

Calculating Forest Values

Calculating an HSI for an old-growth indicator species

—by Glen Jordan

Introduction

Problem

How do you use geographic information system (GIS) technology to explore the ecological well-being of a forest?

The presence of old growth in a forest is part of a healthy forest ecology. An indicator of old growth is a high habitat suitability index (HSI) rating for a species that is known to prefer old-growth conditions. One such species is the Blackburnian warbler in northeastern North America.

In this exercise, you'll analyze a forest for old-growth value, using the Blackburnian warbler as an indicator species. By calculating a warbler HSI for each stand of trees in the Woodlot, you'll be able to compile the average sizes and densities of HSI patches and arrive at an assessment of the forest's ecological well-being from an old-growth perspective.

Location

A small, 1,400-hectare Woodlot in the Acadian-New England forest region of North America

Time to complete the lab

Two hours

Keywords: old growth; habitat suitability index; Blackburnian warbler; characterizing by single numbers; selecting features by attribute; using VB code in Field Calculator; dissolving features; summarizing an attribute

Prerequisites

A basic working knowledge of ArcGIS® software and GIS data, including use of a geodatabase (Some knowledge of computer programming, Visual Basic [VB] in particular, and familiarity with forest inventory data and terminology are helpful but not essential.)

Data used in this lab

- Feature classes and rasters for a forest woodlot (personal geodatabase)
- Geographic coordinate system: NAD 1983 CSRS New Brunswick Stereographic
- Datum: NAD83 datum
- Projection: New Brunswick Double Stereographic Grid (unless otherwise stated)

Student activity

You will explore the analytic thinking involved in calculating a habitat suitability index for an old-growth indicator species and summarize your results in a table.

An HSI is simply a numerical index that rates habitat quality in a given forest for a given species of animal on a scale from 0 (unsuitable) to a larger number (optimal habitat). Calculating an HSI for an indicator species is a way to get a sense of the ecological well-being of a forest. Among forest managers, HSI models are a very common means of assessing habitat availability and quality for a wide range of forest animals.

Any species that defines an environmental characteristic or condition can be an indicator species. With old-growth forests generally in decline, indicator species are often considered when on the lookout for early warning signs of problems in the ecology. For example, in northeastern North America, the Blackburnian warbler (*Dendroica fusca*) is a species that prefers old-growth conditions. It makes a good indicator species for assessing the ecological well-being of a forest, at least from an old-growth perspective.

The details of calculating an HSI can become quite complex, depending on the animal involved. HSI models generate much debate about their accuracy because they use theory of species-habitat relationships, not cause-effect relationships. These models require thorough validation before they can be relied on as a monitoring or management tool (for more information, go to the Environmental Protection Agency [EPA] Atlantic Ecology Division website at <http://www.epa.gov/aed/>).

Results expected

A table summarizing Blackburnian warbler HSI patches by number, area occupied, average size, and density

| OBJECTID * | HSI | Count_HSI | Average_Shape_Area | Sum_Shape_Area | PDensity |
|------------|-----|-----------|--------------------|----------------|-----------|
| 1 | 1 | 60 | 11.652366 | 699.14197 | 8.581948 |
| 2 | 2 | 18 | 1.945334 | 35.016018 | 51.405045 |
| 3 | 3 | 15 | 2.404767 | 36.071498 | 41.58408 |
| 4 | 4 | 37 | 3.655656 | 135.259255 | 27.354876 |
| 5 | 5 | 30 | 3.947439 | 118.423158 | 25.332882 |
| 6 | 6 | 28 | 5.502172 | 154.060814 | 18.174641 |
| 7 | 7 | 35 | 5.881668 | 205.858397 | 17.001978 |
| 8 | 8 | 6 | 2.250034 | 13.500203 | 44.443775 |

Data available

- Cover types feature class: *cover*
- Stand volumes table: *volumes*

Solution steps

1. Assign stands seral stage and type ratings.
2. Calculate HSI values.
3. Form HSI patches.
4. Calculate HSI patch statistics.

ASSIGN STANDS SERAL STAGE AND TYPE RATINGS

What species-habitat relationships would you use in calculating a Blackburnian warbler HSI?

Blackburnian warbler numbers are highest in mature old stands with high percentages of coniferous tree species. The warbler is rarely found in younger, hardwood-dominated stands. You can graphically deduce this habitat relationship in charts that single out the two key variables, stand age and softwood content. The charts illustrate that habitat rating is a bit more sensitive to stand age than softwood content and reaches a significantly higher level only at older ages.

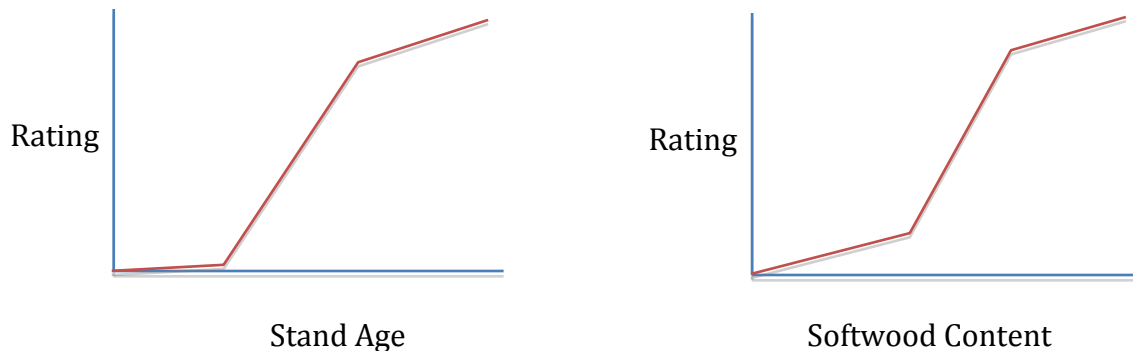


Figure 1. Blackburnian warbler habitat ratings as a function of stand age and softwood content.

Using the charts as a guide, you can build ratings tables, 0 (worst) to 5 (best), to use in classifying stands later on.

| Seral stage | Age | Rating |
|--------------|--------|--------|
| Regenerating | 0–20 | 0 |
| Immature | 21–40 | 0 |
| Pole | 41–60 | 2 |
| Mature | 61–100 | 4 |
| Old | >100 | 5 |

Table 1. Seral stage rating scheme

| Stand type | Softwood | Rating |
|------------|-----------------------|--------|
| Hardwood | HW_ >= 70 | 1 |
| Mixed wood | SW_ < 70 AND HW_ < 70 | 4 |
| Softwood | SW_ >= 70 | 5 |

Table 2. Stand type rating scheme

After assigning these ratings to individual Woodlot stands, you can calculate a composite habitat suitability rating simply by multiplying the two, but that's for later on. For now, just reclassify Woodlot stands by seral stage and stand type.

RELATED CONCEPT: RECLASSIFY USING THEMATIC ATTRIBUTES TO QUANTIFY

- 1 Start ArcMap™, and if you haven't already done so, use *Environment Settings* to establish both your Current Workspace and Scratch Workspace as your *Woodlot* geodatabase.
- 2 Add the *cover* feature class as a layer.
- 3 In the *Cover Types* attribute table, add two new short integer fields named *Type_Rating* and *Age_Rating*.

Recall that spaces and a number of other special characters are not permitted in field names, although you can always assign an alias that includes spaces or special characters.

With the *Type_Rating* and *Age_Rating* fields added, you can go about the business of calculating the rating values (0–5) for each.

Do you know why you should join the *volumes* table to the *Cover Types* attribute table next? You'll need its *SW_* and *HW_* fields in assigning stands to softwood, hardwood, and mixed wood stand types. These fields provide softwood and hardwood percentages, respectively.

- 4 By way of the *STAND_ID* and *Stand#* fields, respectively, join the *volumes* table to the *Cover Types* attribute table.

1. Choose the field in this layer that the join will be based on:
Stand#

2. Choose the table to join to this layer, or load the table from disk:
volumes
 Show the attribute tables of layers in this list

3. Choose the field in the table to base the join on:
STAND_ID

Join Options

Keep all records
All records in the target table are shown in the resulting table. Unmatched records will contain null values for all fields being appended into the target table from the join table.

Keep only matching records
If a record in the target table doesn't have a match in the join table, that record is removed from the resulting target table.

Validate Join

Figure 2. Joining the *volumes* table to the *Cover Types* attribute table.

Now you're all set to classify stands according to their seral stage and stand type as a prelude to calculating HSI values for the Blackburnian warbler.

Standard procedure here would have you use *Select By Attributes* and *Field Calculator* to assign values to the *Type_Rating* and *Age_Rating* fields in a series of steps. While this works, it can become laborious with a large number of queries and calculations to make.

A more efficient alternative is to use VB code in *Field Calculator* as a substitute for *Select By Attributes*. Try it in calculating *Type_Rating* values.

- 5 Use the *VB Script* and *Show Codeblock* options in *Field Calculator* to enter the VB code shown to the left of figure 3.
- 6 Calculate `Type_Rating = Rate`.

Copying and pasting the code into *Field Calculator* won't work unless you build the code in Notepad.

```

Dim Rate
\ Non-stand features
If [cover.AGE] = -99 Then
  Rate = Null
' Hardwood
ElseIf [volumes.HW_] >= 70 Then
  Rate = 1
' Softwood
ElseIf [volumes.SW_] >= 70 Then
  Rate = 5
' Mixedwood
Else
  Rate = 4
End If
    
```

Figure 3. Calculating *Type_Rating* values using a VB code block in *Field Calculator*.

Type_Rating values are calculated in one fell swoop.

Summarizing the *Type_Rating* field, you find 205 softwood-dominated stands, 250 mixed wood stands, and 78 hardwood-dominated stands.

| | OBJECTID * | Type_Rating | Count_Type_Rating |
|---|------------|-------------|-------------------|
| ▶ | 1 | 1 | 78 |
| | 2 | 4 | 250 |
| | 3 | 5 | 205 |

Figure 4. Tally of stand type ratings.

You can use similar VB coding to compute *Age_Rating* values.

7 Use the following VB code in *Field Calculator* to assign *Age_Rating* values:

```

Dim Rate
If [Age] = -99 Then
  Rate = Null
ElseIf [Age] >= 0 and [Age] <= 40 Then
  Rate = 0
ElseIf [Age] > 40 and [Age] <= 60 Then
  Rate = 2
ElseIf [Age] > 60 and [Age] <= 100 Then
  Rate = 4
Else
  Rate = 5
End If
    
```

8 Summarize the *Age_Rating* field to verify your results.

| | OBJECTID * | Age_Rating | Count_Age_Rating |
|---|------------|------------|------------------|
| ▶ | 1 | 0 | 275 |
| | 2 | 2 | 111 |
| | 3 | 4 | 138 |
| | 4 | 5 | 9 |

Figure 5. Tally of stand age ratings.

Completing the first stage of your Blackburnian warbler HSI calculation allows you to use the stand type and age ratings to derive single HSI values for each Woodlot stand, which is next.

CALCULATE HSI VALUES

This is a two-step process. First, you calculate a composite Blackburnian habitat rating by multiplying *Type_Rating* by *Age_Rating*. This produces values ranging from 0 to 25. A 25, for example, indicates an old softwood stand. A 20 includes both mature softwood and old mixed wood stands, which have equal habitat values.

Second, you derive a final HSI by assigning ordinal values between 1 (worst) and 8 (best) to the composite ratings, as shown in table 3.

| Composite Rating | Description | HSI |
|------------------|---|-----|
| 0 | Nonstand features, regenerating and immature stands | 1 |
| 2 | Pole stage hardwood stands | 2 |
| 4 | Mature and old hardwood stands | 3 |
| 9 | Pole stage mixed wood stands | 4 |
| 10 | Pole stage softwood stands | 5 |
| 16 | Mature mixed wood stands | 6 |
| 20 | Mature or old mixed wood stands | 7 |
| 25 | Old softwood stands | 8 |

Table 3. Assigning HSI values to stand type and age composites.

The procedure outlined, however, begs the question: why can't you simply assign each stand type and age combination a unique value at the outset and avoid calculating the *Type_Rating*, *Age_Rating*, and composite ratings altogether?

The reason is simply that eight values are more manageable and more easily interpreted than an unwieldy collection of 16.

Why not add the *Type_Rating* and *Age_Rating* fields instead of multiplying them?

By adding them, you'd create overlaps between suitable and unsuitable habitat conditions. For example, an old hardwood stand (5+1) would have the same rating as a pole stage mixed wood stand (4+2), when in fact the combinations do not have the same habitat value.

RELATED CONCEPT: RECLASSIFY USING THEMATIC ATTRIBUTES TO RANK

- 1 To the *Cover Types* attribute table, add two short integer fields, *Composite* and *HSI*.
- 2 Remove the *volumes* join.

Removing a join is not mandatory, but when working with a large feature class that has hundreds of features, removing a join that's no longer needed improves efficiency in subsequent processing.

- 3 Use *Field Calculator* to calculate *Composite* values by multiplying *Type_Rating* by *Age_Rating*.

This computes *Composite* values ranging from 0 to 25. Reassigning these composite ratings to values between 1 and 8 will compute your HSI for each stand.

- 4 Use some VB coding in *Field Calculator* to calculate HSI values ranging from 1 to 8 as a function of *Composite* values, as follows:

```
Dim Res
If [Composite] = 0 Then
    Res = 1
ElseIf [Composite] = 2 Then
    Res = 2
ElseIf [Composite] = 4 Or [Composite]
= 5 Then
    Res = 3
ElseIf [Composite] = 8 Then
    Res = 4
ElseIf [Composite] = 10 Then
    Res = 5
ElseIf [Composite] = 16 Then
    Res = 6
ElseIf [Composite] = 20 Then
    Res = 7
ElseIf [Composite] = 25 Then
    Res = 8
Else
    Res = Null
End If
```


- 6 Summarize the *HSI* field to get an indication of the relative tallies of each HSI value.

| | OBJECTID * | HSI | Count_HSI |
|---|------------|--------|-----------|
| ▶ | 1 | <Null> | 0 |
| | 2 | 1 | 275 |
| | 3 | 2 | 19 |
| | 4 | 3 | 18 |
| | 5 | 4 | 49 |
| | 6 | 5 | 43 |
| | 7 | 6 | 54 |
| | 8 | 7 | 69 |
| | 9 | 8 | 6 |

Figure 6. Tally of HSI values across the Woodlot.

You discover that 69 stands are classified with an HSI of 7 (adequate habitat), while only 6 rate an HSI of 8 (best habitat).

What are the spatial characteristics of these desirable conditions? Are the stands small in size and widely dispersed, or do they occur in concentrations of relatively large patches? The warbler would prefer the latter spatial configuration.

FORM HSI PATCHES

Before you can assess the spatial configuration of stands with desirable HSI values, you'll need to form patches of common HSI condition. Removing the boundaries between adjacent stands that share a common HSI value—that is, that share a common patch type—accomplishes this.

RELATED CONCEPT: RECLASSIFY SPATIALLY—DISSOLVE

- 1 Use the *Dissolve* tool (*Data Management Tools » Generalization*) to aggregate Woodlot stands into patches based on their HSI values.
- 2 Save the result as a new feature class called *HSI* in your *Woodlot* geodatabase. Do not create multipart features.

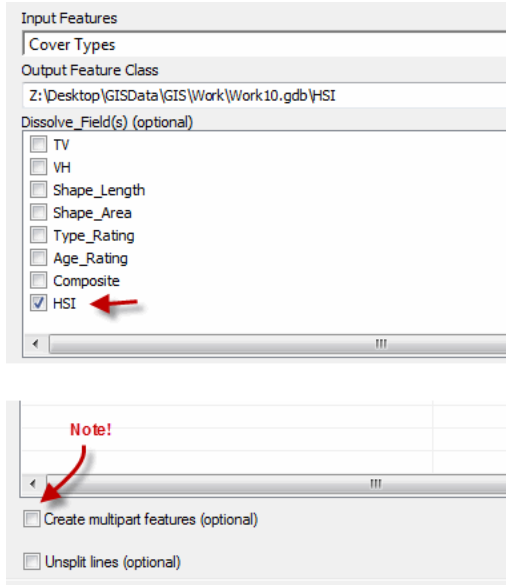


Figure 7. Using the *Dissolve* tool to create *HSI* patches.

Multipart features offer storage and processing advantages, but had you opted for multipart polygons here, the output would have consisted of eight features only, one for each *HSI* value.

In this case, you need the 229 individual polygons (patches).

- 3 Symbolize patches using their unique *HSI* values to get a sense of their spatial distribution.

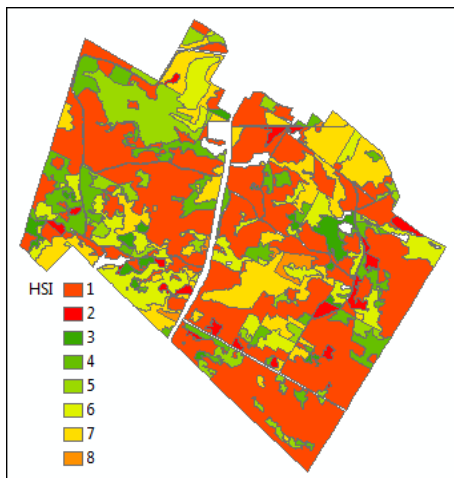


Figure 8. Distribution of 229 Blackburnian warbler patches based on *HSI* value.

How many patches are the desirable *HSI* 7 and 8? On average, are they relatively small or large? Patch configuration characteristics are important in assessing Blackburnian warbler habitat.

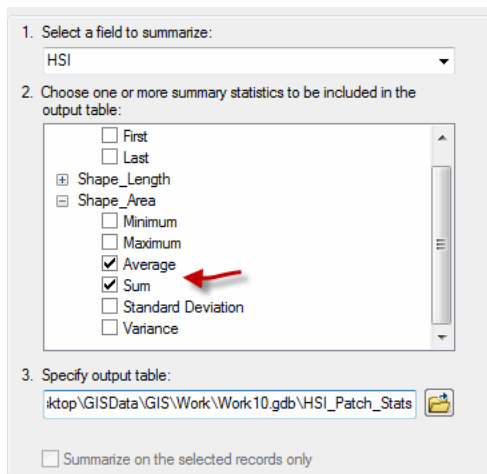
CALCULATE HSI PATCH STATISTICS

There are numerous ways to characterize patches across a forest. Three measures often used in habitat assessment are patch amounts (ha), average patch size (ha), and patch density (number/ha). In general, a few large patches are better than many small, scattered ones.

How will the Blackburnian warbler *HSI* 7 and 8 patches you identified in the Woodlot measure up?

RELATED CONCEPT: CHARACTERIZE USING A SINGLE NUMBER

- 1 In the *HSI* attribute table, summarize the *HSI* field by *Shape_Area* for both average and sum.
- 2 In your *Woodlot* geodatabase, save the result as a table called *HSI_Patch_Stats*.



Using the Summary Statistics tool (Analysis Tools » Statistics) instead of the Summarize function accessible via the attribute table causes some differences in output field names.

Figure 9. Summarizing the *HSI* patches.

| | OBJECTID* | HSI | Count_HSI | Average_Shape_Area | Sum_Shape_Area |
|---|-----------|-----|-----------|--------------------|----------------|
| ▶ | 1 | 1 | 60 | 116523.661638 | 6991419.698307 |
| | 2 | 2 | 18 | 19453.343594 | 350160.184688 |
| | 3 | 3 | 15 | 24047.665295 | 360714.979432 |
| | 4 | 4 | 37 | 36556.55546 | 1352592.552005 |
| | 5 | 5 | 30 | 39474.386119 | 1184231.583577 |
| | 6 | 6 | 28 | 55021.719286 | 1540608.140012 |
| | 7 | 7 | 35 | 58816.684719 | 2058583.965152 |
| | 8 | 8 | 6 | 22500.337959 | 135002.027752 |

Figure 10. Frequency, average size (m²), and area (m²) of *HSI* patches.

Before dividing *Count_HSI* by *SUM_Shape_Area* values to calculate patch density (number/ha), wouldn't it be a good idea to convert square meters to hectares, at least for *SUM_Shape_Area*?

- 3 Use *Field Calculator* to convert square meters to hectares for fields *Average_Shape_Area* and *Sum_Shape_Area* by dividing by 10,000.

| OBJECTID * | HSI | Count_HSI | Average_Shape_Area | Sum_Shape_Area |
|------------|-----|-----------|--------------------|----------------|
| 1 | 1 | 60 | 11.652366 | 699.14197 |
| 2 | 2 | 18 | 1.945334 | 35.016018 |
| 3 | 3 | 15 | 2.404767 | 36.071498 |
| 4 | 4 | 37 | 3.655656 | 135.259255 |
| 5 | 5 | 30 | 3.947439 | 118.423158 |
| 6 | 6 | 28 | 5.502172 | 154.060814 |
| 7 | 7 | 35 | 5.881668 | 205.858397 |
| 8 | 8 | 6 | 2.250034 | 13.500203 |

Figure 11. *HSI* patch statistics in hectares.

As you can see, average patch sizes for *HSI* 7 and 8 patches are quite small, at 5.88 ha and 2.25 ha, respectively. Keep in mind, the Blackburnian warbler is a small bird, and these sizes may support at least a few of the species.

Patch density, or number of patches per hectare, is another way of characterizing patch configuration. Patch density is calculated by dividing the number of patches by their combined area. Computed density values are usually small fractions, so they are often multiplied by 100, with values expressing patches per 100 ha. In any event, high patch density values are not desirable, as they indicate small, dispersed patches.

In this analysis, given the relatively small average patch sizes, you'd expect patch density values for *HSI* 7 and 8 patches to be high.

- 4 Add a *PDensity* field of float type to *HSI_Patch_Stats* and use it to calculate patch density values as $\text{Count_HSI} / \text{Sum_Shape_Area} * 100$.

| OBJECTID * | HSI | Count_HSI | Average_Shape_Area | Sum_Shape_Area | PDensity |
|------------|-----|-----------|--------------------|----------------|-----------|
| 1 | 1 | 60 | 11.652366 | 699.14197 | 8.581948 |
| 2 | 2 | 18 | 1.945334 | 35.016018 | 51.405045 |
| 3 | 3 | 15 | 2.404767 | 36.071498 | 41.58408 |
| 4 | 4 | 37 | 3.655656 | 135.259255 | 27.354876 |
| 5 | 5 | 30 | 3.947439 | 118.423158 | 25.332882 |
| 6 | 6 | 28 | 5.502172 | 154.060814 | 18.174641 |
| 7 | 7 | 35 | 5.881668 | 205.858397 | 17.001978 |
| 8 | 8 | 6 | 2.250034 | 13.500203 | 44.443775 |

Figure 12. *HSI* patch densities (#/100 ha).

Patch density for the best *HSI* 8 habitat is a high 44.4 patches per 100 ha. That, combined with only 13.5 ha of this habitat overall, tells you that the Blackburnian warbler will not find a lot of its preferred conditions, old softwood areas, in this forest.

On the other hand, patch density for its next best habitat, *HSI* 7, mature or old mixed wood conditions, is a relatively low 17 patches per 100 ha. And there are 205 ha overall of *HSI* 7 habitat.

Like many forests, the Woodlot has not been actively managed for old growth. As a result, overall, the Woodlot offers limited habitat value for a species like the Blackburnian warbler and rates poorly from an ecological perspective.

Conclusion

Your analysis used some of the same attribute reclassifying and summarizing functionality often used in forest valuation, whether economic, social, or ecological. In this exercise, however, you reclassified stands spatially (dissolve) as well as aspatially. Visual Basic programming proved helpful in the latter.

Do you think the Blackburnian warbler, and dozens of other species that share similar old-growth habitat requirements, are likely to find a home in the Woodlot? What does your analysis tell you about old-growth value in the Woodlot generally? Is there an ecological problem?

Submit your work

- Summary table of HSI patch statistics: total area (ha), average size (ha), and patch density (#/100 ha)
- Based on lab results, a paragraph detailing an assessment of value in the Woodlot, from an ecological perspective (Is it good news or bad?)
- A summary of the exercise, indicating where and how the related reclassify and characterize concepts and analysis techniques are used (Your summary could take the form of a table that checks off each of these elements.)
- An HSI for another indicator species designed and calculated using techniques similar to those used in developing the Blackburnian warbler HIS

Credits

Sources of supplied data

Course Data

Data\cover, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\highway, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\newprop, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\tin, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Woodlot.mdb, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Codes\Woodlot_Codes.xls, courtesy of University of New Brunswick UNB Faculty of Forestry and Environmental Management

Data\Coordinate Systems\ATS 1977 New Brunswick Stereographic.prj, courtesy of ESRI
Data\Coordinate Systems\NAD 1983 CSRS New Brunswick Stereographic.prj, courtesy of ESRI

Data\GPS\Knowledge.shp, courtesy of University of New Brunswick
Data\GPS\towers.xls, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Layer Files\Age Classes.lyr, courtesy of Glen Jordan
Data\Layer Files\Air Photo Centre Points.lyr, courtesy of Glen Jordan
Data\Layer Files\Main Roads.lyr, courtesy of Glen Jordan
Data\Layer Files\Mgt Compartments.lyr, courtesy of Glen Jordan
Data\Layer Files\Non-forested.lyr, courtesy of Glen Jordan
Data\Layer Files\Secondary Roads.lyr, courtesy of Glen Jordan
Data\Layer Files\Streams.lyr, courtesy of Glen Jordan

Data\Mass Points\DTM.txt, courtesy of Service New Brunswick

Data\Models\Clearcutting.tbx, courtesy of Glen Jordan
Data\Models\Forest Analysis.tbx, courtesy of Glen Jordan
Data\Models\Forest Values.tbx, courtesy of Glen Jordan

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