicate by whom and when. For large data files in the form of matrices, this could be developed as a matrix with varying color coding for those values changed on a given date, with footnotes explaining those changes.

3. Documentation and metadata. Were changes done based on expert opinion, specific surveys or research or new literature? If the former, then a comment on the expert, their expertise, and affiliation is appropriate. If from new literature, then an updated literature review explaining the rationale for changes should be included.

4. Changes should be peer reviewed by at least one and preferably two experts. Reviewers and their affiliations and qualifications should be noted in a permanent record.

## Rationale for HSI for Forest Wildlife Relationships

### *Spatial scale and extent*

Methods of calculating HSI for some species can be applied at many spatial scales, from a 40-acre woodlot to the entire state. For other species, the application is limited, especially at small spatial extents. The following describes issues related to spatial extent of habitat analyses.

- Stand (*ca* 1 to 100 acres). At this spatial extent HSI can be calculated that is meaningful for certain species of small mammals and herps that spend their entire lives within a few acres. The stand may progress to better or worse conditions over time due to harvest or succession—there is little chance of maintaining suitable habitat for numerous species with different requirements as to stand type or tree size class (with the occasional exception of multi-aged stands of forest types such as white pine, oak, and northern hardwoods, which may have numerous tree sizes present that would provide suitable habitat for a variety of small mammals). If the stand is disturbed and, for example, goes from an old multi-aged stand of late-successional species to a young stand of early-successional species, then the species dependent on late-successional stages would be forced to leave, but other species could then use the stand. The ecological principle involved is that all large changes in the environment are positive for one set of species and negative for another set. For larger or more mobile species that use more than one stand daily or seasonally, the HSI calculated at this extent is incomplete and has little meaning. For example, for white-tailed deer in northern Minnesota, both young aspen stands and mature conifer stands are necessary for good habitat. A young aspen stand may be good habitat for grazing, but not offer thermal cover for winter, while an old conifer stand would offer good thermal cover but inadequate food. Thus a stand that provided a high level of function for one component of habitat may be incomplete in terms of total habitat needs.

- Multistand up to a few square miles. A variety of stand types might provide better habitat for certain medium-sized species of birds, but many of the same cautions as for the single stand apply.

- Township, County, Land Type Association. Such areas could offer the variety of stands that make suitable habitat for large mammal species such as black bear, white-tailed deer, and moose. Also, barring a large-scale disturbance such as the 1999 Big Blowdown (Rich et al. 2007), at this spatial extent, there is likely to be a moderately stable variety of age classes and stand types present over time, as harvest shifts from stand-to-stand and stands harvested at various prior dates grow to a variety of size classes. Finally, townships are sometimes used as convenient units to aggregate for an ecoregion or statewide analysis of HSI.

- Ecological Subsection, Section, and Ecoregion. These spatial extents usually encompass at least a million acres. In Minnesota these classifications are described by Minnesota Department of Natural Resources (2003). The chances of a constant flow of disturbance and maintenance of a relatively steady proportion of stands in all stages of development and succession, and a variety of covertypes, are high. The chance of landscape-wide synchronization by a large disturbance event is low. Projections of HSI for most species and response to changes in forest management directed by policy become meaningful at this scale.

- Statewide. Although the statewide extent has even more stability and good statistical basis for projections of future forest conditions than ecoregion of sections, and HSI responses to changes in forest management are very meaningful, there is also the complication that a lot of species ranges do not cover the entire state, and therefore, it is necessary to extract the subset of townships, counties, ecological subsection, sections, or ecoregions where each species occurs to analyze forest change, which introduces considerable complexity into the analyses.

### *Properties of HSI scores*

There is great variability in methods (and complexity of methods) used to calculate HSI values for various species. Many indexes are calculated from formulas that result in a scale from 0 (very poor or nonexistent habitat) to 1 (ideal habitat). Others use the total acreage of a certain forest type in which the species of interest lives across the unit of analysis and track whether that acreage goes up or down over time. Still others use adjusted acreages, whereby the acreage of forest types in which the species of interest lives is subdivided into poor, good, and very good habitat categories, each given a suitable weighting, and summed to yield the adjusted acreage, which may go up or down over time. The sums of suitability scores multiplied by acreages can lead to very large numbers that are not comparable among species. To make all of these methods comparable, they are commonly converted into percent change over time and compared with the index at the starting point of the analysis. This places all species on a similar scale, and makes HSI scores independent among species. However, the percentages can hide the huge variability in acreage used across the landscape and numbers of individuals present among species.

Some approaches to large-scale HSI have used very simple models, such as classifying each stand as a habitat type (based on forest type and successional and developmental stage), and a simple index such as 0, 1, or 2, indicating not used, used, or preferred (i.e., Malcolm et al. 2004). For a given analysis area, the acreage of all habitat types used was multiplied by “1,” and that of all preferred habitat types multiplied by “2,” and the sum was the HSI for that species. In the present analyses we have 15 covertypes and 3 size classes, allowing for a more sophisticated analysis, at least when the data are available for a given species abundance for the 45 available combinations of covertype and tree size class (and when species are sensitive to those differences). However, such data are not available for many species, and some are not thought to respond to all of these combinations. In such cases, as many age and covertype combinations as necessary may be lumped, or assigned the same habitat quality value.

HSI values can be roughly proportional to population and in a sense are population indexes. However, numerous factors other than forest type and age class affect the actual population and level of use of habitat, and it is probably better not to refer to HSI as estimates of population.

Small mammals in particular (hares, rodents), have large cycles in population that usually are not related to habitat quality changes. Neotropical migrant birds may have changes in their winter habitat that affect population even if habitat in Minnesota stays the same. Many species have irregular fluctuations in population in response to ongoing series of events that have individualistic influences on populations.

In all cases, whether for a single stand, a county or the entire state, an estimate of the acreage of each stand type and tree size class at the beginning and end of the analysis period is necessary to estimate changes in HSI for a given species. At large spatial extents, additional factors, such as range limits and differing habitat relationships in different ecoregions may need to be taken into account, so that potential habitat in regions where a given species does not live are not counted.

The highest HSI for habitat of a given species in Minnesota may not be highest for the species throughout its range. Similarly, the highest HSI in northern MN may not be as high as in the southern part of the state or vice versa. Here we use a statewide timberland standard—i.e. habitat characteristics that lead to the highest abundance for a given wildlife species within the forested portion of Minnesota would have the highest HSI score. A given habitat score for a given wildlife species in Minnesota does not imply that the species is as abundant in the state as in other states with comparable HSI calculated independently with forest data from those other states. Similarly, a score of 1.0 in Minnesota does not imply that a species reaches its highest abundance in the state (although that possibility is not excluded).

A final issue related to HSI scores is that of "timberland HSI" versus "total habitat HSI." For wildlife species that use habitats larger than individual forest stands, features of the habitat not directly influenced by timber harvesting, or possibly not influenced by it at all, are an important part of the total habitat. For example, black bears use plants in nonforested swamps as a food source at certain times of the year (Garshelis and Noyce 2008). Ideally, we would have information on distribution of nonforested wetlands and other habitat features adjacent to managed forests in every township throughout the state. Thus, we could create a total habitat HSI. However, such information is often absent or prohibitive to obtain in terms of cost. In the absence of such information, a timberland HSI based just on changes in forest type and tree size class can still be calculated. This is generally what is done here. The advantages are that timberland only HSI isolate and respond in a more sensitive fashion to changes caused by forest management; therefore from the point of view of how timber harvesting changes habitat, all other factors remaining equal, we can point out positive and negative impacts relative to the starting condition. The disadvantage is that forests near these other habitat features are undervalued as habitat.

## Additional Considerations for Habitat Suitability

A constant flow of disturbance and succession is necessary in order to keep a constant supply of any given age class on the landscape. Should we take this into account in an analysis of habitat suitability? As mentioned above, at large spatial extents (statewide, ecoregion, section, and subsection), a high diversity and stability of covertypes and age classes is more likely to exist than at smaller extents. At the stand or multistand scale, stability and diversity of habitats is less likely, and large fluctuation in habitat quality are sure to happen over time. The purpose of HSI is to provide a snapshot at a given time, not the optimum balance over a long time. The balance of habitats over time and cumulative flow of stands among covertypes and age classes in response to harvesting and other disturbances is the domain of forest planning and modeling, which includes balancing the competing needs of various species against one another. Therefore, the HSI presented are a snapshot of conditions at one time; they do not consider the flow of habitats over time.

Road density has been shown to be a factor for many species from bears to birds, however, here we are assuming that road density will change little and are attempting to isolate the effects of changes in covertype and age class. Roads can both help wildlife by providing edges with berry-producing shrubs, and hurt by facilitating traffic deaths and hunting or poaching. Often there are conflicting reports in the peer-reviewed literature of the effects of road density on wildlife habitat quality, even for one species, and effects vary by road type and use. In general, road density is not taken into account in HSI models at this time, but this could be added at a future date for certain species.

The degree to which spatial information can be taken into account varies among species. Large mammals that use relatively large areas may need several covertypes within an area of, for example, a township, whereas smaller mammals may stay within one or a few stands throughout their lives. For the former case, it is possible to differentiate forest characteristics among townships within the range of the species using forest inventory data, but it is not usually possible for the latter case, since intrastand-level information on habitat structure is not available. For large mammals with large territories, the habitat value for a single stand has limited meaning, it might provide useful habitat for a few days or a season of the year for some individuals.

In addition, habitat/wildlife relationships may vary among regions within Minnesota, particularly between the near-boreal forests of the north, deciduous forests that cross the central part of the state from northwest to southeast, and the agricultural lands with intermixed woodlands of the south. White-tailed deer is a good example—see details below.

It is also important to recognize that Minnesota is an “edgy” state. The southern range limits of many boreal plant and animal species occurs in Minnesota, as do the northern range limits of many temperate species, the western range limits of many eastern deciduous forest species, and the eastern range limits of many grassland and savanna species whose main range is on the Great Plains. Therefore, for a number of forest-dependent species it is necessary to outline the range, so that only habitat changes that could possibly be used by the species are analyzed. Ranges can be approximately outlined using ecoregions or counties within Minnesota.

Changes caused by invasive ecosystem engineers such as European earthworms presents a conundrum for modeling HSI. These invasive species do not change the acreage of covertypes in which wildlife species live, but they can in some cases change the value of that acreage for habitat. For example, earthworms can decimate the diverse herb cover and organic soil horizon on the forest floor of northern hardwood forests, changing the habitat value for ground-nesting songbirds such as ovenbird and amphibians such as salamanders (Maerz et al. 2009, Loss and Blair 2011). In the future this could perhaps be taken into account if enough is known so that mature northern hardwood stands might be assigned a lower habitat value for some species (but might also be higher for other species).

# Results

## Updated HSI Models

The matrices from the GEIS were updated after a review of recent literature (the GEIS wildlife paper was published in 1992), and peer review by knowledgeable individuals. Wildlife are divided into four categories: (1) forest-dependent birds; (2) small- and medium-sized mammals; (3) large mammals, and (4) herps (including amphibians and reptiles).

### *Forest-dependent Birds*

The species list has 136 species that were determined for the GEIS wildlife paper (Jaakko Pöyry Consulting, Inc. 1992). The same species list was used here. The method for calculating change in habitat over time consists of multiplying the relative abundance of a given species (e.g., density of nesting pairs per 100 acres) in each habitat type by the acreage for each habitat type and summing the result before and after the period of analysis to get percent change. A revised matrix of relative density by covertype and tree size class that were developed for the GEIS report card (Kilgore et al. 2005) represent the most up-to-date data available at the time of writing this paper. This matrix was developed mostly by the same team that worked on the original GEIS wildlife background paper (Jaakko Pöyry Consulting, Inc. 1992). Two species of birds─ruffed grouse and spruce grouse─were handled separately by Frelich and Jordan in the 1992 analysis, and have updated methods for calculating HSI in this paper (see below).

*Ruffed Grouse*. The procedure used here is very similar to that used in the original GEIS analysis (Jaakko Pöyry Consulting, Inc. 1992), however, it is adjusted somewhat to take into account the work of Rickers et al. (1995), and the result is a hybrid between the GEIS and the newer work. Rickers et al. (1995) recognized four suitability index variables (SIV) corresponding to 0 to12, 13 to 25, 26 to 38, and 38+ year old aspen, whereas here we crosswalk to the size classes of aspen represented in statewide forest inventory data and recognize three size classes: seedling-sapling, pole, and sawtimber (as in the GEIS analysis), but use a monomolecular function reaching an asymptote at 33% for each of three size classes (as opposed to 25% for each of four age classes in Rickers et al. 1995), but use the formula that weights total aspen acreage in the area of interest by the arithmetic mean of the three SIV values. Each of the three SIV values can range from 0 to 1, and therefore the average of the three also ranges from 0 to 1. The actual change in HSI over time is then the adjusted acres compared to the total aspen acres at the start of the analysis period:

SIV1 = f(%aspen seedling-sapling)
SIV2 = f(%aspen pole)
SIV3 = f(%aspen sawtimber)

**Table 1.** Suitability index variable (SIV) factors for adjusted aspen acres for ruffed grouse.

| Percent aspen in | SIV |
|---|---|
| 0 | 0.0 |
| 0.1 - 1.9 | 0.08 |
| 2.0 - 3.9 | 0.17 |
| 4.0 - 5.9 | 0.29 |
| 6.0 - 7.9 | 0.39 |
| 8.0 - 9.9 | 0.48 |
| 10.0 - 11.9 | 0.56 |
| 12.0 - 13.9 | 0.63 |
| 14.0 - 15.9 | 0.68 |
| 16.0 - 17.9 | 0.73 |
| 18.0 - 19.9 | 0.78 |
| 20.0 - 21.9 | 0.83 |
| 22.0 - 23.9 | 0.87 |
| 24.0 - 25.9 | 0.91 |
| 26.0 - 27.9 | 0.94 |
| 28.0 - 29.9 | 0.96 |
| 30.0 - 31.9 | 0.98 |
| >32.0 | 1.0 |

In addition to aspen forest, some grouse live in other forest types, including maple-basswood and oak, which provide moderately suitable habitat and often include some aspen (R. Gutierrez personal communication). Therefore, adjusted acreage for HSI includes these two covertypes multiplied by 0.5.

> HSI for ruffed grouse = Adjusted acres = aspen acres x ((SIV1 + SIV2 + SIV3)/3) + 0.5(oak + maple-basswood acres). The analysis unit is the entire state or other unit of interest, making the assumption that aspen clearcuts are ca 20 acres in size and that age classes of aspen are mixed at that spatial scale.

*Spruce Grouse*. The HSI from the GEIS wildlife paper is for the most part retained here. Spruce grouse use upland jack pine and spruce (and to some extent balsam fir) during the winter and lowland conifers (principally black spruce) and to some extent adjacent upland conifers during summer (Pietz and Tester 1982).

Habitat change in the original GEIS analysis (Jaakko Pöyry Consulting, Inc. 1992) was proportional to changes in acreage of sawtimber-size jack pine, black spruce, and balsam fir. However, given the relatively low frequency of trees attaining sawtimber size in these forest types in northern Minnesota, and recent literature indicating that spruce grouse make substantial use of stands with smaller size classes (Larson and Dick 2010), here we adjust this to be proportional to change in acreage of all size classes: seedling/sapling (but excluding recent clearcuts if possible) + pole + sawtimber):

> HSI = adjusted acres black spruce + jack pine + 0.5 balsam fir. Analysis unit = entire state or other geographic areas of interest.

### *Small- and Medium-sized Mammals*

This update retains the same format that was used in the GEIS. Three matrices were used that take into account: (1) productive forest land, (2) recent clearcuts, within the first 10 years of harvest on productive forest land, and (3) unproductive forest.[2] As in the GEIS wildlife background paper (Jaakko Pöyry Consulting, Inc. 1992), values of 0, 2, 5, and 10 were assigned to each covertype/age class combination to indicate relative abundances: absent, low abundance, moderate abundance, and high abundance, respectively. For each species, the forest area in each abundance category was multiplied by the abundance value, the resulting products were summed, and the sum divided by four to attain a single HSI. Changes in the index relative to the starting point, based on projected forest age class/size class and covertype, were used to evaluate how forest change over time would affect habitat for various scenarios.

For this revision, substantial changes in the habitat matrixes were made for snowshoe hare and lynx (reviewed by Ron Moen), bobcat (reviewed by Paul Kapfer), pine marten, and fisher (reviewed by John Erb). Other species values for each covertype/size class combination remain the same as the 1992 GEIS version.

### *Large Mammals*

The general formula for the three large mammals analyzed in detail here (black bear, white-tailed deer, and moose; timber wolf depends on the population of deer + moose) is as follows:

> HSI = Sum of adjusted acres over all analysis units. Adjusted acres are acreages of forest habitat occurring within an analysis unit, adjusted for the quality of the habitat with a weighting factor that ranges from 0 to 1. Analysis units used should be relevant in scale to the movements of the animals and use of different covertypes during different parts of the daily and seasonal routine, but must also incorporate a tradeoff for accuracy of inventory data and forest change projections. We recommend blocks of 2 x 2 townships, because a unit of that size is likely to have *ca* 15 to 20 FIA plots, at least in heavily forested parts of the state.

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[2] Note these definitions follow terminology used by the US Forest Service in its Forest Inventory and Analysis (FIA) Program. Importantly, productive forest may be Reserved and thus not available for harvesting. Productive forest not in reserve status is termed Timberland by FIA. Similarly, unproductive forest is a general term for forests that do not reach a specified level of growth (20 cubic feet/acre/yr per FIA). Unproductive forest may also be Reserved. Further details on these terms per FIA may be found in US Forest Service (2010).

*Black bear.* In the GEIS, black bear were handled in a simple manner, with changes in HSI equal to 0.5 times the acreage of mast-producing oak forest. However, there are also a substantial number of bears in parts of Minnesota with boreal forests where oaks are rare, and hard mast produced by oaks is only one component of black bear habitat. Northern forests commonly have abundant hazel, which is an alternative form of hard mast in fall. Other components include summer food sources, availability of wetlands, which are important for spring foods and den sites, escape habitat, such as large trees for climbing, and human factors such as forest clearing and conversion to agriculture, size of clearcuts and human-bear interactions (Rogers and Allen 1987). In boreal forests bears eat a variety of foods and optimal habitat is probably best characterized by a diversity of forest types and age classes at the scale of a township or larger, although bears avoid use of purely conifer forests if possible, and use young aspen, birch, and balsam poplar, due to the high abundance of soft mast production (Garshelis and Noyce 2008, Brodeur et al. 2008).

Because timber harvesting does not change the distribution of wetlands, development and clearing of forests, or interactions with humans, and clearcut sizes in Minnesota are small (on the order of 10 to 30 acres), the major impacts of timber harvesting and forest management on black bear habitat are changing the distribution of age classes of stands at the scale of a township, landtype association or county. Described in terms of those factors, mature oak stands and young aspen, birch, and balsam poplar, are the important features. The new formula automatically adjusts for temperate deciduous versus boreal forest because a mature forest of mostly oak in the central part of the state would be excellent habitat (assuming wetlands are locally available), whereas in the north young aspen plus whatever mature oak is present would also create excellent habitat. Thus, for black bear:

> Timberland HSI for black bear = Sum of adjusted acres over all analysis units.
> Adjusted acres per analysis unit = weighting factor from Table 2 x timberland acres in the analysis unit. Recommend analysis units: blocks of 2 x 2 townships, and exclude townships with <30% forest cover.

Future recommendation for a “total habitat HSI” under a situation with an ideal dataset of landscape characteristics: calculate HSI for each township within the range of the black bear using a wetland availability and topographic diversity index, which could constitute about 40% of the index and then add the forest index weighted by 60%, sum the index for all townships within the area of analysis.

**Table 2.** Weighting factors as a function of percent seedling/sapling aspen, birch and balsam poplar + percent pole and sawtimber oak.

| Percent seedling/sapling aspen, birch, and balsam poplar | Percent pole + sawtimber oak | Weighting factor |
|---|---|---|
| >20 | >20 | 1.0 |
| >20 | 10 - 19.9 | 0.9 |
| >20 | 5 - 9.9 | 0.8 |
| >20 | 2 - 4.9 | 0.7 |
| >20 | <2 | 0.6 |
| 10 - 19.9 | >20 | 0.9 |
| 10 - 19.9 | 10 - 19.9 | 0.9 |
| 10 - 19.9 | 5 - 9.9 | 0.8 |
| 10 - 19.9 | 2 - 4.9 | 0.7 |
| 10 - 19.9 | <2 | 0.6 |
| 5 - 9.9 | >20 | 0.8 |
| 5 - 9.9 | 10 - 19.9 | 0.8 |
| 5 - 9.9 | 2 - 4.9 | 0.5 |
| 5 - 9.9 | <2 | 0.4 |
| 2 - 4.9 | >20 | 0.7 |
| 2 - 4.9 | 10 - 19.9 | 0.7 |
| 2 - 4.9 | 5 - 9.9 | 0.5 |
| 2 - 4.9 | 2 - 4.9 | 0.4 |
| 2 - 4.9 | <2 | 0.3 |
| <2 | >20 | 0.6 |
| <2 | 10 - 19.9 | 0.6 |
| <2 | 5 - 9.9 | 0.4 |
| <2 | 2 - 4.9 | 0.3 |
| <2 | <2 | 0.2 |

*White-tailed deer*. Treatment of this species will retain zones 1 and 4 from the GEIS (see zone definitions below), but will merge zones 2 and 3 into one zone. These zones have different habitat features requiring differing analyses for white-tailed deer (Jaakko Pöyry Consulting, Inc. 1992). We also change the calculations somewhat to match the general methodology introduced at the beginning of the large mammal section of the paper, which are also used for black bear and moose. In addition, to get a statewide HSI, HSI must be calculated separately for each of the three regions, and then the adjusted acreages for each of the three summed for a statewide adjusted acreage.

1. Deep snow zone, 16 counties in northern MN: Ecoregions 1, 2, and 3 and northern portion of Ecoregions 4 and 9. Optimum habitat should have at least 10% mature conifer forest for thermal cover (excluding black spruce and tamarack, which are little used by deer), combined with young aspen, birch, and balsam poplar forest in the seedling and sapling stage of development.

Timberland HSI for zone 1 = ∑ of adjusted acres over all analysis units.
Adjusted acres per analysis unit = weighting factor from Table 3 x timberland acres in the analysis unit. Recommend analysis units: blocks of 2 x 2 townships.

**Table 3**. Weighting factors for white-tailed deer zone 1.

| **Percent pole+sawtimber conifer cover (excluding black spruce and tamarack)** | **Percent seedling/sapling aspen, birch and balsam poplar** | **Weighting factor** |
|---|---|---|
| <10 | NA | 0 |
| >10 | 1.0 - 2.4 | 0.3 |
| >10 | 2.5 - 4.9 | 0.5 |
| >10 | 5.0 - 9.9 | 0.75 |
| >10 | 10+ | 1.0 |

2. Central hardwood and mixed-wood zone mostly forested with some agriculture including 10 counties in Ecoregion 4 and the northern tip of 5, plus zone 3, Southern farm-woodland zone, more extensive woodlands in Ecoregions 5 and 6. In this zone, mature oaks producing hard mast as well as recent clearcuts with forage within reach of deer in nonconifer forest types constitute ideal habitat.

Timberland HSI for GEIS zones 2 and 3 = Sum of adjusted acres over all analysis units.
Adjusted acres per analysis unit = weighting factor from deer formula 1 x timberland acres in the analysis unit. Recommend analysis units: blocks of 2 x 2 townships.

*Deer formula* 1: Weighting factor is 2 x (% pole/sawtimber oak + % seedling/sapling) aspen, with the sum hitting an asymptote at 50% (i.e., if % pole/saw oak + seedling/sapling aspen = 50% or more, then the weighting factor = 1.0).

3. Intensive agriculture zone (zone 4 of GEIS), with scattered woodlots and strips of riparian zone forests in an agricultural matrix, Ecoregions 7 and 8, and southern portion of 9. In this region forests occur in isolated woodlots and riparian corridors. Habitat suitability for deer is proportional to mature forest acreage.

The HSI = total pole+sawtimber acreage, weighting factor = 1.

*Moose*. Moose use different forest types during different times at a variety of time scales (day, week, and year). As in the GEIS wildlife background paper (Jaakko Pöyry Consulting, Inc. 1992), habitat is modeled within the core habitat used by moose (keeping the northwest Minnesota habitat for now, even though the herd there has declined dramatically in recent years). Moose require thermal cover throughout the year in the form of shade from conifers, and forage from young seedling/sapling habitat for all covertypes except black spruce and tamarack.

Timberland HSI for moose = Sum of adjusted acres over all analysis units.
Adjusted acres per analysis unit = weighting factor from Table 4 x timberland acres in the analysis unit. Recommend analysis units: blocks of 2 x 2 townships.

**Table 4.** Weighting factors for moose.

| Percent pole + sawtimber conifers + sawtimber black spruce | Percent seedling/sapling forest (except black spruce and tamarack) | Weighting factor |
|---|---|---|
| <15% | NA | 0 |
| >15% | <1 | 0 |
| >15% | 1 - 4.9 | 0.2 |
| >15% | 5.0 - 9.9 | 0.5 |
| >15% | 10 - 19.9 | 0.75 |
| >15% | 20 - 29.9 | 0.9 |
| >15% | 30+ | 1.0 |

*Timber wolf*. As with the GEIS wildlife paper (Jaakko Pöyry Consulting, Inc. 1992), wolves depend on moose and deer as a food source, and remoteness (i.e., absence of roads), rather than covertype and age class of forest. Wolf populations are dependent on human-wolf interactions through roads, hunting, and other factors. However, wolf HSI due to forest management alone should be proportional to the changes in moose and deer habitat suitability. In other words wolf HSI is the area weighted average of the percent change of moose HSI in areas with few deer during winter, such as the Boundary Waters Canoe Area Wilderness and adjacent lands with deep snow cover, and the percent change in deer HSI for the remainder of the range of the wolf in the state, calculated as outlined above.

### *Amphibians and Reptiles (Herps)*

Herps as a group have some unique habitat requirements that make the formation of HSI models based on forest type and size/age class difficult. For frogs and salamanders there are a lot of dependencies on microhabitat features such as leaf litter and coarse-woody debris that are beyond the scope of landscape-scale HSI models, as well as negative relationships with roads and positive relationships with ponds, including beaver ponds (McKenny et al. 2006, Stevens et al. 2006). Salamanders have relatively weak relationships with forest habitats (Pearce and Venier 2009), but as indicated by the GEIS, birch forests and recent clearcuts are generally less suitable than more mature forests (Patrick et al. 2006, Pearce and Venier 2009, Rittenhouse et al. 2009). Most of the studies published since the GEIS give new data on red-backed salamanders, confirming the habitat relationships from the GEIS, and unfortunately do not provide sufficient information to add the blue-spotted salamander to the species that are modeled (Pearce and Venier 2009). Overall, we did not find any new information that would change the habitat relationships specified in the GEIS wildlife technical paper, which also points out that it would be desirable to model four additional species if information necessary to do so should become available in the future: the gray tree frog, blue-spotted salamander, milk snake, and wood turtle (Jaakko Pöyry Consulting, Inc. 1992). Table 5 shows the habitat preferences for HSI for the eight herp species modeled.

**Table 5.** HSI habitat for herp species from Jaakko Pöyry Consulting, Inc. 1992.

| Species | FIA habitat (forest covertype and age class |
|---|---|
| Timber rattlesnake | White pine, oak, maple-basswood, paper birch >20 years |
| Boreal ringneck snake | Maple-basswood >20 years |
| Eastern hognose snake | White pine, maple-basswood >20 years |
| Eastern newt | All types except birch >20 years |
| Red-backed salamander | All types except birch >20 years |
| Wood frog | All types >20 years |
| Spring peeper | Deciduous types >20 years |
| Pickerel frog | Maple-basswood >20 years |

For each species the HSI = total acreage of the specified types for any size analysis unit, weighting factor = 1.

### Updated Database

The original forest wildlife habitat data were drawn from the GEIS wildlife background paper (Jaakko Pöyry Consulting, Inc. 1992). The original HSI models were likewise drawn from that paper. The updated (by this report) data are now available on the IIC website at http://iic.umn.edu. Additionally, the HSIs are now updated to those described in this report.

The updated forest wildlife habitat data show changes made from the original by color coding of data cells, with the color key given in the data matrix itself. The data itself is arranged in a Microsoft Excel Workbook format using a number of worksheets corresponding to birds, large mammals, small and medium mammals, and herps. Associated with these groupings are scientific and common names of species, habitat descriptions, codes for habitat names, HSI for each species by ecoregion and habitat, and various other descriptors and codes. Some of these descriptors were drawn from the Northwoods Database developed by the US Forest Service (Nelson et al. 2012). Also, the database includes supplemental information on any rare species potentially present, including state and federal special concern, threatened, and endangered species.

## Discussion

The forest wildlife habitat data assembled and updated here is a potentially very useful database for describing site specific and overall forest habitat conditions. It owes its origin to the work of many individuals working over many decades. Together with the HSI models, they also represent instructive tools for enabling the assessment of habitat for the various scenarios noted in the introduction. Such assessments might be for individual species, groups of species, e.g., neotropical migrants, or for all of the populations that might be present on a landscape. Toward those ends, we have developed a PC-based HSI model implementation package and trials to aid user interpretation of model outputs on a site specific and overall forest basis to be published later.

The availability of these tools will reduce the extensive and time-consuming data collection and analysis frequently sought in environmental review of proposed forest development projects, improve forest planning model results and aid field decision making for foresters and loggers.

Significant climate change is likely to occur in Minnesota in the next several decades (Frelich and Reich 2010), and the associated change in the environment will affect one group of species positively and another negatively. This will create a need to recalibrate some HSI/forest relationships, hence the need for a flexible system such as that developed here, where species ranges, species relationships with forest types, changes in forest type, and subtractions and additions of species can be easily accomplished.

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## Appendix 1. Forest Wildlife Species and Habitat Data