The Wildlife Habitat Indicator for Native Genera and Species (WHINGS): Methodology and Application

by

John M. Zobel[1] and Alan R. Ek[2]

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and
Department of Forest Resources
College of Food, Agricultural and Natural Resource Sciences
University of Minnesota
St. Paul, Minnesota

[1]Assistant Professor, Department of Forestry, Wildlife and Fisheries, University of Tennessee
[2]Professor and Head, Department of Forest Resources, University of Minnesota

For more information about the Department of Forest Resources and its teaching, research, and outreach programs, contact the department at:

Department of Forest Resources
University of Minnesota
115 Green Hall
1530 Cleveland Avenue North
St. Paul, MN 55108-6112
Ph: 612.624.3400
Fax: 612.625.5212
Email: forest.resources@umn.edu
http://www.forestry.umn.edu/publications/staffpapers/index.html

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Abstract

The Wildlife Habitat Indicator for Native Genera and Species (WHINGS) represents the next iteration of the wildlife habitat model created for the Minnesota Generic Environmental Impact Statement (GEIS) in the 1990s. The WHINGS framework allows and facilitates forestry and related natural resource planners and policy analysts to examine the impacts, both positive and negative, of proposed management scenarios on forest wildlife habitat during environmental review. In addition, the model can aid the synthesis of wildlife management objectives and practices during forest plan development. Further, the model can estimate current site specific wildlife habitat conditions that may influence other aspects of forest management. This research proposed several updates to the current habitat suitability index methodology used in previous versions of the model. A case study for Carlton County, Minnesota demonstrates an application of the updated model for trend analysis across two separate inventories. The output from WHINGS showed that 28% and 24% of bird species experienced improved and diminished habitat, respectively. Habitat suitability increased and decreased for 14% of the small and medium mammals, respectively. Three of the four large mammals saw improved habitat, while the fourth remained stable. However, the herptofauna had no gains in habitat, but 50% of the species experienced reductions. Overall, the results illustrate the fact that changes in forest habitat will benefit some species and negatively impact others. Thus, the significance and utility of WHINGS results will depend on the user and the criteria surrounding their particular application. Finally, we note the results are very much a function of the underlying forest description detail and wildlife species linkages, i.e., habitat suitability indices (HSI). Where model results differ from what has actually been observed for a wildlife populations, it is appropriate to revisit and refine the specific wildlife species HSI.

1. Introduction

The relationship between forest management and wildlife habitat has garnered steadily increasing attention since the 1980s. Evaluating potential habitat impacts has become common in many forest planning efforts. In Minnesota, habitat and other concerns over increasing rates of timber removals lead to a statewide Generic Environmental Impact Statement (GEIS) on timber harvesting and forest management (Jaakko Pöyry Consulting, Inc. 1994). The GEIS and associated technical papers addressed questions regarding the condition and sustainability of various components of local to statewide forest ecosystems under different harvesting scenarios, including wildlife habitat. When considering these habitat issues, the research team quantified habitat abundance and quality using a matrix of species habitat preferences determined through literature review and personal expertise (Jaakko Pöyry Consulting, Inc. 1992a). This matrix was then summarized into habitat suitability indices (HSI) for those forest dependent species native to Minnesota. The GEIS team calculated HSI values for 136 bird species (including ruffed and spruce grouse), 22 small and medium mammals, 4 large mammals, and 8 herptofauna (see Frelich et al. (2012) for a list of species and their habitat preferences). Changes in HSI values between the different harvesting scenarios were observed and used during the environmental impact analysis of the alternative schedules.

Ten years after the completion of the GEIS, a follow-up study assessed the accuracy of the GEIS projections, suggesting modest similarity between actual and predicted habitat conditions (Kilgore et al. 2005). Recent work by Frelich et al. (2012) updated the original habitat matrix and modified several HSI formulae to reflect the latest research on various wildlife species. Their work also sought to outline a method for rapidly assessing wildlife impacts for local (or regional) environmental impact statements within Minnesota.

This study seeks to extend the work of Frelich et al. (2012) through converting their results into a a readily accessible computerized framework. The new framework or model, known as the Wildlife Habitat Indicator for Native Genera and Species (WHINGS), will use cross-sectional or longitudinal data (with respect to time) to compute HSI values for all included wildlife species. In addition, this research proposes several updates to the HSI formulae and methodology to increase accuracy and usability. A case study for Carlton County, Minnesota will exemplify the use of WHINGS when quantifying habitat trends across time, thus providing opportunity for critique. The final model will allow users to reduce the time and financial commitment associated with determining wildlife impacts during an environmental review, establish wildlife management objectives and practices when developing a forest plan or related document, and estimate current site specific wildlife habitat conditions that may impact forest management.

2. Methods

2.1 Input Variables

HSI calculations follow two basic forms in WHINGS: A weighted average of abundance values (birds, small and medium mammals) and species or species group specific HSI equations (grouse, large mammals, herptofauna). The former rely upon the updated GEIS database matrix of species-habitat relationships, with abundance values organized by forest type, stand size class, and ecoregion and weighted by stand area. The latter depend on the same variables, with the addition of stand age and Minnesota county. All the variables are used to define species specific habitat preferences (and their amount) and whether the species temporal range falls within the area of interest. Description of these variables follows below.

2.1.1 Forest Type

A forest type represents the predominant vegetation cover on a specified land area, often in terms of an individual tree species or a species group. Forest types typically include a variety of species, with the designated type determined by the species (one or more) comprising the majority of stocking. This approach is used by the U.S. Forest Service Forest Inventory and Analysis (FIA) program (Arner et al. 2001; O'Connell et al. 2014). The GEIS defined its own forest types using basal area rather than stocking to simplify, yet still approximate the method used by FIA and facilitate projection of future forest type conditions (Jaakko Pöyry Consulting, Inc. 1992a; Jaakko Pöyry Consulting, Inc. 1992b). The Minnesota Department of Natural Resources (MNDNR) uses their own definitions for determining forest type (MNDNR 2012). WHINGS provides the option of using any of these three typing methods (see Appendix 1 for a forest type crosswalk between approaches).

2.1.2 Stand Size Class

A size class represents the predominant tree size or stage of tree development within a forest stand or landscape, e.g., seedling/sapling, poletimber, and sawtimber. The GEIS used these three size classes to maintain consistency with those used by FIA (Jaakko Pöyry Consulting, Inc. 1992a). FIA defined the three size classes based on the stocking majority of large diameter trees (≥ 11.0-in for hardwoods; ≥ 9.0-in for softwoods), medium diameter trees (≥ 5.0-in and less than large trees), or small diameter trees (< 5.0-in), with diameters measured at Dbh (O'Connell et al. 2014). However, the GEIS calculated projected size class based on stand age class and site quality, using the same Dbh criteria (Jaakko Pöyry Consulting, Inc. 1992a). Likewise, some users may have difficulty determining the required size class data for their stands. Therefore, Zobel and Ek (2014b) developed an algorithm for use with WHINGS that generates size class information from age class data (see section 2.1.5 below for additional information).

2.1.3 Ecoregion

For the purposes of this model, an ecoregion within Minnesota represents a collection of similar physical and biophysical characteristics as they relate to forest communities (Jaakko Pöyry Consulting, Inc. 1992a). Boundaries between the ecoregions identify significant shifts in ecological attributes, and wildlife population dynamics often differ between each region. Therefore, determining the ecoregion that contains the forest stand or landscape of interest is necessary for producing accurate model estimates. The GEIS uses nine broad ecoregions in Minnesota, but the U.S. Forest Service and the MNDNR further delineated these nine to define a total of 27 and 26 ecoregions, respectively (Cleland et al. 2007; MNDNR 2000). WHINGS allows users to specify their preferred ecoregion definitions before using the model. See Figure 1 for the GEIS ecoregions and Zobel and Ek (2014a) for an ecoregion crosswalk between definitions.

Figure 1. GEIS ecoregions defined for the wildlife model (from Jaakko Pöyry Consulting, Inc. 1992a). See Cleland et al. (2007) and MNDNR (2000) for alternative and more detailed versions.

2.1.4 Stand Area

Stand area represents the area (in acres, hectares, or other unit) of unique divisions (i.e., stands) within the analysis unit. These divisions are defined by differences in forest type, size class, ecoregion, age class, or county. HSI calculations use stand area as a weighting factor when combining abundance codes across stands (birds, small and medium mammals) (Eq. 1 and 3), or as input values in HSI equations (grouse, large mammals, herptofauna) (Eq. 2, 4, and 5).

2.1.5 Stand Age

Stand age represents the total age (since establishment) of the dominant/codominant trees within the associated size class in the stand. Often this age is obtained through coring two or more representative trees at Dbh, adding the number of years required to reach breast height, and then averaging the results across measured trees (FIA and MNDNR follow this procedure [USDA 2012; MNDNR n.d.]). WHINGS uses stand age when determining large mammal and herptofauna HSI values and for estimating stand size classes when this information is absent or difficult to quantify (see section 2.1.2 above for additional information and Zobel and Ek (2014b)).

2.1.6 Minnesota County

The county in Minnesota that contains the area of interest has significance for the white-tailed deer HSI equation. Deer have different habitat requirements depending on their location or zone in the state (see Frelich et al. (2012) for further details). Therefore, WHINGS recognizes three distinct deer zones and associated HSI formulae in Minnesota (see Appendix 2 for a list of the counties that define each deer zone).

2.2 Habitat Suitability Index (HSI)

Frelich et al. (2012) give full discussion and justification for using HSI methodology in WHINGS, which has seen much use in the wildlife research community (Terrell and Carpenter 1997; Morrison et al. 2006; USFW 1981, Verner et al. 1986). In summary, HSI values provide often coarse measures for describing species-habitat relationships and habitat quality, with higher values indicating favorable habitat for that particular species and low values indicating poor habitat. However, though a species HSI value may approach an optimum, this does not guarantee the species will actually frequent the area, but only that the area represents ideal habitat for that species. Many other factors impact a species population size besides the presence of habitat (see Frelich et al. (2012) for further discussion).

HSI values are calculated using functions that incorporate species habitat preferences. In WHINGS, these calculations rely on the updated GEIS database matrix of species-habitat relationships (Frelich et al. 2012). The HSI formulae for the WHINGS species groups are given below.

$$HSI_{birds} = \left(\sum_{i=1}^{H}(AC_i * acres_i) / \sum_{i=1}^{H} acres_i\right) / \max(AC) \tag{1}$$

$$HSI_{grouse} = \frac{Habitat\ acres}{All\ acres} \tag{2}$$

$$HSI_{SMM} = \left(\sum_{i=1}^{H}(AC_i * acres_i) / \sum_{i=1}^{H} acres_i\right) / \max(AC) \tag{3}$$

$$HSI_{LM} = individual\ species\ weighting\ factors \tag{4}$$

$$HSI_{herps} = \frac{Habitat\ acres}{All\ acres} \tag{5}$$

where *AC* = abundance code (Table 2), *acres* = acres associated with the abundance code, *H* = total number of abundance codes observed, *Habitat acres* = computed or actual acreage of preferred habitat within the analysis unit, *All acres* = total forested acreage within the analysis unit, *SMM* = small/medium mammals, and *LM* = large mammals. See Frelich et al. (2012) for definitions of habitat acres and individual species weighting factors. Also, Table 2 provides the range of abundance codes for the birds and small and medium mammals. The grouse and large mammal groups have individual species specific formulae, given below (see also Table 1 for forest type (FT) codes). All percentages are based on acres relative to the forested area of interest within the analysis unit (except the percentage of all forest types, which is relative to the entire unit area).

$$HSI_{RG} = \left((\overline{SIV})(FT_4) + 0.5(FT_5)\right) / FT_{all} \tag{6}$$

$$\text{where } SIV_i = \begin{cases} 3.125(\%\,FT_i) & if\ \%\,FT_i \leq 0.32 \\ 1 & if\ \%\,FT_i > 0.32 \end{cases}, \text{ for } i = 1, 2, 3 \tag{7}$$

$$HSI_{SG} = (FT_6 + FT_7 + 0.5(FT_8))/FT_{all} \tag{8}$$

$$HSI_{bear} = \begin{cases} 0 & if\ \%\,FT_{all} < 0.3 \\ w_1 + w_2 & if\ \%\,FT_{all} \geq 0.3 \end{cases} \tag{9}$$

$$\text{where } w_1 = \begin{cases} 2.5(\%\,FT_9) & if\ \%\,FT_9 \leq 0.2 \\ 0.5 & if\ \%\,FT_9 > 0.2 \end{cases} \tag{10}$$

$$w_2 = \begin{cases} 2.5(\%\,FT_{10}) & if\ \%\,FT_{10} \leq 0.2 \\ 0.5 & if\ \%\,FT_{10} > 0.2 \end{cases} \tag{11}$$

$$HSI_{moose} = \begin{cases} 0 & if\ \%\,FT_{11} < 0.15 \\ 10(\%\,FT_{11})/3 & if\ \%\,FT_{11} \geq 0.15\ \&\ \%\,FT_{12} \leq 0.3 \\ 1 & if\ \%\,FT_{11} \geq 0.15\ \&\ \%\,FT_{12} > 0.3 \end{cases} \tag{12}$$

$$HSI_{deer_1} = \begin{cases} 0 & if\ \%\,FT_{13} < 0.1 \\ 10(\%\,FT_9) & if\ \%\,FT_{13} \geq 0.1\ \&\ \%\,FT_9 \leq 0.1 \\ 1 & if\ \%\,FT_{13} \geq 0.1\ \&\ \%\,FT_9 > 0.1 \end{cases} \tag{13}$$

$$HSI_{deer_{23}} = \begin{cases} 2(\%\,FT_{10} + \%\,FT_1) & if\ \%\,FT_{10} + \%\,FT_1 \leq 0.5 \\ 1 & if\ \%\,FT_{10} + \%\,FT_1 > 0.5 \end{cases} \tag{14}$$

$$HSI_{deer_4} = FT_{14}/FT_{all} \tag{15}$$

$$HSI_{wolf} = \frac{HSI_{moose}(acres_{zone_1}) + \sum_{i=2}^{4} HSI_{deer_i}(acres_{zone_i})}{\sum_{i=1}^{4} acres_{zone_i}} \tag{16}$$

where *RG* = roughed grouse, *SIV* = suitability index variable (Rickers et al. 1995), $\overline{SIV}$ = mean SIV, *SG* = spruce grouse, and $deer_i$ = deer zone associated with the deer HSI value.

Table 1. Forest type (FT) codes used in the grouse and large mammal HSI equations.

Code	Forest Type	Size Class
FT_1	Aspen	Seedling/Sapling
FT_2	Aspen	Poletimber
FT_3	Aspen	Sawtimber
FT_4	Aspen	All
FT_5	Oak, Maple-Birch	All
FT_6	Black Spruce	All
FT_7	Jack Pine	All
FT_8	Balsam Fir	All
FT_9	Aspen, Birch, Balsam Poplar	Seedling/Sapling
FT_{10}	Oak	Poletimber, Sawtimber
FT_{11}	All Conifers (except T*)	Poletimber, Sawtimber
FT_{12}	All (except BS**, T*)	Seedling/Sapling
FT_{13}	All Conifers (except BS**, T*)	Poletimber, Sawtimber
FT_{14}	All	Poletimber, Sawtimber
FT_{all}	All	All

* T = tamarack; ** BS = black spruce

2.3 Methodology Updates

The methods behind WHINGS are given in Frelich et al. (2012). However, when computerizing the model, several updates were made to assumptions and implementation procedures. These modifications increased model consistency with other HSI research and improved model accuracy and utility.

2.3.1 Scale

The HSI equations given above differ slightly from those in Frelich et al. (2012). These updated formulae now give unitless results between 0-1, instead of HSI values that ranged between 0-∞ (and were in units of acres). Converting results to the new scale followed one of two procedures, depending on the species group. For birds and small and medium mammals, the new scale resulted from dividing the original HSI value by the maximum HSI possible. Thus, if the entire analysis unit was ideal habitat for a given bird species, the weighted average would yield the maximum previous HSI value (35), leading to a new HSI value of 35/35 = 1.000. Note also that if portions of the landscape provide no habitat, then the abundance code zero would be associated with those acres. Therefore, the new HSI scale not only indicates the quality of habitat, but also the quantity. For the grouse, large mammals, and herptofauna, the previous HSI formulae provided “adjusted acres” by multiplying the analysis unit area by a weighting factor describing the relative presence of habitat. The new formulae divide these adjusted acres by the total forested acres within the unit to obtain HSI values on the 0-1 scale (i.e., the weighting factor is now the HSI estimate). This conversion again leads to HSI values suggesting both the quality and abundance of habitat for the grouse species. However, for the large mammals and herptofauna, the formulae do not recognize gradients of habitat, but rather use binary criteria. Therefore, the associated HSI values only describe the extent of habitat relative to the entire analysis unit. For all species, this new scale now maintains consistency with typical HSI applications (Beck and Suring 2009; USFW 1981; Shamberger et al. 1982).

Note that the new scale assumes roughly constant total area of the analysis unit over time. If total area increases or decreases between measurement or projection periods, the new HSI scale will not reflect the potential change in habitat availability. For example, if herptofauna habitat comprised 300 acres in time period zero, and total acreage equaled 1,000, then HSI_{herps} = 300/1000 = 0.3. However, if both habitat and total acreage decreased by 10% in time period one, then HSI_{herps} = 270/900 = 0.3. The HSI values under each period are identical. Thus, the model summarizes habitat suitability and availability *given* the overall analysis unit area remains approximately fixed. Users should consider this assumption in the interpretation of results when using the model.

2.3.2 Age Class Substitute

HSI formulae for bird, small and medium mammals, and grouse species depend on species-habitat relationships defined by forest type and stand size class. For this latter variable, the GEIS patterned their classes after the FIA methodology. However, the FIA size class algorithm proved too cumbersome for use during projections, and thus the GEIS defined stand size classes relative to stand age and site quality (Jaakko Pöyry Consulting, Inc. 1992a). For like situations where size class information is lacking or difficult to obtain, WHINGS provides a forest type specific crosswalk between size classes on poor, medium, and high quality sites and stand age on those same sites (see Zobel and Ek (2014b)).

2.3.3 Bird Abundance Codes

In the original GEIS, bird abundance values were number of pairs per 1,500 hectares (3,707 acres), a continuous value (Jaakko Pöyry Consulting, Inc. 1992a). Some less researched species were assigned a 0-5 code that represented ranges in number of pairs per 40 acres, a discrete scale. When identifying the habitat impacts of each harvesting scenario, the researchers essentially computed the percent change in acres of projected habitat to acres of original habitat, weighted by abundance values. In order to unify the scales, initial work assigned numeric codes (0-5) to specific ranges in bird abundances for well researched species, thus putting all bird species on a discrete scale (Page and Ek 2005). However, this coding is linear, whereas the abundance ranges are nonlinear. Thus, several candidate nonlinear abundance coding schemes were examined for their utility in representing the abundance ranges, as well as their similarity with the nonlinear coding used for the small and medium mammals (Frelich et al. 2012).

After comparison, the selected nonlinear codes were related to the midpoint of the abundance ranges ($new\ abundance\ code = 2\sqrt{midpoint}$), with each code rounded to the nearest integer (except for the 0-1 range, which is rounded up) (see Table 2). This gave codes the most similar in format and methodology to those used for small and medium mammals. The WHINGS model then multiplies acres of habitat by its associated nonlinear abundance code, rather than multiplying by abundance per acre as in the GEIS and Frelich et al. (2012). Comparison between the nonlinear and linear scales (not reported) showed considerable improvement in predictions using the new scale, as the previous scale tended to overestimate HSI.

Table 2. New bird abundance codes used in WHINGS, along with the original discrete coding, GEIS bird abundance ranges and their corresponding range midpoints, and the abundance codes for the small and medium mammals. The new bird coding is double the square root of the midpoints, rounded to integer values. Note that the new code for the 0-1 range is rounded up instead of down. Also, the original units for the bird abundance ranges were breeding pairs/1,500 hectares. In English units, this translates to pairs/3,707 acres.

Birds				**Small/Medium Mammals**	
Original Abundance Codes	*Abundance Ranges*	*Range Midpoint*	*New Abundance Codes*	*Abundance Codes*	*Abundance Ranges*
0	Absent	NA	0	0	Absent
1	0-1	0.5	2	2	Low
2	2-10	6	5	5	Moderate
3	11-50	30.5	11	10	High
4	51-100	75.5	17		
5	101-500	300.5	35		

2.3.4 Analysis Unit

Estimated HSI values for areas ranging from one acre to the entire state will adequately represent habitat conditions for many species (Frelich et al. 2012). However, for some (particularly large mammals), an HSI for small tracts will be meaningless, as they have significantly larger home ranges. In addition, the large mammals often require the presence or adjacency of multiple forest types within their habitat. Using a very large analysis unit (e.g., ecoregion or state) may mask the variations in available habitat at the scale of species ranges. Therefore, Frelich et al. (2012) recommended analysis units of two by two township blocks (as defined by the Public Land Survey System) for the large mammals. This size encompasses considerable FIA data for determining habitat (approximately 31 plots). However, the original GEIS used single townships (roughly 8-10 FIA plots). WHINGS uses the latter approach for the default analysis unit, as this level of inventory information appears sufficient and analyses using other data sources will likely include many more plots. Also, using single townships reduces the spatial complexity of aggregating information into larger units. Still, applications of the model may use any appropriate analysis unit.

Unlike the GEIS and Frelich et al. (2012), WHINGS computes HSI values for all species on each analysis unit. Then similar to the other approaches, the mean HSI value across units provides a single HSI estimate for the entire area of interest. Using the same sized analysis unit allows for comparable estimates of variability (the general spread of HSI values) for all species. Also, only those units that fall within a species geographic distribution are included in the final HSI value (i.e., the final HSI estimate is not affected by the presence or absence of habitat within a region where the species does not occur).

2.4 Precision Estimates

HSI values obtained through species-habitat relationships and/or formulae may not lend well to traditional techniques for determining estimate variability. Several more modern statistical procedures have been suggested as alternative methods for obtaining standard errors, confidence intervals, conducting hypothesis tests, and model validation (Verbyla and Litvaitis 1989). WHINGS employs one of these methods (bootstrapping) to generate approximate standard errors and estimates of bias. For each analysis unit, existing inventory records are randomly selected (with replacement) to form another sample of the same size as the original sample. Application of the WHINGS model to this new dataset provides new estimates of HSI values for each species. Conducting this resampling effort repeatedly (e.g., 1,000 iterations) gives rough sampling distributions of HSI values. The spread of these distributions approximates the HSI standard error by species. In addition, the difference between HSI values from the original dataset and the center of the sampling distributions provides an estimate of model bias.

2.5 Significance

When comparing each harvest projection to the baseline scenario, the GEIS and Frelich et al. (2012) identified significant changes in HSI values as those with absolute percent changes > 25%. A potential problem with this approach occurs when base HSI values are small. In this case, a very slight change in HSI yields a substantial percent change that may not reflect real differences in forest management practices. The new 0-1 scale allows for computing absolute differences (new HSI–old HSI) that have more stability than percent changes and can highlight significant shifts in habitat regardless of base value magnitude. Ultimately, the test of significance and the interpretation of results depends on the needs of the user, but they should be aware of the benefits and deficiencies of the selected approach.

2.6 Maximum Values

Under the new 0-1 scale, many species have a maximum HSI value of 1.000. However, several species will never obtain values near the upper limit. For example, some bird species occur at very low densities (e.g., bald eagle), and thus the maximum possible HSI value for these species is 2/35 = 0.057. This value can mislead analyses, as low values may be construed as suggesting the presence of poor rather than optimal habitat. Therefore, WHINGS provides the option of computing HSI values (and related statistics) *relative* to the highest obtainable HSI. For the above example, this would give an HSI value of 2/2 = 1.000. This optional conversion standardizes the scale across species, facilitating comparisons between species with different density patterns.

2.7 Case Study

In order to demonstrate the implementation of WHINGS, the model was applied to a historical and a current forest inventory on land administered by Carlton County (CC), Minnesota. CC contains roughly 72,000 acres of county managed lands (Fernholz et al. 2014), with a large portion (~65%) classified as stocked forestland (Table 3). To assist in forest planning efforts, two county wide forest inventories were implemented in 1988 and 2003, with both taking several years to complete. Each inventory underwent continuous updating as specific stands were revisited. Application of the WHINGS model to the most recent update of each inventory allows for quantification of habitat trends across the last 12-25 years on CC lands. Table 3 summarizes the input data for both inventories.

Table 3. Total forestland acreage by forest type and size class in Carlton County, Minnesota, as used in the case study. Forest type definitions followed those used by the MNDNR. The data came from forest inventories conducted by Carlton County.

Forest Type	Size Class					
	Sawtimber		Poletimber		Seedling/ Sapling	
	1988	2003	1988	2003	1988	2003
Jack pine	6		16	13		3
Red pine	63	123	121	153	1,092	1,095
White pine	91	78				
Balsam fir	780	496	1,222	719	35	
White spruce	777	724	46	40	185	222
Black spruce		46	2,014	1,827	3,789	4,330
Tamarack	159	446	1,539	1,406	224	309
N. White-cedar	274	363	511	515	67	81
Oak	122	241		9		
Lowland hardwoods	1,700	1,439	2,517	2,727	158	146
Northern hardwoods	1,392	571	1,171	2,726	41	54
Aspen	7,512	4,605	8,023	10,570	6,194	8,317
Birch	1,775	742	1,749	1,394	6	2
Balm of Gilead	433	376	289	96	43	92
Total	15,084	10,251	19,218	22,196	11,834	14,650
Non-stocked	1988: 25,844			2003: 25,321		
All Lands	1988: 71,980			2003: 72,419		

The WHINGS model was programmed in the R statistical package (R Development Core Team 2011), with output exported as comma delimitated files (CSV). Comparisons between projection cycles were made using absolute differences and percent changes in HSI values for each species, with notable changes in habitat receiving further discussion.

3. Results and Discussion

For the CC case study, Table 4 summarizes the percent changes in habitat quality and abundance between the two inventories. For most species groups, the dominant trend showed no significant change in preferred habitat (|HSI change| < 10%). However, of the 118 bird species found in GEIS ecoregion four, just over half saw their habitat undergo significant shifts. Approximately 28% and 24% increased and decreased in habitat, respectively, with more than 30% of the increases being substantial (> 20%). Habitat for the two grouse species remained constant. For the small and medium mammals, most had stable habitat, with approximately 14% experiencing diminished and improved habitat, respectively. However, habitat for two species declined substantially (< 20%), while the increase for another species was very large (> 30%). Three of the four large mammals showed significantly increased habitat between the inventories (with two having substantial increases [> 30%]), and the remaining species had constant habitat. The herptofauna faired poorest, with two species showing reductions in habitat besides the four that remained unchanged.

Table 4. Number of individual species with HSI increasing, decreasing, or remaining unchanged between the 1988 and 2003 inventories for Carlton County, Minnesota. These datasets include updates to individual stands occurring after the original measurement. Values based on percent change. Results include only those species found in GEIS ecoregion four and are reported by species group.

Species Group	NA	Decrease		No Change	Increase		
		20-30%	10-20%	0-10%	10-20%	20-30%	>30%
Birds	18	0	28	57	23	10	0
Grouse	0	0	0	2	0	0	0
Small/medium mammals	0	2	1	16	2	0	1
Large mammals	0	0	0	1	1	0	2
Herptofauna	2	0	2	4	0	0	0

For most species in the bird and small/medium mammal groups, those that had an increasing HSI generally preferred forest types in the seedling/sapling size class, whereas those that decreased preferred types in the poletimber/sawtimber size class. Still, some species saw changes due to unique shifts in the size class distribution of specific forest types. For the large mammals, the black bear, white-tailed deer, and gray wolf all benefited from increased acreage in older stands. Interestingly, two herptofauna species experienced reduced habitat, even with the presence of older stands (which herptofauna typically prefer). This was due to very specific trend anomalies that showed either fewer acres and/or younger stands in certain forest type groups. As expected, the results generally mirrored the changes in age class and size class distributions between the inventories, reflecting the movement towards older and yet smaller stands (see FIA data for additional evidence of this trend in Minnesota). Forest management and planning may continue or reverse the direction of the individual HSI values, depending on CC objectives for their forestland and any particular wildlife species of interest.

Overall, the above findings are not unique. For all forest habitat models that relate species preferences to forest type and size class information, changing (or not changing) the landscape in some way will benefit some species and diminish others. Therefore, the actual importance and utility of these and other WHINGS results will depend on the user, the criteria surrounding their particular application, and the desired composition of species to promote on the landscape. For this case study, WHINGS facilitates estimation of habitat trends over a 15 year period, and thus assists with management planning to achieve desired county objectives while addressing environmental issues and best practices.

Importantly, the precision and accuracy of the forest inventory data is well understood. However, the HSI models were developed from a necessarily coarse synthesis of species-habitat relationships that have yet to be rigorously tested. Trials such as these, therefore, may also suggest improvements needed for the models for the various wildlife species. Still, the difficulty in estimating population numbers and habitat use for many species complicates refining the models. Until mitigation of these issues, results from the current version of WHINGS should be viewed as instructive, but not definitive.

Further research will incorporate the current WHINGS functionality in R into a publically available Visual Basic program hosted online. The need remains for future studies to increase the detail in WHINGS and continue updating the matrix of species-habitat relationships to reflect advances in wildlife research (see Frelich et al. 2012). The WHINGS model has great potential to aid forest and wildlife management, but only if the precision and accuracy of the component species-habitat models are well known and documented.

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Appendix 1: Forest Type Crosswalk

Table A1.1 gives the crosswalk between the GEIS, FIA, and MNDNR forest type definitions (Jaakko Pöyry Consulting, Inc. 1992a; O'Connell et al. 2014; MNDNR 2012). Those forest types at the end of the table represent forest types encountered in Minnesota FIA data that did not directly correspond to a GEIS forest type. For these nonmatching types that reference a specific species, the most closely related forest type (by species) recognized by the GEIS was selected (e.g., Scotch pine mapped to red pine). For those types that referenced broad groups (e.g., other hardwoods), the individual tree data was consulted to determine the most prolific species within that FIA forest type. The associated GEIS forest type then mirrored the dominant tree species.

Table A1.1. Forest type definition crosswalk between the GEIS, FIA, and MNDNR approaches. The forest types are grouped by broad forest type categories. Substantial portions of this table are reproduced from Page and Ek (2005).

GEIS Birds	GEIS Mammals	FIA Group Code	FIA Forest Type Group	FIA Code	FIA Forest Type	CSA Code	MNDNR-CSA Cover Types
Upland pine	Jack pine	100	White, red, jack pine	101	Jack pine	53	Jack pine
Upland pine	Red pine	100	White, red, jack pine	102	Red pine	52	Norway pine
Upland pine	White pine	100	White, red, jack pine	103	Eastern white pine	51	White pine
Upland spruce/fir	Upland spruce/fir	120	Spruce fir	121	Balsam fir	62	Balsam fir
Upland spruce/fir	White spruce	120	Spruce fir	122	White spruce	61	White spruce
Lowland conifer	Black spruce	120	Spruce fir	125	Black spruce	71	Black spruce, lowland
Lowland conifer	Black spruce	120	Spruce fir	125	Black spruce	74	Black spruce, upland
Lowland conifer	Black spruce	120	Spruce fir	125	Black spruce	75	Stagnant spruce
Lowland conifer	Tamarack	120	Spruce fir	126	Tamarack	70	Upland larch
Lowland conifer	Tamarack	120	Spruce fir	126	Tamarack	72	Tamarack
Lowland conifer	Tamarack	120	Spruce fir	126	Tamarack	76	Stagnant tamarack
Lowland conifer	Northern white-cedar	120	Spruce fir	127	Northern white-cedar	73	Northern white-cedar
Lowland conifer	Northern white-cedar	120	Spruce fir	127	Northern white-cedar	77	Stagnant cedar
Northern hardwoods	Oak	500	Oak hickory	503	White oak/red oak/hickory	30	Oak
Northern hardwoods	Oak	500	Oak hickory	504	White oak	30	Oak
Northern hardwoods	Oak	500	Oak hickory	505	Northern red oak	30	Oak
Northern hardwoods	Oak	500	Oak hickory	509	Bur oak	30	Oak
Northern hardwoods	Oak	500	Oak hickory	512	Black walnut	25	Walnut
Northern hardwoods	Oak	500	Oak hickory	513	Black locust	40	Central hardwoods
Northern hardwoods	Oak	500	Oak hickory	516	Cherry/white ash/yellow-poplar	40	Central hardwoods
Northern hardwoods	Oak	500	Oak hickory	517	Elm/ash/black locust	40	Central hardwoods
Northern hardwoods	Oak	500	Oak hickory	519	Red maple/oak	40	Central hardwoods

GEIS Birds	GEIS Mammals	FIA Group Code	FIA Forest Type Group	FIA Code	FIA Forest Type	CSA Code	MNDNR-CSA Cover Types
				520	Mixed upland hardwoods		
	Elm-ash-cottonwood	700	Elm, ash, cottonwood	701	Black ash/American elm/red maple	1	Ash
				702	River birch/ sycamore	9	Lowland hardwoods
				703	Cottonwood	15	Cottonwood
				704	Willow	6	Willow
				705	Sycamore/pecan/American elm	9	Lowland hardwoods
				706	Sugarberry/hackberry / elm/green ash		
				707	Silver maple/American elm		
				708	Red maple/lowland		
				709	Cottonwood/willow	15	Cottonwood
	Maple-basswood	800	Maple, beech, birch	801	Sugar maple/beech/ yellow birch	20	Northern hardwoods
				802	Black cherry		
				805	Hard maple/ basswood		
				809	Red maple/upland		
Aspen-birch	Aspen	900	Aspen-birch	901	Aspen	12	Aspen
						78	Offsite aspen
	Paper birch			902	Paper birch	13	Birch
	Balsam poplar			904	Balsam poplar	14	Balm of Gilead
	Aspen-birch			905	Pin cherry		
Upland pine	Red pine	380	Exotic softwoods	381	Scotch pine	54	Scotch pine
	White pine	400	Oak pine	401	White pine/red oak/white ash		
Northern hardwoods	Elm-ash-cottonwood	990	Exotic hardwoods	995	Other exotic hardwoods		
	Oak	170	Other eastern softwoods	171	Eastern redcedar	81	Red cedar
		400	Oak pine	402	Eastern redcedar/ hardwood		
Aspen-birch	Aspen-birch	400	Oak pine	409	Other pine/hardwood		
		960	Other hardwoods	962	Other hardwoods		

Appendix 2: White-tailed Deer Zones

Table A2.1. Minnesota counties comprising the white-tailed deer zones used in the GEIS and WHINGS. See Frelich et al. (2012) for a description of the deer zones.

Zone 1		Zone 2 & 3		Zone 4	
FIA County Code	**County Name**	**FIA County Code**	**County Name**	**FIA County Code**	**County Name**
7	Beltrami	1	Aitkin	11	Big Stone
21	Cass	3	Anoka	13	Blue Earth
29	Clearwater	5	Becker	15	Brown
31	Cook	9	Benton	23	Chippewa
57	Hubbard	17	Carlton	27	Clay
61	Itasca	19	Carver	33	Cottonwood
69	Kittson	25	Chisago	43	Faribault
71	Koochiching	35	Crow Wing	47	Freeborn
75	Lake	37	Dakota	51	Grant
77	Lake of the Woods	39	Dodge	63	Jackson
89	Marshall	41	Douglas	73	Lac qui Parle
113	Pennington	45	Fillmore	81	Lincoln
119	Polk	49	Goodhue	83	Lyon
125	Red Lake	53	Hennepin	85	McLeod
135	Roseau	55	Houston	91	Martin
137	St. Louis	59	Isanti	101	Murray
		65	Kanabec	103	Nicollet
		67	Kandiyohi	105	Nobles
		79	Le Sueur	107	Norman
		87	Mahnomen	117	Pipestone
		93	Meeker	121	Pope
		95	Mille Lacs	127	Redwood
		97	Morrison	129	Renville
		99	Mower	133	Rock
		109	Olmsted	149	Stevens
		111	Otter Tail	151	Swift
		115	Pine	155	Traverse
		123	Ramsey	165	Watonwan
		131	Rice	167	Wilkin
		139	Scott	173	Yellow Medicine
		141	Sherburne		
		143	Sibley		
		145	Stearns		
		147	Steele		
		153	Todd		
		157	Wabasha		
		159	Wadena		
		161	Waseca		
		163	Washington		
		169	Winona		
		171	Wright		