1993 Project Abstract
FOR THE PERIOD ENDING JUNE 30, 1995
This project was supported by the MN Future Resources Fund

TITLE: Description and evaluation of Minnesota Old-growth Forests - Continuation
PROGRAM MANAGER: Kurt A. Rusterholz
ORGANIZATION: Department of Natural Resources
LEGAL CITATION: M.L. '93 Chp. 172, Sec. 14, Subd. 6(c)
APPROPRIATION AMOUNT: $250,000

Statement of Objectives: A) to accelerate evaluation of DNR old-growth candidate stands, B) to develop detailed descriptions of old-growth examples of three forest types, and C) to characterize the ecotrophic mycorrhizal fungi found in important old-growth forest types.

Project Results: 449 DNR Old-growth candidate stands were sampled during the project. This number constitutes 87% of old-growth candidate stands outside Itasca State Park. Of these 449 stands, 415 have now been formally evaluated and recommended for protection or release. Final disposition of these stands will be determined by DNR Regional Planning Teams.

A total of 51 forest stands of three forest types: maple-basswood, oak, and black ash swamp were sampled for species and structural composition. For maple-basswood and oak, matched pairs of old-growth and younger stands on similar sites were identified. Overall, old-growth stands had significantly greater basal area of living trees and down log volume than did comparable younger more disturbed stands. In all three forest types, old-growth stands showed a significantly higher proportion of trees in large size classes and relatively fewer trees in small size classes.

Mycorrhizal fungi fruiting bodies (mushrooms) were quantitatively surveyed in two old-growth forest types: red pine and northern hardwood-conifer and compared to the mushroom diversity in younger stands. Sampling used transects and replicate plots. An unexpectedly high species richness was documented (220 species in red pine and 110 in northern hardwood-conifer) in comparison to reports for younger stands. Species composition varied both seasonally and between years. Mushroom abundance ranged from 200 to 3,300 fruitbodies per hectare (2.5 acres) in northern hardwood-conifer forest and from 19,800 to 34,900 per hectare in red pine forest. There was little overlap in species composition between these two forest types and two additional old-growth forest types, maple-basswood and white pine, which were briefly examined. Differences exist between old-growth and younger forests. Of the 315 species, approximately 200 (65%) appear to be new state records. This study provides the first data on mushroom diversity in old-growth forests for eastern North America and will provide baseline data for environmental monitoring of forest health. However, several addition years of research are required to document the total richness of this "flora".

Use and dissemination of project results: The results of the old-growth stand evaluations are now being used by the DNR to identify which candidate stands will be protected as old growth. These evaluation procedures and a summary of the results were presented at two national conferences on eastern old growth and will be published this fall as a book chapter in a book on eastern old growth (Island Press). A similar evaluation procedure is now being used by Superior National Forest for evaluating potential old-growth pine stands. The description of old-growth forest types will be published in a refereed journal and will be used in a future revision of the DNR Old Growth Guideline. Results of the fungi research were presented at poster sessions at the International Mycological Congress, Vancouver, August 1994; Department of Plant Biology, Univ. of Minnesota, Sept. 1994; and the Minnesota Native Plant Society Symposium on Minnesota's Coniferous Forests, April 1995. Talks on the fungi research were also presented to the Minnesota Native Plant Society, the Minnesota Mycological Society, and the St. Paul Audubon Society.

Date of Report: - July 1, 1995

LCMR Final Report - Summary - Research

I. Project Title: Description and Evaluation of Minnesota Old-growth Forests - Continuation

Program Manager: Kurt A. Rusterholz
Natural Heritage Program
Department of Natural Resources - Box 7
500 Lafayette Road
St. Paul, Minnesota 55155
(612) 297-7265

A. M.L. 93, Chpt. 172, Sec. 14, Subd. 6(c).

Total Biennial LCMR Budget: $250,000
Anticipated Balance (7/1/95): $ 0

Appropriation Language as drafted 7/27/92: Subd. 6(c). This appropriation is from the future resources fund to the commissioner of natural resources to accelerate the evaluation of old-growth candidate stands ($90,000), develop detailed descriptions of old-growth forest types ($110,000) and determine habitat relations of forest fungi in old growth forests ($50,000) for completion of the implementation of the department of natural resources old growth guidelines.

B. LMIC Compatible Data Language: Not applicable

C. Status of Match Requirement: Not applicable

II. Project Summary: This project combines inventory necessary for implementation of the Minnesota Department of Natural Resources' Old Growth Guidelines with research on the species composition and structure of old-growth forests. The inventory portion of this project is an accelerated field evaluation of forest stands designated as old-growth candidates under the DNR's Old Growth Guidelines. Field evaluation will be used to determine which stands will be protected as old-growth forest sites and which stands will be released for other forest management.

The research portion of this project contains two objectives. The first objective is to develop descriptions of the structure and composition of old-growth maple-basswood forests, oak forests, and black ash swamp forests. Descriptions will be developed from data obtained by sampling known old-growth examples of these forest types. At the same time, younger, more disturbed stands will be sampled for comparison with old-growth stands. Descriptions developed from this research will be used to set standards for identifying additional old-growth stands and can be used as models for management of older forests to promote biological diversity. The second research objective is to characterize the ectotrophic mycorrhizal fungi in old-growth forests. These forest fungi are very poorly known in Minnesota, yet these symbiotic fungi are essential to healthy tree grow' Furthermore, it appears that these fungi

important advance indicators of declines in forest productivity. These fungi will be sampled throughout the growing season in old-growth and younger stands used to characterize old-growth forest types. The resulting baseline data will be invaluable in assessing environmental trends in Minnesota forests.

III. Statement of Objectives:

A. Accelerate evaluation of DNR old-growth candidate stands.

B. Develop detailed descriptions of old-growth examples of three forest types.

C. Characterize the ectotrophic mycorrhizal fungi found in important old-growth forest types.

IV. Research Objectives

A. Title of Objective: Accelerate evaluation of DNR old-growth candidate stands ($90,000).

A.1. Activity: Begin and complete field evaluation of 200 old-growth candidate stands. Stands will be evaluated by trained teams of DNR resource professionals and perhaps contract ecologists.

A.1.a. Context within the project: This activity is largely independent of the research portion of the project; however, descriptions of old-growth northern hardwood forests developed by the FY 92-93 old-growth research project will be used to construct criteria for evaluation of old-growth candidate northern hardwood stands.

A.1.b. Methods: Standardized evaluation procedures will be developed for each forest type to be evaluated. These procedures will allow evaluators to assign a relatively objective numerical score to each stand based on the following criteria: 1) stand age, 2) degree of human disturbance, 3) stand size and context, and 4) stand structure.

Following each field season, the Natural Heritage Program Forest Ecologist will rank candidate stands of each type within each ecoregion of the state using the field evaluators' scores. These rankings will be used to determine which candidate stands will be recommended for protection as old growth and which stands will be released for other management.

A.1.c. Materials: Equipment necessary to complete field evaluations consists primarily of standard forestry inventory tools including diameter tapes, increment borers, clinometers, compasses, etc. In addition, hand lenses and binocular dissecting scopes will be necessary to count tree rings in some species.

A.1.d. Budget: $90,000
Anticipated Balance (7/1/95): $ 0

A.1.e. Timeline:	7/93	1/94	6/94	1/95	6/95
Develop evaluation procedures	**		*		*
Field evaluation of candidate stands	****		*******	***	
Recommendations of sites for protection		**		**	

AA. Status: This objective has been successfully completed. In fact, we sampled 449 old-growth candidate stands, more than twice the number that we initially proposed to evaluate (see Section A.1).

As the project progressed it became apparent that we could assign contractors to gather stand data that would allow us to complete evaluations of more than 400 stands. Subsequently field checking of old-growth candidate stands was carried out by contractors supervised by the DNR Forestry Resource Assessment Unit in Grand Rapids. These contractors and a group of DNR resource professionals were trained to gather data on candidate stands at a two-day training session conducted by the Natural Heritage Program (NHP) and DNR Forestry.

At the beginning of the summer in 1993, contracts to gather data on 445 old-growth candidate stands were let. These 445 stands included 156 northern hardwood stands, 126 lowland hardwood stands, 48 black ash stands, 108 white-cedar stands, and 7 oak stands. Of these 445 stands, all but 29 stands were sampled during the 1993 field season, for a total of 415 stands sampled, or twice the number indicated in the workprogram. Those 29 stands not sampled were generally inaccessible due to wet conditions present in 1993. These stands will be added the list to be sampled by DNR personnel in the future.

In addition to the 415 stands sampled in 1993, 34 candidate stands in northern Minnesota were sampled in May and June 1995; and nine more stands are scheduled to be sampled in late June.

The 415 stands sampled in 1993 were sampled as 272 sample units of one or more stands. Some sample units contained two or more adjacent stands that were judged to be an ecological unit. Data from each sample unit were summarized and analyzed using a computer program that assigned points to sample units based on their ecological attributes. Additional analysis of the tree species composition of each sample unit was completed using multivariate statistical techniques. This information is being used to help revise the Natural Heritage Program Natural Community Classification.

Scoring of the sample units was completed manually by the NHP Forest Ecologist. We then ranked sample units of each forest type for each ecoregion of the state. Using this information the NHP has prepared preliminary recommendations on which stands should be designated and protected as old growth and which stands should be returned to other management. Because many stands were of intermediate old-growth quality (e.g., they had experienced a moderate amount of past selective logging but otherwise exhibited many old-growth features), we chose three types of recommendations: 1) reserve as old growth, 2) reserve until stands can be evaluated in a landscape context as part of the DNR regional planning process, and 3) release for other appropriate management. Stands of intermediate quality were assigned to category 2.

The next step in the process of protecting old-growth stands will be accomplished at the regional level within the DNR. Here the information and recommendations regarding the old-growth candidate stands prepared by the NHP will be used in the Regional Planning Process. In this process interdisciplinary planning teams in each ecoregion of the state will choose candidate stands for long-term protection based on their quality, NHP recommendations, and context within the landscape.

Problems: No significant problems were encountered. More than twice as many old-growth candidate stands were evaluated as were originally outlined in this workprogram. The process of using outside forest inventory contractors worked reasonably well. The only real problem, scattered misidentification of tree species, was minor. We were able to correct most of these errors, which had little, if any effect on the scoring of stands.

Summary: The formal evaluation of hundreds of potential old-growth stands by the Minnesota DNR is the first project of its kind in the eastern U.S. As a result of this LCMR project, 87% of the remaining DNR candidate stands outside Itasca State Park were field checked. This project will eventually result in thousands of acres of old-growth forest in Minnesota receiving long-term protection. In addition, thousands of acres of old-growth candidate stands temporarily reserved since 1991, and which did not qualify as old growth will be available for other management. (A more detailed summary of this aspect of the project will be published this fall by Island Press as a chapter in a book on eastern old growth; a reprint of this chapter will then be provided to LCMR.)

B. Title of Objective: Develop detailed descriptions of old-growth examples of three forest types ($110,000).

B.1. Activity: Identify research sites in maple-basswood, oak, and black ash swamp forests.

B.1.a. Context within the project: Descriptions of old-growth forest types will require field data from representative examples of old growth. In order to distinguish characteristics typical of old-growth forest stands from those of mature, typically second-growth, forests, it will also be necessary to sample younger stands. This project will continue to cooperate with the Forest-Bird Diversity LCMR Project. Old-growth study sites sampled in this project will be censused for birds during the following field season.

B.1.b. Methods: At least ten old-growth stands will be located for each of the three forest types. Ten younger/more disturbed sites will be located for both maple-basswood forest and oak forest. The old-growth stands will be chosen from sites in the Natural Heritage Information System and from state and federal forest inventory databases.

B.1.c. Materials: Existing databases as described above will provide data to be entered in an ARC/INFO GIS. Materials necessary to field check sites are limited to appropriate vehicles.

B.1.d. Budget: $6,000
Anticipated Balance (7/1/95): $0

B.1.e. Timeline:	7/93	1/94	6/94	1/95	6/95
Compile list of potential sites	**				
Enter sites in GIS	*				
Select short list of sites	*				
Field check sites	*****		*		
Develop final list of sites			*		

B.2. Activity: Quantitatively sample at least ten plots in old-growth stands and at least ten plots in mature forest stands of maple-basswood forest and oak forest and ten plots in old-growth black ash forest.

B.2.a. Context within the project: Descriptions of old-growth forest types will be developed by quantitatively sampling both old-growth and mature stands using procedures designed to measure important old-growth features including stand age, tree species composition and size-class distribution, and size and volume of coarse woody debris.

B.2.b. Methods: Each stand will be sampled using a 0.1 ha (20 x 50 m) plot located within a representative portion of the stand. A plot of these dimensions allows the use of 20 x 20 m subplots for Minnesota Natural Heritage Program standard releves to sample species composition and vegetation structure.

Within each plot we will record data on trees and snags (e.g. species, diameter, canopy position); down logs; tip-up mounds; saplings; and seedlings. Stand origin date, site information, and indicators of human disturbance will be recorded.

B.2.c. Materials: Equipment needed for field sampling includes vehicles for transportation and field materials such as fiberglass plot tapes, dbh tapes, increment borers, tree core trays, clinometer, soil probe, pH meter, data books, etc.

B.2.d. Budget: $42,000
Anticipated Balance (7/1/95): $0

B.2.e. Timeline:	7/93	1/94	6/94	1/95	6/95
Sample field sites	****		******		***

B.3. Activity: Analyze field data and develop descriptions of old-growth forest types.

B.3.a. Context within the project: Analysis of field data is an essential step in the development of descriptions of old-growth forests. This activity will elucidate differences in structure and composition between old-growth forests and younger and often more disturbed mature forests.

B.3.b. Methods: We will use statistical analysis to characterize differences in the groups of old-growth and mature stands. The analysis will also be extended to characterize differences and similarities between different old-growth types, utilizing data from our previous project which focused on pine and northern hardwoods.

B.3.c. Materials: Statistical software packages and MS-DOS computers for these analyses are available in D. Mladenoff's laboratory at NRRI. Statistical consultants are also available on staff at NRRI to advise us in the analysis.

B.3.d. Budget: $ 62,000
Anticipated Balance (7/1/95): $ 0

B.3.e. Timeline:	7/93	1/94	6/94	1/95	6/95
Enter plot data in computer database		***		*****	
Tree core analysis		****		****	
Enter releve data in DNR releve database			****		****
Enter Element Occurrence Records in Natural Heritage Information System			**********		
Preliminary data analysis	**				
Final data analysis				*****	
Development of old-growth descriptions					*******

BB. Status: Site selection and sampling.
Fifty-one stands were sampled. These sites included 11 paired (old-growth and mature) maple-basswood forest sites, ten paired red oak forest sites, and seven old-growth and two mature black ash forest sites. Three additional old-growth black ash forest sites will be sampled during the next several weeks (see Problems Section). These results will be included in a final report submitted by NRRI. Stands were located throughout the range of each cover type in Minnesota (see accompanying report). For each site sampled, two to three sites were field checked and rejected because they had been disturbed or because they did not make good pairs. Maple-basswood sites ranged from Houston County in the southeast to Becker County in the northwest. Red oak sites ranged from Houston County to Mahnomen

County in the northwest. Black Ash sites sampled ranged from Pine County in east-central Minnesota to Itasca and St. Louis Counties in northern Minnesota. Stand ages ranged from 77-172 years for maple-basswood forest, from 66-164 years for oak, and 109 to 234 years for ash.

Analysis and Results: Structural characteristics.

Step-wise logistic regression was used to analyze the importance of the following structural characteristics in determining old-growth conditions: basal area/ha, down log volume/ha, snag volume/ha, number of saplings/ha, number of large seedling/ha, and number of small seedlings/ha. When this analysis technique was used for structural data within each cover type, no variables were significant. This is probably due to the relatively small sample size in each cover type (22 in maple-basswood, 20 in oak, and 9 in ash). When the same analysis was done for all stands irrespective of cover type, basal area and down log volume were selected as significant variables. As values for these characteristics increase, so does the probability that a stand would be identified as old growth. The concordance value of the regression model of 81.6% indicates a very good predictive ability.

Size class distribution in all tree cover types showed similar "reverse-J" patterns overall from old growth to mature, with most trees in the smallest size classes and numbers decreasing progressively through the large size classes. Old-growth sites, however, do show a significant flattening of this curve. In all three forest types, the mature stands show a larger concentration of stems in the smaller size classes and few if any in the larger classes. Old-growth sites show fewer trees in smaller size classes and a noticeable presence of trees in larger size classes.

Decay class distributions of down logs in all three cover types approximated a normal distribution. (Five decay classes ranging from little decay to barely recognizable were used). In maple-basswood and black ash forests, there were more well-decayed logs in old-growth stands than in mature stands of these types. Oak stands did not show this difference, perhaps because several mature oak stands retained downed tree tops and secondary branches from heavy selective logging. Further analysis of oak stand data is planned to parcel out these apparent effects.

Species composition. A classification technique was used to analyze species data from releves gathered in the 51 plots. The analysis resulted in groups that were based largely on geography, and many matched pairs ended up in the same group. Some divisions, however, produced species groupings that may be useful is describing old-growth vs. mature stands. Three of the highest quality maple-basswood sites and the highest quality mature site were associated with a group of plant species that were recorded primarily in these stands and rarely found at the other sites. These species were wild ginger, maiden-hair fern, red baneberry, wild leek, and a species of sedge. Another group of highly disturbed stands was characterized by high cover values for Pennsylvania sedge, paper birch and hog peanut.

Discussion: Tree basal area, size class distribution, and down log decay class distribution showed significant differences between mature and old-growth stands in spite of considerable geographic variation and necessarily small sample sizes. Although the analysis of the species composition data was complicated by geographical differences, there were some species that

significant old-growth stands;

3) Provide information on old-growth forests that can be used to integrate management for old-growth features and associated biological diversity into the management of commercial forests;

4) Provide detailed information on old-growth forests that can be used to revise the DNR Old Growth Guidelines; and

5) Provide baseline data on ectotrophic mycorrhizal fungi of old-growth forests that will be essential for monitoring the health of Minnesota's forest ecosystems.

VIII. Dissemination: Results of the research portions of this project will be disseminated in several major ways: 1) through the Natural Heritage Information System, 2) by direct sharing of information on quantitative old-growth features with the Nature Conservancy and the U.S. Forest Service, and 3) through presentation and publications in both scientific and popular formats.

Data on each old-growth study site will be entered into the Rare Features Database of the Minnesota Natural Heritage Information System. This database is the only repository for statewide locational information on rare natural features. It is used by a variety of agencies and individuals for land conservation programs, environmental review, planning, management, research, and education.

Direct sharing of structural and compositional data with the U.S. Forest Service and The Nature Conservancy will involve providing these agencies pertinent data in order to facilitate the development of regional old-growth descriptions. Some data from our FY92-93 project will be available for sharing in late 1992.

The results of our research will be presented at national and regional scientific and professional meetings. Research findings will be submitted to appropriate refereed journals. New information on old-growth will be incorporated into slide presentations and used for popular magazine articles and a revision of the preliminary Biological Report on Minnesota Old-Growth Forests.

IX. Time: This project will be completed in two years.

X. Cooperation: The project manager will spend 70% of his time on this project; 50% on Objective A and 20% on Objective B. On July 1, 1994, Dr. Mladenoff will be replaced by Dr. John Pastor as the principal investigator for the old growth characterization research. We anticipate that this change will have little effect on the project.

1. Dr. David J. Mladenoff
   Research Associate, Center for Water and the Environment
   Natural Resources Research Institute, University of Minnesota - Duluth

Dr. Mladenoff has published in refereed journals and conducted research in the areas of forest ecology of the Lake Superior region, biodiversity, and landscape scale analysis using Geographical Information Systems. He has studied old-growth northern hardwood

XI. Reporting Requirements

Semiannual status reports will be submitted not later than January 1, 1994, July 1, 1994, January 1, 1995, and a final status report by June 30, 1995.

XII. Use of Classified Employees

A. Type and Amount of Classified Salaries

# Staff	Classification	Hours	Amount
1	Nat. Res. Spec. Sr.	3,744 (part-time)	$80,000

B. Unique Qualifications

1. Work Description

A. Employee must prepare and administer two research contracts with the University of Minnesota to study old-growth forests.

B. Employee must provide field researchers with over one hundred locations of potential study sites, and help the researchers locate appropriate study sites.

C. Employee must coordinate entry of data into the Natural Heritage Information System.

D. Employee must devise a uniform sampling procedure to gather data necessary to evaluate DNR Old Growth Candidate Stands.

E. Employee must prepare and conduct a training session for old growth evaluators.

F. Employee must coordinate and oversee data entry and data analysis for evaluation of more than 400 DNR Old Growth Candidate Stands.

G. Employee must field check appropriate old growth sites.

H. Employee must prepare recommendations as to which DNR Old Growth Candidate Stands should be formally protected as old growth sites.

I. Employee must review reports prepared by University of Minnesota scientists

J. Employee must administer LCMR project.

2. Special qualification of the employee

A. Employee must have a good understanding of the nature and distribution of old-growth forests in Minnesota.

B. Emp[illegible] must have a background in forest ecology [illegible]rder to

review research reports.

C. Employee should have experience evaluating old-growth forests and designing formal evaluation procedures for a large number of stands.

D. Employee must be familiar with the Natural Heritage Information System.

E. Employee must be familiar with the DNR Old Growth Guidelines and understand the nature of the existing list of Old-Growth Candidate Stands.

3. The current LCMR Project Manager has the special qualifications listed above.

C. Expense to the state

Given the extremely specialized qualifications necessary to complete the project and the short, two-year project length, it would be prohibitively expensive to train a contractor or additional unclassified staff. Furthermore, no one is available to provide the necessary training. The project manager (a part-time classified employee) has more than six years experience concentrating on Minnesota old-growth, and it is in the best interest of the state to use that expertise to complete the project.

D. Supplemental Nature of Appropriation

Without LCMR funding, the none of the work described in this workprogram, including the evaluation of the DNR Old Growth Candidate Stands could be completed. There are no other funds available to pay the salary of the project manager, who is responsible for the duties listed above in Section XII.B

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FOR THE PERIOD ENDING JUNE 30, 1995
This project was supported by the MN Future Resources Fund

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Date of Report: - July 1, 1995

LCMR Final Report - Detailed for Peer Review - Research

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Program Manager: Kurt A. Rusterholz
Natural Heritage Program
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AA. Status: This objective has been successfully completed. In fact, we sampled 449 old-growth candidate stands, more than twice the number that we initially proposed to evaluate (see Section A.1).

As the project progressed it became apparent that we could assign contractors to gather stand data that would allow us to complete evaluations of more than 400 stands. Subsequently field checking of old-growth candidate stands was carried out by contractors supervised by the DNR Forestry Resource Assessment Unit in Grand Rapids. These contractors and a group of DNR resource professionals were trained to gather data on candidate stands at a two-day training session conducted by the Natural Heritage Program (NHP) and DNR Forestry.

At the beginning of the summer in 1993, contracts to gather data on 445 old-growth candidate stands were let. These 445 stands included 156 northern hardwood stands, 126 lowland hardwood stands, 48 black ash stands, 108 white-cedar stands, and 7 oak stands. Of these 445 stands, all but 29 stands were sampled during the 1993 field season, for a total of 415 stands sampled, or twice the number indicated in the workprogram. Those 29 stands not sampled were generally inaccessible due to wet conditions present in 1993. These stands will be added the list to be sampled by DNR personnel in the future.

In addition to the 415 stands sampled in 1993, 34 candidate stands in northeastern Minnesota were sampled in May and June 1995; and nine more stands are scheduled to be sampled in late June.

The 415 stands sampled in 1993 were sampled as 272 sample units of one or more stands. Some sample units contained two or more adjacent stands that were judged to be an ecological unit. Data from these sample units were entered into specially-designed Dataflex database by the NHP. Data from each sample unit were summarized and analyzed using a Dataflex program that assigned points to sample units based on their ecological attributes. Additional analysis of the tree species composition of each sample unit was completed using PCORD and CANOCO. This information is being used to help revise the Natural Heritage Program Natural Community Classification.

Scoring of the sample units was completed manually by the NHP Forest Ecologist. We then ranked sample units of each forest type for each ecoregion of the state. Using this information the NHP has prepared preliminary recommendations on which stands should be designated and protected as old growth and which stands should be returned to other management. Because many stands were of intermediate old-growth quality (e.g., they had experienced a moderate amount of past selective logging but otherwise exhibited many old-growth features), we chose three types of recommendations: 1) reserve as old growth, 2) reserve until stands can be evaluated in a landscape context as part of the DNR regional planning process, and 3) release for other appropriate management. Stands of intermediate quality were assigned to category 2.

The next step in the process of protecting old-growth stands will be accomplished at the regional level within the DNR. Here the information and recommendations regarding the old-growth candidate stands prepared by the NHP will be used in the Regional Planning Process. In this process interdisciplinary planning teams in each ecoregion of the state will choose candidate stands for long-term protection based on their quality, NHP recommendations, and context within the landscape.

Problems: No significant problems were encountered. More than twice as many old-growth candidate stands were evaluated as were originally outlined in this workprogram. The process of using outside forest inventory contractors worked reasonably well. The only real problem, scattered misidentification of tree species, was minor. We were able to correct most of these errors, which had little, if any effect on the scoring of stands.

Summary: The formal evaluation of hundreds of potential old-growth stands by the Minnesota DNR is the first project of its kind in the eastern U.S. As a result of this LCMR project, 87% of the remaining DNR candidate stands outside Itasca State Park were field checked. This project will eventually result in thousands of acres of old-growth forest in Minnesota receiving long-term protection. In addition, thousands of acres of old-growth candidate stands temporarily reserved since 1991, and which did not qualify as old growth will be available for other management. (A more detailed summary of this aspect of the project will be published this fall by Island Press as a chapter in a book on eastern old growth; a reprint of this chapter will then be provided to LCMR.)

B. Title of Objective: Develop detailed descriptions of old-growth examples of three forest types ($110,000).

B.1. Activity: Identify research sites in maple-basswood, oak, and black ash swamp forests.

B.1.a. Context within the project: Descriptions of old-growth forest types will require field data from representative examples of old growth. In order to distinguish characteristics typical of old-growth forest stands from those of mature, typically second-growth, forests, it will also be necessary to sample younger stands. This project will continue to cooperate with the Forest-Bird Diversity LCMR Project. Old-growth study sites sampled in this project will be censused for birds during the following field season.

B.1.b. Methods: At least ten old-growth stands will be located for each of the three forest types. Ten younger/more disturbed sites will be located for both maple-basswood forest and oak forest. The old-growth stands will be chosen from sites in the Natural Heritage Information System and from state and federal forest inventory databases.

B.1.c. Materials: Existing databases as described above will provide data to be entered in an ARC/INFO GIS. Materials necessary to field check sites are limited to appropriate vehicles.

B.1.d. Budget: $6,000
Anticipated Balance (7/1/95): $0

B.1.e. Timeline:

	7/93	1/94	6/94	1/95	6/95
Compile list of potential sites	**				
Enter sites in GIS	*				
Select short list of sites	*				
Field check sites	*****		*		
Develop final list of sites			*		

B.2. Activity: Quantitatively sample at least ten plots in old-growth stands and at least ten plots in mature forest stands of maple-basswood forest and oak forest and ten plots in old-growth black ash forest.

B.2.a. Context within the project: Descriptions of old-growth forest types will be developed by quantitatively sampling both old-growth and mature stands using procedures designed to measure important old-growth features including stand age, tree species composition and size-class distribution, and size and volume of coarse woody debris.

B.2.b. Methods: Each stand will be sampled using a 0.1 ha (20 x 50 m) plot located within a representative portion of the stand. A plot of these dimensions allows the use of 20 x 20 m subplots for Minnesota Natural Heritage Program standard releves to sample species composition and vegetation structure.

Within each plot we will record data on trees and snags (e.g. species, diameter, canopy position); down logs; tip-up mounds; saplings; and seedlings. Stand origin date, site information, and indicators of human disturbance will be recorded.

B.2.c. Materials: Equipment needed for field sampling includes vehicles for transportation and field materials such as fiberglass plot tapes, dbh tapes, increment borers, tree core trays, clinometer, soil probe, pH meter, data books, etc.

B.2.d. Budget: $42,000
Anticipated Balance (7/1/95): $0

B.2.e. Timeline:

	7/93	1/94	6/94	1/95	6/95
Sample field sites	****		******		***

B.3. Activity: Analyze field data and develop descriptions of old-growth forest types.

B.3.a. Context within the project: Analysis of field data is an essential step in the development of descriptions of old-growth forests. This activity will elucidate differences in structure and composition between old-growth forests and younger and often more disturbed mature forests.

B.3.b. Methods: We will use statistical analysis to characterize differences in the groups of old-growth and mature stands. The analysis will also be extended to characterize differences and similarities between different old-growth types, utilizing data from our previous project which focused on pine and northern hardwoods.

B.3.c. Materials: Statistical software packages and MS-DOS computers for these analyses are available in D. Mladenoff's laboratory at NRRI. Statistical consultants are also available on staff at NRRI to advise us in the analysis.

B.3.d. Budget: $ 62,000
Anticipated Balance (7/1/95): $ 0

B.3.e. Timeline:

	7/93	1/94	6/94	1/95	6/95
Enter plot data in computer database		***		*****	
Tree core analysis		****		****	
Enter releve data in DNR releve database			****		****
Enter Element Occurrence Records in Natural Heritage Information System			**********		
Preliminary data analysis	**				
Final data analysis				*****	
Development of old-growth descriptions					*******

BB. Status: Site selection and sampling.
Fifty-one stands were sampled. These sites included 11 paired (old-growth and mature) maple-basswood forest sites, ten paired red oak forest sites, and seven old-growth and two mature black ash forest sites. Three additional old-growth black ash forest sites will be sampled during the next several weeks (see Problems Section). These results will be included in a final report submitted by NRRI. Stands were located throughout the

range of each cover type in Minnesota (see accompanying report). For each site sampled, two to three sites were field checked and rejected because they had been disturbed or because they did not make good pairs. Maple-basswood sites ranged from Houston County in the southeast to Becker County in the northwest. Red oak sites ranged from Houston County to Mahnomen County in the northwest. Black Ash sites sampled ranged from Pine County in east-central Minnesota to Itasca and St. Louis Counties in northern Minnesota. Stand ages ranged from 77-172 years for maple-basswood forest, from 66-164 years for oak, and 109 to 234 years for ash.

Analysis and Results: Structural characteristics.

Step-wise logistic regression was used to analyze the importance of the following structural characteristics in determining old-growth conditions: basal area/ha, down log volume/ha, snag volume/ha, number of sapling/ha, number of large seedlings/ha, and number of small seedlings/ha. Stand age was not used as an independent variable since it was a criterion in site selection. In order to compare regression coefficients for different independent variables where their magnitudes were very different, independent variables were standardized to a Z-distribution.

When step-wise logistic regression was used for structural data within each cover type, no variables were significant. This is probably due to the relatively small sample size in each cover type (22 in maple-basswood, 20 in oak, and 9 in ash). When the same analysis was done for all stands irrespective of cover type, basal area and down log volume were selected as significant variables with p values = .0023 and .0157, respectively. Parameter values for basal area and log volume indicate that as values for these characteristics increase, so does the probability that a stand would be identified as old growth. The concordance value of the regression model of 81.6% indicates a very good predictive ability.

Size class distribution in all tree cover types showed similar "reverse-J" patterns overall from old growth to mature, with most trees in the smallest size classes and numbers decreasing progressively through the large size classes. Old-growth sites, however, do show a significant flattening of this curve. In all three forest types, the mature stands show a larger concentration of stems in the smaller size classes and few if any in the larger classes. Old-growth sites show fewer trees in smaller sized classes and a noticeable presence of trees in larger size classes. Chi-squared tests on the differences between the old growth vs. mature distributions show them to be highly significant at asymptotic p-values =.0000.

Decay class distributions of down logs in all three cover types approximated a normal distribution. (Five decay classes ranging from little decay to barely recognizable were used). In maple-basswood and black ash forests, there were more well-decayed logs in old-growth stands than in mature stands of these types. These differences were highly significant, asymptotic p-values = .0000. Oak stands did not show this difference, perhaps because several mature oak stands retained downed tree tops and secondary branches from heavy selective logging. Further analysis of oak stand data is planned to parcel out these apparent effects.

Species composition. TWINSPAN, a divisive classification technique, was used to analyze species data from releves gathered in the 51 plots. The analysis resulted in groups that were based largely on geography, and many matched pairs ended up in the same group. Some divisions, however, produced species groupings that may be useful is describing old-growth vs. mature stands. Three of the highest quality maple-basswood sites and the highest quality mature sites were associated with groups of plant species that were recorded primarily in these stands and rarely found at the other sites. These species were wild ginger (*Asarum canadense* L.), maiden-hair fern (*Adiantum pedatum* L.), red baneberry (Actaea rubra (Ait.) Willd.), wild leek (*Allium tricoccum* Ait.), and a sedge (*Carex albersina*). Another group of highly disturbed stands was characterized by high cover values for Pennsylvania sedge (*Carex pensylvanica* Lam.), paper birch (*Betula papyrifera* March.) and hog peanut (*Amphicarpa bracteata* (L.) Fern.).

Discussion: Tree basal area, size class distribution, and down log decay class distribution showed significant differences between mature and old-growth stand in spite of considerable geographic variation and necessarily small sample sizes. Altnhough, the analysis of the species composition data was complicated by geographical differences, there were some species that did appear to be present primarily in old-growth systems. These species are long-lived, disturbance sensitive, shade-tolerant species, often with poor dispersal abilities.

Summary of differences between mature and old growth by forest type. Old-growth maple-basswood forests had a distinctive herbaceous plant association that included long-lived perennial and shade-tolerant species. (see Table 2 in accompanying report). Old-growth stands also showed a size class distribution of live trees that had relatively fewer small size class trees and a decay class distribution of down logs with a relatively higher volume of wood in advanced decay classes. The mature maple-basswood stands supported an herbaceous plant association with species indicative of disturbance and higher light levels. Mature stands also had size class distributions with more trees in the small size classes and few if any trees in the larger size classes and a decay class distribution with relatively more of the down log volume in younger decay classes.

Old-growth and mature red oak forest sites showed a stronger geographic effect in their species composition than did maple-basswood sites, however, a few sites contained species groups indicative of old-growth conditions in maple-basswood forests. The pattern of tree size class distributions and decay class distributions seen in old growth and mature oak forest sites were similar to those seen in maple-basswood sites.

Old-growth black ash swamp forests showed some very distinctive herbaceous plant species (see Table 2 in accompanying report) and relatively high values of basal area/ha and down log volume/ha, with much less variability than seen in the oak and maple-basswood sites. This lack of variability in structural conditions may be a result of the relatively low probability of human disturbance in black ash stands compared to the other forest types studied here. These patterns may be clarified when data from three additional old-growth black ash stands are included.

Additional Analysis. Additional data analysis will be conducted by the primary field researcher Cindy Hale for her Master's Thesis at the University of Minnesota - Duluth. Additional analysis will include: 1) Comparison of the diversity of plant families between old-growth and mature stands, 2) comparison of similarity indices between old-growth and mature stands with similarity indices among old-growth stands and among mature stands, 3) partialling out the geographic component in TWINSPAN analyses,

4) further multivariate analysis using CANOCO, 5) a comparison of patterns of suppression and release for canopy and subcanopy trees in old-growth vs. mature forests (using data from 500 tree cores).

Problems: The location of study sites in southern Minnesota during the 1993 field season, particularly mature stands, proved to be more difficult and time consuming than anticipated. Because most forest land in the region is privately owned, forest inventory information is extremely limited. A great deal of time was spent talking to local foresters, city and county park officials, private landowners, and Minnesota County Biological Survey ecologists. In addition, mature stands between 70 and 120 years-old turned out to be very rare to non-existent in southeastern Minnesota. This was due to the settlement and land-use history of the area. Therefore, we redefined mature stands in southern Minnesota as stands between 100 and 120 years old that had experienced significant human disturbance in the past.

In 1994, the field investigator experienced a back injury and the resignation of two field assistants. These unforeseen exigencies reduced the length of the relatively short field season in black ash swamps in northern Minnesota. Therefore, the original workprogram was amended with LCMR approval to sample the remaining old-growth black ash stands during the 1995 field season. The data from these stands have not yet been analyzed but will be included in a report to be provided to LCMR in fall 1995.

The problems discussed above were exacerbated by the funding schedule for LCMR projects and fiscal year constraints. Field research projects such as this one in which field research can only be conducted during a limited field season are hampered when funds for approved projects become available in the middle of the summer field season. As a result, only one complete field season is available for research for a two-year project.

C. Title of Objective: Characterize the ectotrophic mycorrhizal fungi found in important old-growth forest types ($50,000).

C.1 Activity: In red pine and northern hardwood-conifer forests select and quantitatively sample old-growth and mature stands and qualitatively sample white pine forest plots. (Rationale for these changes: The original intent of the study was to provide quantitative data on mycorrhizal fungi in one conifer and one hardwood forest type. Field examination of the study sites showed that only the red pine forest and the northern hardwood-conifer forest sites were: 1) large enough to hold the study plots, 2) had necessary site characteristics, and 3) were accessible enough to accommodate the frequent site visits necessary for adequate sampling. In Section C.1.b., the reason that only one site for each forest type is sampled is that the number of mycorrhizal species we found in old-growth plots was two to three times that expected based on information from second growth forest (no comparable data are available from old growth in eastern North America). Because of the effort needed to document and identify the large number of species, only one forest of each type could be surveyed. In Section C.1.b., we changed our sampling methods: 1) to make the data comparable to that from an old-growth conifer forest study by Dr. J. Ammiratti at the University of Washington and 2) because a modified sampling design was needed to adequately sample the dispersed distribution of species encountered in this study.)

C.1.a. Context within the project: This activity will utilize stands identified in previous studies of old-growth and mature forests. To distinguish characteristics of ectotrophic mycorrhizal fungi of old-growth forests, it is necessary to sample and compare fungi with those found in mature stands. Mushroom diversity and abundance are determined by fruitbody production, which is weather-dependent.

C.1.b. Methods: We will establish 15 permanent 100 m transects of 20 circular 4 m^2 sampling areas (each divided into three replicate plots) in each of the four forest types: old-growth red pine, mature red pine, old-growth northern hardwood-conifer, and mature northern hardwood-conifer forests. Previously studied mature and old-growth sites will be visited to decide on the most suitable sites. Old-growth and nearby mature sites will be in similar site ecosystems.

At each site one plot will be located within the 20 x 20 m releve plot previously used to characterize the site. Woody plant distribution, logs and stumps will be mapped out for each plot if not already available. Organic content and pH of the soil will be determined if adequate data are not available.

Sites will be visited every two to three weeks and the number of fruitbodies of each species in each circular sampling area will be recorded. Species will be described using a standard format and photographed to aid in identification in the field and in the laboratory.

At sites to be sampled occasionally, a list of species present in 16 x 16 m plots will be recorded once or twice during the fruiting season and voucher specimens will be collected. Species present, their distribution by sampling unit, and date collected will be entered into the computer database. Species and site data for voucher specimens will be entered into the University of Minnesota Herbarium fungal database. Species-area curves will be plotted to determine whether sampling areas are large enough to give representative sampling for each species.

C.1.c. Materials: For field sampling, equipment needs include: vehicle for transportation; field materials, such as plot marks, rod/rope, photographic film, data sheets, bags and hot air drier for voucher specimens, knives, etc.

C.1.d. Budget: $ 30,000
Balance: $ 0

C.1.e. Timeline:

	7/93	1/94	6/94	1/95	6/95
Select and field check sites; lay out plots	**				
Sample field sites		****	*******		

C.2 Activity: Analyze field data to characterize ectotrophic mycorrhizal fungi of old-growth forests.

C.2.a. Context within the project: Analysis of field data will yield the ectotrophic mycorrhizal fungal species composition of old-growth forests. These data will indicate whether species diversity changes with stand age and whether certain species are characteristic of old-growth forests. It will also provide data that can be correlated with meteorological data to provide a baseline for assessing environmental changes.

C.2.b. Methods: For identification, specimens are examined microscopically and spores, etc., measured; microchemical tests are made; and keys are used to determine the species. While some mushroom groups are well known in North America, others are not. In the latter case descriptions will be typed and sent with specimens to scientists in other institutions for determination. Analysis of data will include species area curves, comparison of species diversity between forest types, fruitbody density, species and percent frequency and phenology to assess variation in species abundance and distribution, and fruiting patterns on a 1 or 2 year basis.

C.2.c. Materials: Laboratory supplies include microscope slides, chemicals, xeroxing charges, computer supplies and mailing.

C.2.d. Budget: $ 20,000
Balance: $ 0

C.2.e. Timeline:

	7/93	1/94	6/94	1/95	6/95
Enter site data in computer database	*				
Identify fungi and enter species in database	******		******		
Enter species in Herbarium database		**		**	
Preliminary data analysis		**			
Final data analysis				*****	

CC. **Status:** This study of ectotrophic mycorrhizal fungi was initiated because of the close association of these fungi with forest trees and their dramatic decline in Europe. To obtain baseline data on fungal diversity in old-growth and mature forests in Minnesota, we began studies in 1993 in four forest types; data from two types were quantitative and data from two types were qualitative. Twenty sites were visited during five weeks in July and August 1993 to choose stands for sampling. Sites were chosen based on characteristics of the vegetation, size of site, protection status, lack of disturbance, density of the understory, and accessibility.

Quantitative Sampling Procedures and Results: For collection of quantitative data we established permanent transects in 1993 in two old-growth red pine forest stands (Scenic State Park) and in three old-growth northern hardwood-conifer forest stands (Tettegouche and George H. Crosby-Manitou State Parks). During June and early July 1994 additional permanent transects were located in one old-growth and three mature red pine stands (Scenic SP) and three younger northern hardwood-conifer stands (Tettegouche SP).

Each of the four stand types was sampled with three 0.5 ha (50 x 100m) replicate plots. Each replicate plot contained five transects of 20 $4m^2$ sampling circles, for a total sampling area of 400 m^2 per replicate plot. We counted mushroom fruitbodies of taxa containing potentially ectomychorrizal species in each sampling circle. Presence of additional species within the plots was also recorded. Specimens were collected when necessary for identification and documentation. Specimen identification is an ongoing process, therefore the numbers of species reported below are estimates.

In 1993, four visits to the old-growth red pine stands in Scenic SP yielded data from ten transects (800 m^2) and adjacent areas (5000 m^2). Ninety-eight potentially mycorrhizal species were documented at this site (70% in sampling circles). In addition, 15 undocumented species (i.e. additional species that were not collected for later identification) were recorded. Three visits to two old-growth northern hardwood-conifer sites, of which six transects (480 m^2) and 3000 m^2 of adjacent areas were sampled, yielded 69 species (60% in sampling circles) plus ten undocumented species.

In 1994 the full set of 15 transects (1200 m^2) and adjacent area (15,000 m^2) was sampled for each of four sets of three plots (old-growth red pine, mature red pine, old-growth northern hardwood-conifer and younger northern hardwood-conifer forests). Transects were visited during four trips on a rotating basis every three to four weeks between July and the end of September. As a result all transects were sampled twice during the field season. In old-growth red pine plots 140 mycorrhizal species were documented (80% in sampling circles) compared with 165 species (83% in sampling circles) in mature red pine stands. The combined species total for red pine was 213 species. In northern hardwood-conifer forest plots a total of only 77 species were documented, in part due to drier weather. Sixty-two species were documented in old-growth plots (77% in sampling circles), whereas only 35 species were found in younger plots (61% in sampling circles). At least 19 of the northern hardwood-conifer species were also present in red pine forest plots, and a total of 265 mychorrhizal taxa were documented for these two forest types. There were additional undocumented species in both forest types. Also during 1994, soil samples were collected and vegetation analysis, tree diameter measurements, and mapping were partially completed. Tree measurement were completed for the red pine plots in June 1995.

Qualitative sampling procedures and results:

Two qualitative sampling sites were established in 1993, one in an old-growth maple-basswood forest (Townsend Woods Scientific and Natural Area, Rice County) and one in an old-growth white pine forest (Superior National Forest north of Loon Lake, Cook County). The two stands were each sampled using a 0.5 ha (50 x 100 m) plot. A completely sampled plot contained ten parallel 100 m transects spaced 5 m apart. These line transects included a two meter wide sampling area, for a total sampling area per transect of 200 m^2. Mushroom species within the sampling areas were recorded, and additional species between transects were noted. Each site was sampled

once.

In the maple-basswood forest ten transects (0.2 ha) and adjacent areas (0.5 ha) yielded 19 species (15 in transects and four in adjacent areas) plus six undocumented species. In the white pine forest site we recorded 36 species (22 in transects and 14 in adjacent areas) plus 14 undocumented species in **one** transect (200 m^2) and an adjacent area of 500 m^2. Sampling of additional transects was prevented by injury to the researcher.

In 1994, the ectomycorrhizal fungi of the same area of maple-basswood forest in Townsend Woods SNA were sampled again. Thirty-eight species (31 new for the site) were documented during this visit on August 23-24. Numerous species had high frequencies. The Loon Lake old-growth white pine forest was visited again on September 12, but this trip was cut short because of very poor mushroom fruiting caused by dry weather. Only one transect (200 m^2) was sampled; twelve species were present (seven new for the site) in the transect, with no additional species found in the vicinity.

Data management and analysis: Field data have been entered into a computer database and used to generate labels for voucher specimens and for quantitative analysis (see accompanying report). For each species the data are used to determine percent frequency, abundance, distribution within plot, fruiting phenology, species diversity by plot, and yearly variation. Methods of data analysis include calculations of similarity and diversity indices and principal component ordinations of species.

Results and discussion: Initial qualitative sampling of old-growth sites in 1993 yielded 150 mycorrhizal species. More extensive sampling in 1994 revealed many more species of which more than 150 were documented for a total of over 300 species documented from red pine and northern hardwood-conifer forest sites. Approximately 220 species were recorded from red pine forests and 110 species in northern hardwood-conifer forest (see accompanying report for species lists). Based on the unpublished *Checklist of Higher Fungi of Minnesota*, we estimate that about 200 (65%) of the species are new state records. In 1994, the number of mushroom species observed per 0.5 ha plot ranged from six to 40 for northern hardwood-conifer forest and from 86 to 116 for red pine forest. The sampling circles totaling 400 m^2 covered only 8% of the 0.5 ha plot, yet 48-80% (mean = 69%) of the species documented for a plot were recorded within the circles. Estimated mushroom fruitbody productivity per plot in 1994 ranged from 200 to 3,325 per ha for northern hardwood-conifer forest and from 19,750 to 34,850 for red pine forest. The higher species diversity and much greater fruitbody numbers for red pine forest may indicate a greater importance of mycorrhizal fungi in sandy soils. In addition to significant differences in species richness between red pine and northern hardwood-conifer forests, differences are also apparent in fungal composition between old-growth and younger stands. Ongoing data analysis is also providing an initial estimate of species characteristic of old-growth versus younger forests.

Species diversity for most stands was very high for the size of the areas sampled (1.5 ha per forest type/age class). The number of species recorded is two to four times the numbers found in most published reports from immature or second-growth stands. However, species richness is comparable to that being obtained by O'Dell and Ammirati (pers. comm.) for old-growth Douglas-fir and hemlock forests in Olympic National Park.

Complications and problems: The occurrence and fruitbody production of each species of mychorrizal fungus varies with the season and from year to year. Forty-six species (30%) documented in 1993 were not observed in 1994. Furthermore, seasonal variation in number of species demonstrates that diversity continues to increase throughout the season and that sampling should be extended into October, weather permitting. In order to understand which species are common or rare and whether they are restricted to a particular habitat or successional stage, quantitative analysis must be carried out for several years. This requires long-term research funding.

Much time has been needed to document the great diversity of fungi discovered in this study. In 1994 four to seven days were required by a team of three people to complete one site visit consisting of 18 transects in one forest type (nine transects in old growth and nine in mature stands); specimen description and processing often took until late evening. Obtaining specimen vouchers is a continuing process. Some specimens were inadequate for identification, and in some cases too many new species were obtained at the same time to document all species. The principal field person spent 820 hours on the project (June 16 - September 30, 1994). In addition, one student and six volunteers participated. More than 850 fungal specimens were collected for later species identification and documentation. As a result, very little time was available for technical species identification during the field season.

During winter and spring 1995, in addition to processing and analysis of specimens and data, 27 species (56 specimens) of *Amanita*, *Clavariadelphus*, *Laccaria*, and *Russula* were examined; of these 27 species, seven species remain unidentified. Initial microscopic work was done on many *Cortinarius* and *Hebeloma* collections. Thirty minutes to over six hours are required for each species identification. Taxonomically difficult genera require more extensive examination and literature review. Identification of *Laccaria* specimens have been confirmed by consultation with G. Mueller, Field Museum of Natural History, Chicago. Specimens of Entolomataceae have been sent to T. Baroni, State University of New York at Cortland, and specimens of *Tricholoma* have been sent to C. Ovrebo, University of Central Oklahoma for identification.

In summary, the ectotrophic mychorrhizal fungi "flora" of mature and old-growth red pine and northern hardwood-conifer forests in Minnesota is extremely rich and varies within and between years. Adequate characterization of this diversity, which has never before been attempted in the eastern U.S., will require long-term funding to support extensive field and lab work.

V. Evaluation: This project will be evaluated based on the success at completing the following objectives:

1) field evaluation of at least 200 DNR old-growth candidate stands;

2) development of old-growth descriptions for maple-basswood, oak, and black ash swamp forests that highlight the differences between old-growth forests and mature, more disturbed secondary forests; and

3) development of characterizations of the ectotrophic mycorrhizal fungal flora of two old-growth forest types and how these flora differ from those found in younger forests of the same type.

VI. Context with field: Old-growth forests have become an important nationwide environmental issue within the last decade. The first step towards protection and management of old-growth forests is to identify those forests that are old growth. Except for the Pacific Northwest, relatively little research has been directed to old-growth forests in an area as large as Minnesota. Most information on old growth comes from a few specific sites in a region or studies in which old-growth was not a specific focus. Systematic studies of old-growth forests are lacking for nearly all of the eastern United States including Minnesota.

A systematic effort to describe old-growth in the major regional forests types in the eastern United States is now being undertaken as a joint project between The Nature Conservancy and the U.S. Forest Service. This joint project, however, will not generate new field data. Rather, these descriptions will be based on the very limited information already present in the literature and may not be able to represent regional variations in old-growth descriptions because they will cover several states.

The LCMR old growth research project for FY92-93 and its continuation (this project) are unique research efforts that will provide objective descriptions of old-growth conditions based on primary data in six major forest type in Minnesota.

The study of ectotrophic mycorrhizal fungi comes in the context of recent catastrophic declines in similar forest mushrooms in Europe. This loss of a well-studied flora preceded widespread forest decline in Europe. Therefore, these symbiotic fungi appear to be important advance indicators of forest decline due to acidification and eutrophication. Baseline data on fungal species composition and abundance are absent for most of North America and are very limited for Minnesota where most records in the University of Minnesota Herbarium are from a few sites.

VII. Benefits: This project will provide important information that will allow agencies and individuals to protect and manage old-growth forests and the biological diversity associated with these forests. More specifically, the results of this project will:

1) Allow a more rapid evaluation of DNR old-growth candidate stands, assuring that those unique stands worthy of protection will be protected while other stands that do not meet old-growth criteria will quickly be released for other management;

2) Provide criteria for identification of important old-growth types that will allow resource managers and private individuals to identify significant old-growth stands;

3) Provide information on old-growth forests that can be used to integrate management for old-growth features and associated biological diversity into the management of commercial forests;

4) Provide detailed information on old-growth forests that can be used to revise the DNR Old Growth Guidelines; and

5) Provide baseline data on ectotrophic mycorrhizal fungi of old-growth forests that will be essential for monitoring the health of Minnesota's forest ecosystems.

VIII. Dissemination: Results of the research portions of this project will be disseminated in several major ways: 1) through the Natural Heritage Information System, 2) by direct sharing of information on quantitative old-growth features with the Nature Conservancy and the U.S. Forest Service, and 3) through presentation and publications in both scientific and popular formats.

Data on each old-growth study site will be entered into the Rare Features Database of the Minnesota Natural Heritage Information System. This database is the only repository for statewide locational information on rare natural features. It is used by a variety of agencies and individuals for land conservation programs, environmental review, planning, management, research, and education.

Direct sharing of structural and compositional data with the U.S. Forest Service and The Nature Conservancy will involve providing these agencies pertinent data in order to facilitate the development of regional old-growth descriptions. Some data from our FY92-93 project will be available for sharing in late 1992.

The results of our research will be presented at national and regional scientific and professional meetings. Research findings will be submitted to appropriate refereed journals. New information on old-growth will be incorporated into slide presentations and used for popular magazine articles and a revision of the preliminary Biological Report on Minnesota Old-Growth Forests.

IX. Time: This project will be completed in two years.

X. Cooperation: The project manager will spend 70% of his time on this project; 50% on Objective A and 20% on Objective B. On July 1, 1994, Dr. Mladenoff will be replaced by Dr. John Pastor as the principal investigator for the old growth characterization research. We anticipate that this change will have little effect on the project.

1. Dr. David J. Mladenoff
   Research Associate, Center for Water and the Environment
   Natural Resources Research Institute, University of Minnesota - Duluth

   Dr. Mladenoff has published in refereed journals and conducted research in the areas of forest ecology of the Lake Superior region, biodiversity, and landscape scale analysis using Geographical Information Systems. He has studied old-growth northern hardwood forests in Michigan and Wisconsin, and his current research includes projects on old-growth forest biodiversity funded by the U.S. Forest Service and The Nature Conservancy, and work funded by the National Science Foundation and the National Park Service. Besides research, his experience includes nearly eight years working cooperatively with state and federal land management agencies on biodiversity issues. Dr. Mladenoff is currently advising the graduate student conducting the current field research to describe old-growth red pine, white pine, and northern hardwood forests (LCMR Old-Growth Project for FY92-93). He will continue in that role in this project.

Dr. Mladenoff will commit 10% of his time during the 2-year project on Objective B. This time also includes supervision of a full-time graduate student working on Objective B.

2. Dr. David J. McLaughlin
Professor, Department of Plant Biology
University of Minnesota - St. Paul

Dr. McLaughlin has conducted research in the areas of fungal evolution and biodiversity and has published in refereed journals. He has studied mushrooms and their relatives in Minnesota since 1969. He teaches course in mushroom identification and is Curator of Fungi in the University Herbarium. Projects involving field studies of Minnesota mushrooms include analysis of the mushroom flora of Nature Conservancy Preserves and Scientific and Natural Areas supported by The Nature Conservancy; of Cedar Creek Natural History Area supported by the CCNHA Area fund; of Washington County supported by the County Biological Survey; and northern Minnesota wetlands for a long-term ecological research project supported by a grant to E. Gorham from the Andrew W. Mellon Foundation. The graduate student who will carry out most of the field work on this project has extensive experience with mushroom identification and has had experience in laying out and analyzing forest plots.

Dr. McLaughlin will commit 16.25% (5% during two 9-month academic years and 50% during two 3-month summer periods) of his time to the project, working on Objective C. He will be supervising a full-time graduate student working on the project (Objective C).

3. Dr. John Pastor
Senior Research Associate
Natural Resources Research Institute - University of Minnesota-Duluth

Dr. Pastor received his Ph.D. in Soil Science and Forestry from the University of Wisconsin, Madison in 1980. He was a post-doctoral fellow at Oak Ridge National Laboratory, Tennessee. He is currently Senior Research Associate at the Natural Resources Research Institute in Duluth and Adjunct Professor in the Department of Fisheries and Wildlife, University of Minnesota, St. Paul. His research interests include the functioning of northern ecosystems, impact of climate change on ecosystem functioning, ecosystem-herbivore interactions, and effects of timber harvesting on forest ecosystems.

XI. Reporting Requirements

Semiannual status reports will be submitted not later than January 1, 1994, July 1, 1994, January 1, 1995, and a final status report by June 30, 1995.

XII. Use of Classified Employees

A. Type and Amount of Classified Salaries

# Staff	Classification	Hours	Amount
1	Nat. Res. Spec. Sr.	3,744 (part-time)	$80,000

B. Unique Qualifications

1. Work Description

A. Employee must prepare and administer two research contracts with the University of Minnesota to study old-growth forests.

B. Employee must provide field researchers with over one hundred locations of potential study sites, and help the researchers locate appropriate study sites.

C. Employee must coordinate entry of data into the Natural Heritage Information System.

D. Employee must devise a uniform sampling procedure to gather data necessary to evaluate DNR Old Growth Candidate Stands.

E. Employee must prepare and conduct a training session for old growth evaluators.

F. Employee must coordinate and oversee data entry and data analysis for evaluation of more than 400 DNR Old Growth Candidate Stands.

G. Employee must field check appropriate old growth sites.

H. Employee must prepare recommendations as to which DNR Old Growth Candidate Stands should be formally protected as old growth sites.

I. Employee must review reports prepared by University of Minnesota scientists

J. Employee must administer LCMR project.

2. Special qualification of the employee

A. Employee must have a good understanding of the nature and distribution of old-growth forests in Minnesota.

B. Employee must have a background in forest ecology in order to review research reports.

C. Employee should have experience evaluating old-growth forests and designing formal evaluation procedures for a large number of stands.

D. Employee must be familiar with the Natural Heritage Information System.

E. Employee must be familiar with the DNR Old Growth Guidelines and understand the nature of the existing list of Old-Growth Candidate Stands.

3. The current LCMR Project Manager has the special qualifications listed above.

C. Expense to the state

Given the extremely specialized qualifications necessary to complete the project and the short, two-year project length, it would be prohibitively expensive to train a contractor or additional unclassified staff. Furthermore, no one is available to provide the necessary training. The project manager (a part-time classified employee) has more than six years experience concentrating on Minnesota old-growth, and it is in the best interest of the state to use that expertise to complete the project.

D. Supplemental Nature of Appropriation

Without LCMR funding, the none of the work described in this workprogram, including the evaluation of the DNR Old Growth Candidate Stands could be completed. There are no other funds available to pay the salary of the project manager, who is responsible for the duties listed above in Section XII.B